Agricultural Sciences Bachelor

1. Semester

First Year Examinations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-2001-02L</td>
<td>Chemistry I</td>
<td>O</td>
<td>4</td>
<td>2V+2U</td>
<td>J. Cvengros, J. E. E. Buschmann, P. Funck, R. Verel</td>
</tr>
</tbody>
</table>

Abstract

General Chemistry I: Chemical bond and molecular structure, chemical thermodynamics, chemical equilibrium.

In the course "Chemistry I", the competencies of process understanding, system understanding, modeling, concept development and data analysis & interpretation are taught, applied and examined.

Objective

Introduction to general and inorganic chemistry. Basics of the composition and the change of the material world. Introduction to the thermodynamically controlled physico-chemical processes. Macroscopic phenomena and their explanation through atomic and molecular properties. Using the theories to solve qualitatively and quantitatively chemical and ecologically relevant problems.

Content

1. Stoichiometry
   - Amount of substance and mass. Composition of chemical compounds. Reaction equation. Ideal gas law.
2. Atoms
3. Chemical bonding and its representation.
4. Basics of chemical thermodynamics
5. First law of thermodynamics
6. Second law of thermodynamics
   - Entropy. Change of entropy in chemical systems and universe. Reaction entropy.
7. Gibbs energy and chemical potential.
8. Chemical equilibrium
9. Acids and bases
10. Dissolution and precipitation.

Lecture notes

Online-Skript mit durchgerechneten Beispielen.

Literature

- Catherine Housecroft, Edwin Constable, CHEMISTRY: AN INTRODUCTION TO ORGANIC, INORGANIC AND PHYSICAL CHEMISTRY, 3. Auflage, Prentice Hall, 2005.(englisch)

Competencies

<table>
<thead>
<tr>
<th>Competency</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>assessed</td>
<td>assessed</td>
<td>fostered</td>
<td>fostered</td>
</tr>
<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
<td>Decision-making</td>
<td>fostered</td>
<td>Adaptability and Flexibility</td>
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<td>Media and Digital Technologies</td>
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<td>Creative Thinking</td>
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<td>Problem-solving</td>
<td>fostered</td>
<td>Critical Thinking</td>
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<td>Media and Digital Technologies</td>
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<td>Project Management</td>
<td>fostered</td>
<td>Integrity and Work Ethics</td>
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<td>Cooperation and Teamwork</td>
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<td>Self-awareness and Self-reflection</td>
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<tr>
<td>Project Management</td>
<td>fostered</td>
<td>fostered</td>
<td>fostered</td>
<td>Self-direction and Self-management</td>
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<tr>
<td>Social Competencies</td>
<td>fostered</td>
<td>Communication</td>
<td>fostered</td>
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<td>Personal Competencies</td>
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<tr>
<td>401-0251-00L</td>
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<td>O</td>
<td>6</td>
<td>4V+2U</td>
<td>A. Cannas da Silva</td>
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</table>

Abstract

This course covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems - notably through ordinary differential equations.

Objective

Mathematics is of ever increasing importance to the Natural Sciences and Engineering. The key is the so-called mathematical modelling cycle, i.e. the translation of problems from outside of mathematics into mathematics, the study of the mathematical problems (often with the help of high level mathematical software packages) and the interpretation of the results in the original environment.

The goal of Mathematics I and II is to provide the mathematical foundations relevant for this paradigm. Differential equations are by far the most important tool for modelling and are therefore a main focus of both of these courses.
Adaptability and Flexibility

This introductory lecture in ecology covers basic ecological concepts and the most important levels of complexity in ecological research.

**Analytical Competencies**

Documents, lecture slides, exercises and relevant literature are available in Moodle. The lecture provides a science-based exploration of environmental aspects from three research fields: earth, climate, and health sciences.

**Subject-specific Competencies**

The lecture is the first in a series of two lectures given over two semesters for students with biology as a basic subject.

**Social Competencies**

Fostered: familiarity with the basic notions from Calculus, in particular those of function and derivative.

**Personal Competencies**

First in a series of two lectures given over two semesters for students of agricultural and food sciences, as well as of environmental sciences.

**Lecture notes**

Fostered: assessment of biodiversity, why it is threatened and how it can be managed.
World Food System

Abstract
Die Grundlagen des Welternährungssystems werden anhand von Fallbeispielen aus der Forschung entlang der Wertschöpfungskette vermittelt.

Objective
Mit Besuch dieser Lehrveranstaltung soll Verständnis geschaffen werden, was ein Welternährungssystem ist, wo aktuell die grossen Herausforderungen liegen, was Elemente und Einflussfaktoren auf die Ernährungssicherheit sind, welche Wechselwirkungen zwischen diesen Elementen und Einflussfaktoren bestehen, und welche potentiellen Lösungsstrategien sich für spezifische Herausforderungen ableiten lassen.

Content

Lecture notes
Skripte und zusätzliches Lernmaterial werden auf Moodle verfügbar gemacht.

Prerequisites / notice

This course introduces basic economic concepts and theories. Beginning with microeconomics, the course starts with the topics of supply and demand, markets, and behavioral economics before moving on to the key macroeconomic concepts of national accounts, the labor market, trade, and monetary policy.

Objective
After successful completion of the course you will be able to:
-Describe the basic micro- and macroeconomic problems and theories.
-Introduce economic reasoning appropriately to a given topic.
-Evaluate economic measures.

Content
Households, firms, supply and demand: How are household preferences and consumption patterns formed? How does a household react to price changes? How are goods prices formed? At what prices are companies willing to offer goods? How do we make economic decisions?

Markets: What is "perfect competition" and how does a competitive market work? Are monopolies always a bad thing? How can the state influence the market?

Market failure: What happens when prices give wrong signals?

Labour market: How do supply and demand work in the labour market? What influences unemployment?

National accounts: How big is the Swiss economy?

Foreign trade: Why do countries trade with each other? What are the consequences for the domestic market?

Money and inflation: What exactly is money? How does money creation work and what happens when there is too much (or too little) money on the market?

Students will be asked to apply these concepts to issues in their own field of study and to current issues in society. This goal will be achieved through participation in exercises, class discussions and reading material from current media. By the end of the course, students should be able to apply economic analysis confidently and independently.

Lecture notes
no script available

Literature
The classification and analysis of natural and artificial compounds is a key subject of this course. It provides an introduction to elementary laboratory techniques, and the experiments cover a wide range of analytic and synthetic techniques. The students learn to apply selected concepts and tools from computer science for working on interdisciplinary projects. The following topics are covered: modeling and simulations, managing data with lists, tables and relational databases, introduction to programming.

- choose and apply appropriate tools from computer science,
- process and analyze real-world data from their subject of study,
- handle the complexity of real-world data,
- query databases and understand and evaluate the corresponding database model,
- encode a problem into a program, test the program, and correct errors,
- implement models from the natural sciences as a simulation.

The handling of chemicals and proper laboratory techniques represent the main learning targets. Furthermore, the description and recording of laboratory processes is an essential part of this course.

The experiments cover a wide range of techniques, including analytical and synthetic techniques (e.g., investigation of soil and water samples or the preparation of simple compounds). Furthermore, the handling of gaseous substances is practised.

The synthesis of simple inorganic complexes or organic molecules is practised. Furthermore, the preparation and handling of environmentally relevant gaseous species like carbon dioxide or nitrogen oxides is a central subject of the Praktikum.

The experiments cover a wide range of analytic and synthetic tasks: Selected samples (e.g., soil and water) will be analysed with various methods, such as titrations, spectroscopy or ion chromatography. The chemistry of aqueous solutions (acid-base equilibria and solvation or precipitation processes) is studied.

Method-specific Competencies
- fostered

Social Competencies
- fostered

Lecture notes
- The instructions to the experiments will be published on Moodle.

Literature
- A thorough study of all script materials is requested before the course starts.

Further reading (not obligatory):
- Fostered

For further reading (not obligatory):
- Gerhard Wanner: Mikroskopisch-Botanisches Praktikum, Georg Thieme Verlag, Stuttgart.
Introduction to basic methods and fundamental concepts of statistics and probability theory for practitioners in natural sciences.

Adaptability and Flexibility fostered
Concepts and Theories fostered
Analytical Competencies fostered
Learning and applying of concepts (models) and quantitative methods to address concrete problems of environmental relevance.

Overhead slides will be made available through the course website.

Physics II

Abstract
Introduction to the way physicists think and work with the help of concept questions, demonstration experiments and problem solving. Wherever possible, applications from thermodynamics, electricity and magnetism are taught from the areas of the degree programmes.

Objective
Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve them.

Content
Thermodynamics with first and second law, phase transformations, transport phenomena. Introduction to electricity and magnetism, as well as waves and modern physics.

Lecture notes
A script will be distributed

Literature
Friedhelm Kuypers
Physik für Ingenieure und Naturwissenschaftler
Band 2 Elektrizität, Optik, Wellen
Wiley-VCH, 2012

Mathematics III: Systems Analysis

Abstract
The objective of the systems analysis course is to deepen and illustrate the mathematical concepts on the basis of a series of very concrete examples. Topics covered include: linear box models with one or several variables, non-linear box models with one or several variables, time-discrete models, and continuous models in time and space.

Objective
Learning and applying of concepts (models) and quantitative methods to address concrete problems of environmental relevance. Understanding and applying the systems-analytic approach, i.e., Recognizing the core of the problem - simplification - quantitative approach - prediction.

Content
Models for dynamic system behavior with one or several variables, including: simple linear box models, non-linear box models, and to solve them. Wherever possible, applications from thermodynamics, electricity and magnetism are taught from the areas of the degree programmes.

Lecture notes
Overhead slides will be made available through the course website.

Literature

Mathematics IV: Statistics

Abstract
Introduction to basic methods and fundamental concepts of statistics and probability theory for practitioners in natural sciences. The concepts will be illustrated with some real data examples and applied using the statistical software R.

Objective
Capacity to learn from data; good practice when dealing with data and recognizing possible fraud in statistics; basic knowledge about the laws of randomness and stochastic thinking (thinking in probabilities); application of simple methods in inferential statistics (e.g., several hypothesis tests will be introduced), i.a. also using the statistical software R. The lecture will be held in German.

Content
Einführung in die Wahrscheinlichkeitsrechnung (Grundregeln, Zufallsvariablen, diskrete und stetige Verteilungen, Ausblick auf Grenzwertsätze), Beschreibende Statistik (einschließlich grafische Methoden), Methoden der Analytischen Statistik: Schätzungen, Tests (einschließlich Binomialtest, 1-Test, Vorzeichentest, F-Test, Wilcoxon-Test), Vertrauensintervalle, Vorhersageintervalle, Korrelation, einfache und multiple lineare Regression. Einführung in die statistische Programmiersprache R.

Lecture notes
Ausführliches Skript zur Vorlesung ist erhältlich.

Literature

Prerequisites / notice
Die Übungen (ca. die Hälfte der Kontaktstunden; einschließlich Computerübungen) sind ein wichtiger Bestandteil der Lehrveranstaltung.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies assessed
Problem-solving assessed
Project Management fostered
Social Competencies
Communication assessed
Personal Competencies
Adaptability and Flexibility fostered
Critical Thinking assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

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<tr>
<td>402-0063-00L</td>
<td>Physics II</td>
<td>O</td>
<td>5</td>
<td>3V+1U</td>
<td>A. Vaterlaus</td>
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<tr>
<td>701-0071-00L</td>
<td>Mathematics III: Systems Analysis</td>
<td>O</td>
<td>4</td>
<td>2V+1U</td>
<td>C. Brunner, R. Knutti, H. Wernli</td>
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<td>401-0624-00L</td>
<td>Mathematics IV: Statistics</td>
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<td>4</td>
<td>2V+1U</td>
<td>N. Meinshausen</td>
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<td>752-4001-00L</td>
<td>Microbiology</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>M. Schupper, M. La Fortezza, M. Pilhofer, S. Robinson</td>
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Basic Courses (Second Year)

Examination Block

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<tr>
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<td>O</td>
<td>5</td>
<td>3V+1U</td>
<td>A. Vaterlaus</td>
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<tr>
<td>701-0071-00L</td>
<td>Mathematics III: Systems Analysis</td>
<td>O</td>
<td>4</td>
<td>2V+1U</td>
<td>C. Brunner, R. Knutti, H. Wernli</td>
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<tr>
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<td>Mathematics IV: Statistics</td>
<td>O</td>
<td>4</td>
<td>2V+1U</td>
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<tr>
<td>752-4001-00L</td>
<td>Microbiology</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>M. Schupper, M. La Fortezza, M. Pilhofer, S. Robinson</td>
</tr>
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</table>
Abstract
Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylology and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Objective
Teaching of basic knowledge in microbiology.

Content

Lecture notes
Wird von den jeweiligen Dozenten ausgegeben.

Literature
Die Behandlung der Themen erfolgt auf der Basis des Lehrbuchs Brock, Biology of Microorganisms

Competencies
Subject-specific Competencies: Concepts and Theories, Techniques and Technologies.

701-0501-00L Pedosphere
Abstract
Introduction to the formation and properties of soils as a function of parent rock, landscape position, climate, and soil organisms. Complex relationships between soil forming processes, physical and chemical soil properties, soil biota, and ecological soil properties are explained and illustrated by numerous examples.

Objective
Understanding of soils as integral parts of ecosystems, development and distribution of soils as a function of environmental factors, and processes leading to soil degradation.

Content
The course "Pedosphere" teaches and examines the competences process understanding and systems understanding.

Prerequisites / notice

Competencies
Subject-specific Competencies: Concepts and Theories, Techniques and Technologies.

751-1311-00L Introduction to Agricultural Management
Abstract
Vermittlung von betriebswirtschaftlichen Grundlagenwissen und Analyse- und Planungsinstrumenten mit Anwendung auf Unternehmen der Agrar- und Ernährungswirtschaft

Objective
Teilnehmer des Kurses sollen am Ende der Vorlesung i) grundlegende Unternehmensentscheide strukturieren und analysieren können, ii) verschiedene Analyse- und Planungsinstrumente auf Fragestellungen der Produktionsplanung, Investition und Finanzierung an Beispielen anwenden zu können, iii) verschiedene Werkzeuge zur unternehmerischen Entscheidungsunterstützung anwenden können und iv) die Spezifika von Unternehmen in der Agrar- und Ernährungswirtschaft kennen.

Content
Die Vorlesung geht auf folgende Inhalte, mit spezifischen Anwendungen im Agrar- und Ernährungssektors ein:

- Grundlagen und Ziele unternehmerischen Entscheidens
- Kosten und Leistungsrechnung
- Produktionstheorie
- Produktionsprogrammplanung
- Investitionsplanung und Finanzierung
- Entscheidungen unter Unsicherheit und Risikomanagement

Lecture notes
Vorlesungsunterlagen werden im Laufe des Semesters zur Verfügung gestellt

Library

Competencies
Subject-specific Competencies: Concepts and Theories, Techniques and Technologies.

752-6003-00L Introduction to Nutritional Science
Abstract
This course introduces basic concepts of micro- and macronutrient nutrition. Micronutrients studied include fat-soluble and water-soluble vitamins, minerals and trace elements. Macronutrients include proteins, fat and carbohydrates.

Objective
To introduce the students to the both the macro- and the micronutrients.

Content
The course is divided into two parts: Micronutrients and macronutrients. The micronutrient part includes fat-soluble vitamins, water-soluble vitamins, minerals and trace elements. The macronutrient part introduces basic nutritional aspects of proteins, fats, carbohydrates and energy metabolism. The nutrients are described in relation to digestion, absorption and metabolism. Special aspects of homeostasis and homeoeosis are emphasized.

Lecture notes
There is no script. Powerpoint presentations will be made available.
Agricultural Sciences Basic Courses

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<tr>
<th>Number</th>
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<tr>
<td>751-8003-00L</td>
<td>Genetics in Agricultural Sciences</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>H. Pausch, B. Studer</td>
</tr>
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</table>

Abstract
- Important concepts from population, quantitative and molecular genetics are introduced and applied to plant and animal populations.
- Students will work with genetic polymorphisms and explain mechanisms underlying allele frequency changes in natural and experimental populations.
- They will determine factors affecting the selection intensity.
- Students will explain the difference between genotypic and phenotypic values.
- They will calculate the expected genetic gain per time unit.
- Important molecular methods to determine genetic polymorphisms will be explained.
- Traits in plant and animal populations using molecular marker information will be mapped.
- Students will integrate different concepts from population, molecular and quantitative genetics and explain their importance for applications in genetics in agricultural sciences.

Content
- Molecular genetics (15%)
  - DNA sequence variation
  - Marker & genotyping technologies (SSRs, AFLPs, SNPs, KASP, GBS, RADseq, AmpSeq, Chip Technologies)
- Population genetics (30%)
  - Allele- and genotype frequencies in populations
  - Hardy-Weinberg equilibrium
  - Genetic drift, differentiation of populations
  - Fitness, selection
  - Inbreeding, relationship, effective population size
- Quantitative genetics (40%)
  - Recombination, crossing over, linkage analysis, genetic mapping
  - QTL mapping
  - Forms of selection and selection differential
  - Heritability
  - Quantification of expected genetic gain
  - Genotypic value, allele substitution effect, breeding value
- Integrative genetics (15%)
  - Genome-wide association mapping
  - Estimation of genomic breeding values

Lecture notes
Slides and exercises will be provided in advance of each class via Moodle

Literature
Further reading:
- Falconer & Mackay: Introduction to Quantitative Genetics
- Lübberstedt & Varshney: Diagnostics in Plant Breeding

Prerequisites / notice
- German

Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
  - Analytical Competencies: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed
- Method-specific Competencies
  - Creative Thinking: fostered
  - Critical Thinking: fostered
- Personal Competencies
  - Subjects specific competencies
  - Concepts and Theories: fostered

Agricultural Sciences Disciplines

Agricultural Economics

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<tr>
<th>Number</th>
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<tr>
<td>351-1109-00L</td>
<td>Introduction to Microeconomics (GESS Science in Perspective)</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>M. Wörter, M. Beck</td>
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This course is only for students enrolled in a Bachelor's degree programme.

Students enrolled in a Master's degree programme may attend "Principles of Microeconomics" (LE 363-0503-00L) instead.

Note for D-MAVT students: If you have already successfully completed "Principles of Microeconomics" (LE 363-0503-00L), then you will not be permitted to attend it again.

Abstract
The course introduces basic principles, problems and approaches of microeconomics. It describes economic decisions of households and firms, and their coordination through perfectly competitive markets.

Objective
Students acquire a deeper understanding of basic microeconomic models.
They acquire the ability to apply these models in the interpretation of real world economic contexts.

Students acquire a reflective and contextual knowledge on how societies use scarce resources to produce goods and services and distribute them among themselves.

Autumn Semester 2024
751-0903-00L  Microeconomics of the Agriculture and Food Sector  W+  3 credits  2V  L. Zachmann

Abstract
In dieser Vorlesung werden ökonomische Charakteristika des Agrar- und Lebensmittelsektors herausgearbeitet und anderen Sektoren gegenübergestellt. Fokus ist dabei Lebensmittelindustrie in der Schweiz und in der EU. Es werden mikroökonomische Zusammenhänge, insbesondere zur Preis- und Mengenbildung in verschiedenen Wettbewerbsmodellen, am Fallbeispiel des Agrar- und Ernährungssektors vermittelt.

Objective

Content
- Der Agrar- und Lebensmittelsektor in der EU und der Schweiz
- Preiselastizitäten von Angebot und Nachfrage im Ernährungssektor
- Gewinnmaximierung
- Grundlagen der Spieltheorie
- Monopol / Monopolistischer Wettbewerb
- Oligopol (Stackelberg, Cournot, Bertrand)
- Monopson
- Produktdifferenzierung
- Preisdiskriminierung
- Kartelle

Literature

Prerequisites / notice
Empfohlene Vorkenntnisse:
- Grundkenntnisse der Ökonomie/Agrarökonomie
- Vorlesung Einführung in die Mikroökonomie

751-0401-00L  Optimization of Agricultural Production Systems  W+  3 credits  2G  R. Huber

Abstract
Introduction in to optimization of agricultural production systems with linear and non-linear programming models.

Objective
Students will be able to a) solve linear and non-linear optimization problems in the context of agricultural production; b) properly interpret the results; and c) critically discuss the economic implications.

Content
The course is an application of Operations Research (OR), First, the theory and application of linear programming (LP) is presented. Students will learn the underlying principles (Optimization, Duality, Simplex) and solve exercises in the context of agricultural production. In the second part of the course, the foundation of non-linear programming (NLP) is introduced (Lagrange, Kuhn-Tucker) and illustrated with various examples.

Literature

363-0537-00L  Resource and Environmental Economics  W+  3 credits  2G  A. Miftakhova, A. Minabutdinov

Abstract
Relationship between economy and environment, market failures, external effects and public goods, contingent valuation, internalisation of externalities, economics of non-renewable resources, economics of renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.
A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Finally, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economics theory and policy at international level, e.g. to the problem of climate change.

The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power. When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

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<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>751-3700-00L</td>
<td>Plant Ecophysiology</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>N. Buchmann, A. Walter</td>
</tr>
</tbody>
</table>

The general theme of this course is the effect of environmental factors (such as light, temperature, relative humidity, CO2 concentrations, etc.) on plant physiology: water uptake and transport, transpiration, CO2 gas exchange of plants (photosynthesis, respiration), growth and C allocation, yield and production, stress physiology. Working with measurement data and Jupyter Notebooks is included.

The students will understand the impact of environmental factors on plant physiology and will learn the theoretical basis and terminology of plant ecophysiology that is necessary to analyze yield potentials in agriculture. The students will learn about classical and latest studies in plant ecophysiology. Students will check and implement their knowledge and understanding of ecophysiology using measurement data.
Content

The aim of these lecture is to present the processes controlling the uptake and transport of nutrients by the plant, the assimilation of nutrients in the plant, the effect of nutrients on crop yield and quality, the role of the soil as a source of nutrients for crops, and the basic principles of fertilization of different crop types using mineral and organic fertilizers.

Objective

At the end of the lecture, students know how mineral nutrients are taken up through roots and circulate in the plants and what their roles in plants are. They understand the importance of nutrients for yield formation and for crop product quality. They are able to propose fertilization plans adapted for field crops growing under Swiss conditions.

Literature


Prerequisites

Production and Grassland Systems.

Competencies

Subject-specific Competencies: Concepts and Theories; Analytical Competencies; Media and Digital Technologies; Problem-solving; Critical Thinking

Personal Competencies: assessed

751-3401-00L Plant Nutrition I

Abstract

The aim of the course is to present the processes controlling the uptake and transport of nutrients by the plant, the assimilation of nutrients in the plant, the effect of nutrients on crop yield and quality, the role of the soil as a source of nutrients for crops, and the basic principles of fertilization of different crop types using mineral and organic fertilizers.

Objective

At the end of the course, students have a deep understanding of the processes of mineral nutrition and fertilization in plants, and the practical application of these principles in real-world farming scenarios.

Literature


Schubert S 2011 Pflanzennährung Grundwissen Bachelor Ulmer UTB

Competencies

Subject-specific Competencies: Concepts and Theories; Techniques and Technologies; Analytical Competencies; Decision-making; Problem-solving; Critical Thinking

Personal Competencies: assessed

751-4108-00L Startup for Smart Sustainable Farming

Abstract

The course is based on the understanding that sustainable agriculture is essential for addressing global challenges such as feeding the increasing world population, reducing climate change, and preserving natural resources. The course aims to equip students with the skills necessary to develop innovative solutions in the field of sustainability and entrepreneurship.

Objective

The course focuses on identifying, evaluating, and implementing sustainable farming practices, with an emphasis on using digital technologies and entrepreneurship to drive innovation in the agricultural sector.

Prerequisites

Maximum number of students: 16 (four teams will be formed). Students interested should come to the first lecture (25th September). There, details of this year’s format will be explained. In case students are then still interested to visit the class, they have to write a motivational letter to Achim.Walter@usys.ethz.ch until (27th September). Participants will be selected according to the following criteria:

1.) Convincing motivational letter

2) Agricultural science students of the BSc program, 5. Semester

2 b) Students of other semesters or study programs, who will be selected with a view to forming interdisciplinary and diverse teams. The definitive acceptance to the course will be communicated to students by (27.9.). The definitive inscription will subsequently been done by the study secretariate.

Notice

The slides will be distributed to participants.

Number of participants limited to 16.

All students interested should come to the first lecture (23.9.). There, details of this year’s format will be explained. In case students are then still interested to visit the class, they have to write a motivational letter of max. 100 words and send it via email to achim.walter@usys.ethz.ch until (25.9.). Participants will be selected according to the following criteria:

1.) Convincing motivational letter

2) Agricultural science students of the BSc program, 5. Semester

2 b) Students of other semesters or study programs, who will be selected with a view to forming interdisciplinary and diverse teams. The definitive acceptance to the course will be communicated to students by (27.9.). The definitive inscription will subsequently been done by the study secretariate.
### Competencies

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<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Media and Digital Technologies</td>
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<td>Communication</td>
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<td>Self-presentation and Social Influence</td>
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<td>Negotiation</td>
<td>Adaptability and Flexibility</td>
<td>Critical Thinking</td>
<td>Integrity and Work Ethics</td>
<td>Self-awareness and Self-reflection</td>
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### 751-4504-00L Plant Pathology I

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<th>2 credits</th>
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<th>B. McDonald</th>
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<tr>
<td>Lecture Topics and Tentative Schedule</td>
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</table>

#### Abstract

Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems. Students will understand: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems. Topics under the first theme will include pathogen life cycles, disease cycles, and an overview of plant pathogenic nematodes, viruses, bacteria, and fungi. Topics under the second theme will include plant defense strategies, host range, passive and active defenses, and chemical and structural defenses. Topics under the third theme will include the disease triangle and cultural control strategies.

#### Objective

- Students will understand: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems.

#### Content

- Course description: Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems. Topics under the first theme will include pathogen life cycles, disease cycles, and an overview of plant pathogenic nematodes, viruses, bacteria, and fungi. Topics under the second theme will include plant defense strategies, host range, passive and active defenses, and chemical and structural defenses. Topics under the third theme will include the disease triangle and cultural control strategies.

### Lecture Topics and Tentative Schedule

#### Week 1
- The nature of plant diseases, symbiosis, parasites, mutualism, biotrophs and necrotrophs, disease cycles and pathogen life cycles.

#### Week 2
- Nematode attack strategies and types of damage. Viral pathogens, classification, reproduction and transmission, attack strategies and types of damage. Examples TMV, BYDV. Bacterial pathogens and phytoplasmas, classification, reproduction and transmission.

#### Week 3
- Bacterial attack strategies and symptoms. Example bacterial diseases: fire blight, Agrobacterium crown gall, soft rots. Fungal and oomycete pathogens, classification, growth and reproduction, sexual and asexual spores, transmission.

#### Week 4
- Fungal and oomycete life cycles, disease cycles, infection processes, colonization, phytoxins and mycotoxins. Attack strategies of fungal necrotrophs and biotrophs. Symptoms and signs of fungal infection. Example fungal diseases: potato late blight.

#### Week 5
- Example fungal diseases: wheat stem rust, grape powdery mildew, wheat septoria tritici blotch. Plant defense mechanisms, host range and non-host resistance, Passive structural and chemical defenses, preformed chemical defenses. Active structural defense, histological and cellular (papillae).

#### Week 6
- Active chemical defense, hypersensitive response, pathogenesis-related (PR) proteins, phytoalexins and disease resistance. Pisatin and pisatin demethylase. Local and systemic acquired resistance (LAR, SAR), induced systemic resistance (ISR), signal molecules, defense activators (Bion). Pathogen effects on food quality. Positive and negative transformations.

#### Week 7

#### Week 8
- Epidemiology: Disease pyramid, environmental effects on epidemic development, plant effects on development of epidemics, including resistance, physiology, density, uniformity.

#### Week 9
- Disease assessment: incidence and severity measures, keys, diagrams, scales, measurement errors. Correlations between incidence and severity. Molecular detection and diagnosis of pathogens. Host indexing, serology, monoclonal and polyclonal antibodies, ELISA.

#### Week 10
- Molecular detection and diagnosis of pathogens: PCR, rDNA and loop-mediated isothermal amplification. Strategies for minimizing disease risks: calculating disease thresholds, disease forecasting systems.

#### Week 11

#### Week 12
- Physical control methods. Cultural control methods: avoidance, tillage practices, crop sanitation.

#### Week 13
- Cultural control methods: fertilizers, crop rotations.

#### Week 14
- Open lecture.
Abstract
This class conveys current topics and methods of agroecological and food systems research through selected case studies from ongoing research of the Sustainable Agroecosystems group. Students will be encouraged to develop critical thinking competencies, through individual and group work, on major agricultural and food system challenges and paths towards agricultural and food system transformation.

Objective
(1) Systematically analyse and discuss case studies from ongoing agroecological and food system research.
(2) Learn and experiment on methods for field and laboratory investigations in agroecology.
(3) Engage with positive and empowering frameworks that motivate critical reflection and action on the types of transformative responses needed to adapt and thrive within agricultural and food systems.
(4) Reflect critically on agricultural and food system transformation tools and methods from the perspective a food system stakeholder.
(5) Identify and describe institutions in the context of sustainable agricultural development (for Bachelor and Master thesis and internships).

Content
The course will address a wide range of agricultural and food system challenges (e.g. food security, climate crisis, soil degradation, etc.) in both temperate and tropical contexts. In class we will address topics like building food system resilience through innovative measures, improving soil fertility management or understanding the effects of agroforestry systems.

Case studies from the on-going research in the Sustainable Agroecosystems Group (sae.ethz.ch) will be presented, covering different scales (e.g. food value-chains, farm dynamics and soil management).

The class is complemented by practical group work conducted with the CSA Meh Als Gmues in Zürich on Measuring and monitoring Agroecological performance.

Students will gain an overview on institutions and actors' roles in the field of sustainable agricultural development. Throughout the group work, students will learn to engage directly with various stakeholders, monitor agroecological transition and communicate their research to a wider audience. Ultimately, this class should provide an overview on methods, tools, innovations and platforms that support a sustainable food transformation.

Literature


Prerequisites / notice
Prior participation in the lecture Nachhaltige Agrarökosysteme I (Sustainable Agroecosystems I) 751-5000-00G (spring term) recommended.

Competencies

Subject-specific Competencies
Concepts and Theories

Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving
Project Management

Social Competencies
Communication
Cooperation and Teamwork
Self-presentation and Social Influence

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Abstract
The importance and specificities of the different horticultural crops are shown in this course in the autumn semester. It deals with fruit growing (8 h), berry production (4 h), vegetables (6 h) and viticulture (6 h).

Objective
You are able to describe the production systems of the horticultural crops fruits, berries, vegetables and viticulture (yield formation and physiology, cultivation methods, main varieties, quality factors).

You are able to assess the importance of new conditions (climate, politics, trade) for the production of horticultural crops and identify options for action for production.

Content
The importance and specificities of the different horticultural crops are shown in this course in the autumn semester. It deals with fruit growing (8 h), berry production (4 h), vegetable growing (6 h) and viticulture (6 h).

Under the responsibility of Agroscope representatives, basic knowledge of production systems (yield formation and physiology, cultivation methods, main varieties, quality) of these horticultural crops, which are important in Switzerland, is imparted.

Lecture notes
Delivered during the lectures by the different teachers, Moodle upload.

Literature
Not needed, maybe specific literature is specified by the different teachers.

Language and script: German or French, maybe selected parts in English.

Competencies

Subject-specific Competencies
Concepts and Theories

Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving

Social Competencies
Customer Orientation

Number: 751-4201-00L
Title: Horticulture
Credit: 2
Hours: 2V
Lecturers: C. Carlen, W+, C. Carlén, A. Bühlmann, A. Naf, T. Verdenal, to be announced

Abstract
You are able to describe the production systems of the horticultural crops fruits, berries, vegetables and viticulture (yield formation and physiology, cultivation methods, main varieties, quality factors).

Objective
You are able to assess the importance of new conditions (climate, politics, trade) for the production of horticultural crops and identify options for action for production.

Content
The importance and specificities of the different horticultural crops are shown in this course in the autumn semester. It deals with fruit growing (8 h), berry production (4 h), vegetable growing (6 h) and viticulture (6 h).

Under the responsibility of Agroscope representatives, basic knowledge of production systems (yield formation and physiology, cultivation methods, main varieties, quality) of these horticultural crops, which are important in Switzerland, is imparted.

Lecture notes
Delivered during the lectures by the different teachers, Moodle upload.

Literature
Not needed, maybe specific literature is specified by the different teachers.

Language and script: German or French, maybe selected parts in English.
This lecture is part of the BSc programme in Agricultural Sciences (3rd semester)

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: fostered
- Project Management: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: assessed

**PERFORMANCE ASSESSMENT:** 1 final written examination (100% of grade)

**Lecture notes**
- Handouts/scripts are provided by the the lecturers.

**Literature**
- Specific literature recommendations will be provided by the lecturers as appropriate

**Prerequisites / notice**
- This lecture is part of the Agricultural Sciences Bachelor (3rd Semester)
- Being able to attend the exam on the only possible date of the 31.10.2024 from 8.00-10.00 is a prerequisite.

**751-7501-00L Introduction to Housing and Behaviour of Farm Animals**

**Objective**
- Students will:
  - Understand the basis of animal behaviour of farm animals
  - Acquire knowledge of housing systems and management of domestic animals

**Content**
- CONTENTS
  1. Introduction to housing
  2. Introduction to animal behaviour
  3. Housing and behaviour of pigs
  4. Housing and behaviour of cattle
  5. Housing and behaviour of small ruminants
  6. Housing and behaviour of chickens

**Lecture notes**
- Handouts in German language will be provided by each lecturer on the Moodle platform when starting his part of the lecture.

**Literature**
- Blockkurs in Halbtagesform; eingeschlossen sind Betriebsbesuche. Fach mit benoteter Semesterleistung.

**Prerequisites / notice**
- This lecture is part of the BSc programme in Agricultural Sciences (3rd semester)

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed

**Social Competencies**
- Communication: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered

**4 credits**

**751-7103-00L Animal Feed and Feeding of Ruminants**

**Abstract**
The knowledge of the nutrition of ruminants and of the feeds used is deepened. Particular emphasis is put on the variety of home-grown feeds, their production and conservation and their application in the nutrition of dairy cows, cattle and small ruminants. Finally, information on specific problems of animal nutrition is communicated.

**Lecture notes**
- Handouts in German language will be provided by each lecturer on the Moodle platform when starting his part of the lecture.

**Literature**
- Blockkurs in Halbtagesform; eingeschlossen sind Betriebsbesuche. Fach mit benoteter Semesterleistung.
Objective
Purchase of basic skills in agricultural livestock nutrition.

Content

Lecture notes
Script is available in German language and will be provided by each lecturer when starting his part the lecture.

Literature
Eine Literaturliste ist im Skript enthalten.

Prerequisites / notice
Fach mit benoteter Prüfung am Ende der Lehrveranstaltung.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered

Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Abstract
Zusammen mit nervaler Kontrolle, spielen Hormone und Zytokine als Signalmediatoren eine besondere Rolle bei der Regulation der Homöostase von Körperfunktionen (Flüssigkeits-, Temperatur-, Energie-Homöostase). Insbesondere im Zusammenhang mit pathologischen Konstellationen (Fieber, Stress, metabolische Imbalance, Schmerzen) wird diese komplexe Funktion verständlich.

Objective

Content
- Thermoregulation (Fieber)
- Flüssigkeitshomöostase (Durchfall)
- Calciumregulation (Milchfieber)
- Energiehomöostase (Ketose)
- Schmerz (zootechnische Eingriffe)
- Stress (allostatische Last, Epigenetik)

Lecture notes
Unterlagen werden individuell von den Dozierenden abgegeben.

Literature
Spezifische Literatur wird individuell von den Dozierenden angegeben.

Prerequisites / notice
Diese Vorlesung is Teil der BSc Agrarwissenschaften (5. Semester)

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Methods

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<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>751-0441-00L</td>
<td>Scientific Analysis and Presentation of Data</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>H. Pausch, N. K. Kadri, A. Leonard</td>
</tr>
</tbody>
</table>

Abstract
Students will get an introduction to the scientific work with data covering all steps from data import from Excel via statistical analyses to producing correct scientific graphical output. Exercises with the software R/RStudio will provide hands-on opportunities to get acquainted with data analysis and presentation in adequate graphs.

Objective
This lecture with exercises gives an introduction to the scientific work with data, starting with data acquisition and ending with statistical analyses as they are often required for a bachelor thesis (descriptive statistics, linear regression, simple analyses of variance etc.). Using open-source R/RStudio software will be the primary focus via a hands-on approach. An important aspect will be to learn which graphical representation of data are best suited for the task (how can data be presented clearly and still scientifically correct?)
Tentative Programme:
- Introduction
- Introduction to 'R'
- Data import and graphical presentation
- Correct and problematic graphical data displays
- Statistical distribution and confidence intervals
- Statistical tests - Repetition and hands-on applications
- Correlation analysis
- Linear regressions
- Analysis of Variance

Last week of semester: examination (Leistungskontrolle)

Lecture notes
German and English

Prerequisites / notice
Theoretical background in ensemble statistics from the mandatory course in the 4th semester; students should have cleared the examination of that fundamental course to be able to follow

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management assessed

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered

751-1010-00L Introduction to Scientific Methods Part II: Scientific Writing
O 3 credits 4G

Abstract
Die Studierenden kennen die Grundlagen und die Konventionen des wissenschaftlichen Schreibens in den Naturwissenschaften, können wissenschaftliche Literatur suchen und verwalten sowie wissenschaftliche Publikationen analysieren. Sie setzen das Gelernte beim Schreiben eines eigenen Textes um.

Objective
Die Studierenden kennen die Grundlagen und die Konventionen des wissenschaftlichen Schreibens in den Naturwissenschaften. Sie setzen das Gelernte beim Schreiben eines kritischen Literaturberichtes zu einem agrarwissenschaftlichen Thema ihrer Wahl um. Die Lehrveranstaltung bereitet die Studierenden auf weitere schriftliche Arbeiten im Studium der Agrarwissenschaften vor, beispielsweise auf die Bachelor-Arbeit.

Lecture notes
Es wird ein Skript abgegeben.

Prerequisites / notice
Die Note für die LV Wissenschaftliches Arbeiten (Teil I: Grundlagen (WiA) und Teil II: Wissenschaftliches Schreiben (WiSch)) setzt sich aus den Leistungen der Lehrveranstaltungen im 4. und 5. Semester zusammen. Die Note für WiSch (5. Sem.) zählt zu 80% zur Gesamtnote.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies assessed
Problem-solving assessed
Project Management assessed

Social Competencies
Communication assessed
Cooperation and Teamwork assessed

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking fostered
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

751-0206-00L Applied Laboratory Techniques in Agricultural Sciences
The course is compulsory for students in 5th semester BSc Agricultural Sciences.
O 3 credits 3P

Abstract
Die Lehrveranstaltung ist zweiteilig aus einem Laborpraktikum und einem angewandten Methodentraining aufgebaut. Im Laborpraktikum werden an 6 Kurstagen die wichtigsten Techniken der Molekularbiologie gelehrt. Das folgende Methodentraining findet an 5 Kurstagen im Block in einer der beteiligten Forschungsgruppen statt, um die wichtigsten Methoden aus dem jeweiligen Fachgebiet praxisnah anzuwenden.

Objective
- Aneignung von guter Laborpraxis (Sicherheit, Effizienz, Qualität und Dokumentation)
- Erlernen der wichtigsten Labor- und Feldmethoden in den Agrarwissenschaften sowie deren korrekte und sichere Anwendung
- Vertieftes Verständnis von molekularen, physiologischen und biochemischen Prozessen in aktuellen agrarwissenschaftlichen Themenbereichen
- Aneignung von Kompetenzen für zukünftige Bachelor-, Master-, und Doktorarbeiten
- Kritische Beurteilung der angewandten Methoden für verantwortungsvolle Forschung
Microeconomics of the Agriculture and Food Sector


In dieser Vorlesung werden ökonomische Charakteristika des Agrar- und Lebensmittelsektors herausgearbeitet und anderen Sektoren gegenübergestellt. Fokus ist dabei Lebensmittelindustrie in der Schweiz und in der EU. Es werden mikroökonomische Zusammenhänge, insbesondere zur Preis- und Mengenbildung in verschiedenen Wettbewerbssituationen, am Fallbeispiel des Agrar- und Ernährungssektors vermittelt.


Nach erfolgreichem Abschluss der Lehrveranstaltung können die Studierenden die ökonomischen Folgen von verschiedenen Wettbewerbssituationen differenziert abschätzen und Empfehlungen für Management und Politik ableiten.
Agriculture needs to become more sustainable via innovative approaches. This course allows students to explore in group work, how this

### StartUp for Smart Sustainable Farming

**Number of participants limited to 16.**

All students interested should come to the first lecture (25th September). There, details of this year’s format will be explained. In case students are then still interested to visit the class, they have to write a motivational letter of max. 100 words and send it via email to achim.walter@usys.ethz.ch until (25.9.). Participants will be selected according to the following criteria:

1.) Convincing motivational letter
2 a) Agricultural science students of the BSc program, 5. Semester
2 b) Students of other semesters or study programs, who will be selected with a view to forming four interdisciplinary and diverse teams. The definitive acceptance to the course will be communicated to students by (27.9.). The definitive inscription will subsequently be done by the study secretariat.

**Abstract**

Agriculture needs to become more sustainable via innovative approaches. This course allows students to explore in group work, how this could be realized. There are short impulse talks on ‘Smart Farming’ given by experts on technology, sustainability and entrepreneurship. Most importantly, students elaborate the first steps to create a startup company in this field.

**Objective**

During the course, the students generate their own ideas. They explore e.g., which technologies provide possibilities for a more sustainable farming. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

**Prerequisites / notice**

Maximum number of students: 16 (four teams will be formed)

All students interested should come to the first lecture (25th September). There, details of this year’s format will be explained. In case students are then still interested to visit the class, they have to write a motivational letter of max. 100 words and send it via email to Achim.Walter@usys.ethz.ch until (27th September). Participants will be selected according to the following criteria:

1.) Convincing motivational letter
2 a) Agricultural science students of the BSc program, 5. Semester
2 b) Students of other semesters or study programs, who will be selected with a view to forming four interdisciplinary and diverse teams. The definitive acceptance to the course will be communicated to students by (29th September). The definitive inscription will subsequently be done by the study secretariat.

**Content**

The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit-analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power.

When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

**Literature**

### Plant Pathology I

**W** 2 credits  
B. McDonald

#### Abstract

Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems.

#### Objective

Students will understand: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems. Topics under the first theme will include pathogen life cycles, disease cycles, and an overview of plant pathogenic nematodes, viruses, bacteria, and fungi. Topics under the second theme will include plant defense strategies, host range, passive and active defenses, and chemical and structural defenses. Topics under the third theme will include the disease triangle and cultural control strategies.

#### Content

**Week 1**  
The nature of plant diseases, symbiosis, parasites, mutualism, biotrophs and necrotrophs, disease cycles and pathogen life cycles.

**Week 2**  
Nematode attack strategies and types of damage. Viral pathogens, classification, reproduction and transmission, attack strategies and types of damage. Examples TMV, BYDV. Bacterial pathogens and phytoplasmas, classification, reproduction and transmission.

**Week 3**  
Bacterial attack strategies and symptoms. Example bacterial diseases: fire blight, Agrobacterium crown gall, soft rots. Fungal and oomycete pathogens, classification, growth and reproduction, sexual and asexual spores, transmission.

**Week 4**  
Fungal and oomycete life cycles, disease cycles, infection processes, colonization, phytopoxins and mycotoxins. Attack strategies of fungal necrotrophs and biotrophs. Symptoms and signs of fungal infection. Example fungal diseases: potato late blight.

**Week 5**  
Example fungal diseases: wheat stem rust, grape powdery mildew, wheat septoria tritici blotch. Plant defense mechanisms, host range and non-host resistance. Passive structural and chemical defenses, preformed chemical defenses. Active structural defense, histological and cellular (papillae).

**Week 6**  
Active chemical defense, hypersensitive response, pathogenesis-related (PR) proteins, phytoalexins and disease resistance. 
Pisatin and pisatin demethylase. Local and systemic acquired resistance (LAR, SAR), induced systemic resistance (ISR), signal molecules, defense activators (Bion). Pathogen effects on food quality. Positive and negative transformations.

**Week 7**  

**Week 8**  
Epidemiology: Disease pyramid, environmental effects on epidemic development, plant effects on development of epidemics, including resistance, physiology, density, uniformity.

**Week 9**  
Disease assessment: incidence and severity measures, keys, diagrams, scales, measurement errors. Correlations between incidence and severity. Molecular detection and diagnosis of pathogens. Host indexing, serology, monoclonal and polyclonal antibodies, ELISA.

**Week 10**  
Molecular detection and diagnosis of pathogens: PCR, rDNA and loop-mediated isothermal amplification. Strategies for minimizing disease risks: calculating disease thresholds, disease forecasting systems.

**Week 11**  

**Week 12**  

**Week 13**  
Cultural control methods: fertilizers, crop rotations.

**Week 14**  
Open lecture.

#### Lecture Topics and Tentative Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The nature of plant diseases, symbiosis, parasites, mutualism, biotrophs and necrotrophs, disease cycles and pathogen life cycles.</td>
</tr>
<tr>
<td>2</td>
<td>Nematode attack strategies and types of damage. Viral pathogens, classification, reproduction and transmission, attack strategies and types of damage. Examples TMV, BYDV. Bacterial pathogens and phytoplasmas, classification, reproduction and transmission.</td>
</tr>
<tr>
<td>3</td>
<td>Bacterial attack strategies and symptoms. Example bacterial diseases: fire blight, Agrobacterium crown gall, soft rots. Fungal and oomycete pathogens, classification, growth and reproduction, sexual and asexual spores, transmission.</td>
</tr>
<tr>
<td>4</td>
<td>Fungal and oomycete life cycles, disease cycles, infection processes, colonization, phytopoxins and mycotoxins. Attack strategies of fungal necrotrophs and biotrophs. Symptoms and signs of fungal infection. Example fungal diseases: potato late blight.</td>
</tr>
<tr>
<td>5</td>
<td>Example fungal diseases: wheat stem rust, grape powdery mildew, wheat septoria tritici blotch. Plant defense mechanisms, host range and non-host resistance. Passive structural and chemical defenses, preformed chemical defenses. Active structural defense, histological and cellular (papillae).</td>
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<td>6</td>
<td>Active chemical defense, hypersensitive response, pathogenesis-related (PR) proteins, phytoalexins and disease resistance. Pisatin and pisatin demethylase. Local and systemic acquired resistance (LAR, SAR), induced systemic resistance (ISR), signal molecules, defense activators (Bion). Pathogen effects on food quality. Positive and negative transformations.</td>
</tr>
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<td>8</td>
<td>Epidemiology: Disease pyramid, environmental effects on epidemic development, plant effects on development of epidemics, including resistance, physiology, density, uniformity.</td>
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<td>Disease assessment: incidence and severity measures, keys, diagrams, scales, measurement errors. Correlations between incidence and severity. Molecular detection and diagnosis of pathogens. Host indexing, serology, monoclonal and polyclonal antibodies, ELISA.</td>
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<tr>
<td>10</td>
<td>Molecular detection and diagnosis of pathogens: PCR, rDNA and loop-mediated isothermal amplification. Strategies for minimizing disease risks: calculating disease thresholds, disease forecasting systems.</td>
</tr>
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<td>13</td>
<td>Cultural control methods: fertilizers, crop rotations.</td>
</tr>
<tr>
<td>14</td>
<td>Open lecture.</td>
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</table>
This class conveys current topics and methods of agroecological and food systems research through selected case studies from ongoing research of the Sustainable Agroecosystems group. Students will be encouraged to develop critical thinking competencies, through individual and group work, on major agricultural and food system challenges and paths towards agricultural and food system transformation.

<table>
<thead>
<tr>
<th>Content</th>
<th>Objective</th>
<th>Competencies</th>
<th>Prerequisites / notice</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>The course will address a wide range of agricultural and food system challenges (e.g. food security, climate crisis, soil degradation, etc.) in both temperate and tropical contexts. In class we will address topics like building food system resilience through innovative measures, improving soil fertility management or understanding the effects of agroforestry systems.</td>
<td>(1) Systematically analyse and discuss case studies from ongoing agroecological and food system research.</td>
<td>Social Competencies</td>
<td>Prior participation in the lecture Nachhaltige Agrarökosysteme I (Sustainable Agroecosystems I) 751-5000-00G (spring term) recommended.</td>
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<tr>
<td>The class is complemented by practical group work conducted with the CSA Mehl Als Gmues in Zürich on Measuring and monitoring Agroecological performance. Students will gain an overview on institutions and actors' roles in the field of sustainable agricultural development. Throughout the group work, students will learn to engage directly with various stakeholders, monitor agroecological transition and communicate their research to a wider audience. Ultimately, this class should provide an overview on methods, tools, innovations and platforms that support a sustainable food transformation.</td>
<td>(2) Learn and experiment on methods for field and laboratory investigations in agroecology.</td>
<td>Subject-specific Competencies</td>
<td>- Programmteil Wiederkäuer: Einführung in die Winterfütterungsplanung für Milchkühe, Betriebsbesuch (Erfassung aller notwendigen Daten für Mischfuttermittel anhand verschiedener Beispiele; Einsatzgrenzen von Futtermittel; technologische Futterbearbeitung.</td>
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<tr>
<td>Case studies from the on-going research in the Sustainable Agroecosystems Group (sae.ethz.ch) will be presented, covering different scales (e.g. food value-chains, farm dynamics and soil management).</td>
<td>(3) Engage with positive and empowering frameworks that motivate critical reflection and action on the types of transformative responses needed to adapt and thrive within agricultural and food systems.</td>
<td>Method-specific Competencies</td>
<td>- Programmteil Nicht-Wiederkäuer: Der Energie- und spezifische Nährstoffbedarf beim Schwein und Geflügel; Besonderheiten der Fütterung in den verschiedenen Produktionsphasen; Fütterungsempfehlungen und -hinweise. Rationengestaltung und -optimierung für Mischfuttermittel anhand verschiedener Beispiele; Einsatzgrenzen von Futtermittel; technologische Futterbearbeitung.</td>
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<tr>
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<td>(4) Reflect critically on agricultural and food system transformation tools and methods from the perspective a food system stakeholder.</td>
<td>Social Competencies</td>
<td>Dozierenden geben in der Lehrveranstaltung die relevante Literatur bekannt.</td>
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<tr>
<td>The class is complemented by practical group work conducted with the CSA Mehl Als Gmues in Zürich on Measuring and monitoring Agroecological performance. Students will gain an overview on institutions and actors' roles in the field of sustainable agricultural development. Throughout the group work, students will learn to engage directly with various stakeholders, monitor agroecological transition and communicate their research to a wider audience. Ultimately, this class should provide an overview on methods, tools, innovations and platforms that support a sustainable food transformation.</td>
<td>(5) Identify and describe institutions in the context of sustainable agricultural development (for Bachelor and Master thesis and internships).</td>
<td>Personal Competencies</td>
<td>Blockkurs in Halbtagesform; eingeschlossen sind Betriebsbesuche. Fach mit benoteter Semesterleistung.</td>
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</table>

<table>
<thead>
<tr>
<th>Literature</th>
<th>Abstract</th>
<th>Competencies</th>
<th>Prerequisites / notice</th>
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</table>

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Agroecology is a discipline, an agricultural practice, and a political-social movement. Students will attend public lectures by experts from different fields and will reflect on agroecology and its principles. Moreover, students will expand their knowledge with case studies and discuss about the role of agroecology to support sustainable agriculture and food systems.

Students will be able to transfer their disciplinary and interdisciplinary knowledge about the thirteen principles as guiding principles for policymakers, practitioners, and other stakeholders across the food system in planning, managing, and evaluating agroecological transformation. Students are part of small groups focusing on selected principles of the HLPE. During the course, students discuss the potential and limitations of agroecology and learn about scientific contributions to agroecology. Students form an opinion on the role of agroecology, reflect and argue on the different facets and develop recommendations for real-world applications of agroecology in supporting a transition towards sustainable food systems.

Handouts will be available on the webpage of the course.
Prerequisites / notice
This course is based on fundamental knowledge about plant ecophysiology, soil science, biogeochemistry, crop and forage science, and ecology in general. The course will be taught in English. The course is only offered in fall.

Competencies

Subject-specific Competencies
- Concepts and Theories
  - assessed
- Analytical Competencies
  - fostered
- Project Management
  - fostered

Method-specific Competencies
- Communication
  - assessed
- Cooperation and Teamwork
  - assessed
- Sensitivity to Diversity
  - fostered

Social Competencies

Personal Competencies
- Critical Thinking
  - assessed
- Self-direction and Self-management
  - assessed

Bachelor’s Thesis

Number | Title                  | Type | ECTS  | Hours | Lecturers
---- | ---------------------- |----- |------ |------ |----------
751-1020-10L | Bachelor's Thesis     | O    | 14 credits | 30D | Lecturers

Abstract
Die Bachelorarbeit stellt den Abschluss des Bachelorstudiums dar. Sie ist eine wissenschaftliche und selbständige Arbeit unter der Leitung einer Dozentin oder eines Dozenten der Studienrichtung Agrarwissenschaft.

Objective
Selbständiges Verfassen einer wissenschaftlichen Arbeit.

Content
Verfassen einer wissenschaftlichen und selbständigen Arbeit unter der Leitung einer Dozentin oder eines Dozenten der Studienrichtung Agrarwissenschaft.

Agricultural Sciences Bachelor - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
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<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</tbody>
</table>

Key for Hours

V  | lecture
G  | lecture with exercise
U  | exercise
S  | seminar
K  | colloquium

P  | practical/laboratory course
A  | independent project
D  | diploma thesis
R  | revision course / private study

ECTS
European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
### Agricultural Sciences TC

Detailed information on the programme at: www.didaktischeausbildung.ethz.ch

#### Educational Science

Bitte beachten Sie, dass sich die Lerneinheitsnummer ab dem HS24 geändert hat. Diese Änderung hat keinen Einfluss auf die bisher absolvierten Lerneinheiten und erbrachten Leistungen und wird für den jeweiligen Studienabschluss anerkannt.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>871-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern, M. Rau</td>
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<tr>
<td></td>
<td><em>This lecture is only apt for students who intend to enrol in the programs &quot;Teaching Diploma&quot; or &quot;Teaching Certificate&quot;. It is about learning in childhood and adolescence.</em></td>
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<td>Abstract</td>
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<td></td>
<td>This course looks into scientific theories and also empirical studies on human learning and relates them to the school.</td>
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<td>Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.</td>
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<td>Content</td>
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<td>Thematische Schwerpunkte:</td>
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<td>Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen; Intelligenztheorien, Geschlechtsunterschiede beim Lernen</td>
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<td>Lernformen:</td>
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<td>Lecture notes</td>
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<td>Folien werden zur Verfügung gestellt.</td>
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<td></td>
<td>Literature</td>
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<td>Prerequisites / notice</td>
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| 871-0242-06L | Cognitive Activating Instructions in MINT Subjects ■ W 2 credits 2S R. Schumacher |
|              | *Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).* |
|              | Abstract                                        |      |      |       |                            |
|              | This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance. |
|              | Objective                                       |      |      |       |                            |
|              | - Get to know cognitively activating instructions in MINT subjects |
|              | - Get information about recent literature on learning and instruction |
|              | Prerequisites / notice                          |      |      |       |                            |
|              | Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht. |

| 871-0242-07L | Human Intelligence W 1 credit 1S E. Stern |
|              | *Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).* |
|              | Abstract                                        |      |      |       |                            |
|              | The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed. |
|              | Objective                                       |      |      |       |                            |
|              | - Understanding of research methods used in the empirical human sciences |
|              | - Getting to know intelligence tests |
|              | - Understanding findings relevant for education |

| 871-0240-22L | Coping with Psychosocial Demands of Teaching (EW4 W DZ) ■ 2 credits 3S S. Maurer, P. Caprez, I. Sargenti |
|              | *The successful participation in EW1 ("Human Learning") and EW2 ("Designing Learning Environments for School") is recommended, but not a mandatory prerequisite.* |
|              | Abstract                                        |      |      |       |                            |
|              | In this class, students will learn concepts and skills for coping with psychosocial demands of teaching |
|              | Objective                                       |      |      |       |                            |
|              | (1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks). |
|              | (2) They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. illegal or psychological services). |

| 871-0228-00L | Formation of Knowledge in STEM Fields in Primary and Secondary School ■ 2 credits 1S U. Markwalder |
|              | Adressen to students enrolled either in Teaching Diploma* (TD) or Teaching Certificate (TC) (excluding Teaching Diploma Sport). |
|              | This course unit can only be enrolled after successful |

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Teaching Internship Including Examination Lessons

**Abstract**
The course promotes exchange between student teachers and elementary school teachers in STEM teaching with 3 parts: 1) block seminar (ca. 16 h), 2) collaboration with elementary school teacher in a class (ca. 34 h, with approx. 50% spent in the elementary or middle school class and ca. 50% for preparation), and 3) final report (ca. 10 h). Registration implies participation in all 3 parts.

**Objective**
Deepening the understanding of knowledge formation and learning processes of primary and secondary students from a cognitive and developmental psychology perspective for students. The assistant ship provides didactic experience and exposure to a different school level (more heterogeneous groups such as for example low-performing to very high-performing Children, language problems etc.).

**Content**
Students learn more about the potential and challenges of pupils. They get to know the early stages of knowledge as well as the development of pre-concepts of students in their subject area. The seminar with a phase of cooperation consists of three phases: In the block seminar, pre-concepts are discussed in their own subject as well as theoretical inputs from developmental and cognitive psychology. During the cooperation phase, a teaching task defined by the primary and secondary school teachers is actively undertaken in a class. Finally, a final report is written, which contains a description of the students' level of knowledge. This seminar is only suitable for students who can adapt flexibly to the needs of pupils from lower class levels.

**Prerequisites**
https://www.minterlink.ch/student

**Competencies**

<table>
<thead>
<tr>
<th>Type</th>
<th>Subjects</th>
<th>Social</th>
<th>Method</th>
<th>Communication</th>
<th>Sensitivity to Diversity</th>
<th>Adaptability and Flexibility</th>
<th>Creative Thinking</th>
<th>Critical Thinking</th>
<th>Self-awareness and Self-reflection</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subject-specific</strong></td>
<td>Concepts and Theories</td>
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<td><strong>Method-specific</strong></td>
<td>Analytical Competencies</td>
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<td>Cooperation and Teamwork</td>
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<td>Leadership and Responsibility</td>
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<td><strong>Personal Competencies</strong></td>
<td>Adaptability and Flexibility</td>
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<td>Self-awareness and Self-reflection</td>
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</table>

**Number** 751-9020-00L

**Title** Teaching Internship Including Examination Lessons

**Type** W

**ECTS** 6

**Hours** 13P

**Abstract**
The teaching internship can just be visited if all other courses of TC are completed. Repetition of the teaching internship is excluded even if the examination lessons are to be repeated.

**Objective**
- Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.
- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

**Content**

**Lecture notes**
Dokument: schriftliche Vorbereitung für Prüfungslektionen.

**Literature**
Wird von der Praktikumslehrperson bestimmt.

**Competencies**

<table>
<thead>
<tr>
<th>Type</th>
<th>Subjects</th>
<th>Social</th>
<th>Method</th>
<th>Communication</th>
<th>Sensitivity to Diversity</th>
<th>Adaptability and Flexibility</th>
<th>Critical Thinking</th>
<th>Self-awareness and Self-reflection</th>
<th>Lecturers</th>
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**Number** 751-9005-00L

**Title** Mentored Work Subject Didactics Agricultural Science

**Type** O

**ECTS** 2

**Hours** 4A

**Abstract**
In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.
Objective
The aim is for the students
- to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.
- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.
- To try out different options for specialist further training in their profession.

Content
Themenische Schwerpunkte:

Lernformen:

Lecture notes
Eine Anleitung zur mentorierten Arbeit in FV wird zur Verfügung gestellt.

Literature
Die Literatur ist themenspezifisch. Sie muss je nach Situation selber beschafft werden oder wird zur Verfügung gestellt.

Prerequisites / notice
Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Method-specific Competencies
Communication assessed
Customer Orientation assessed

Social Competencies
Adaptability and Flexibility assessed

Personal Competencies
Creative Thinking assessed

Agricultural Sciences TC - Key for Type

| O | Compulsory | E- | Recommended, not eligible for credits |
| W+ | Eligible for credits and recommended | Z | Courses outside the curriculum |
| W | Eligible for credits | Dr | Suitable for doctorate |

Key for Hours

| V | lecture | P | practical/laboratory course |
| G | lecture with exercise | A | independent project |
| U | exercise | D | diploma thesis |
| S | seminar | R | revision course / private study |
| K | colloquium | |

ECTS European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
Agricultural Sciences Master

► Major in Animal Sciences

►► Disciplinary Competences

►►► LivestockSystems

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>751-6501-00L</td>
<td>Ruminant Science</td>
<td>W+</td>
<td>4</td>
<td>4G</td>
<td>M. Niu, M. Terranova, U. Witschi</td>
</tr>
</tbody>
</table>

Abstract
The course provides the scientific basis of the central aspects of reproduction and nutrition physiology of ruminants, and of the implications for animal health, product quality, and breeding programs. Means of knowledge transfer include interdisciplinary approaches, disciplinary parts, web-based learning and self-study.

Objective
At the end of the course the students are able to apply, by a comprehensive understanding of the underlying mechanisms, their knowledge in various fields of ruminant science. They will be able to develop and recommend best strategies for breeding programs, feed formulation, improving forage quality, and increasing animal health. They will be trained to carry out interdisciplinary and disciplinary research at the highest level.

Content
- Fields (contact hours)
  - Introduction: 2 h
  - Special topics: 20 h
    - Rumen Anatomy
    - Hohenheim Gas Test
    - Calf health
    - Reproduction Techniques
    - Fertility in Cows
  - Disciplinary topics: 32 h
    - Ruminal Digestion: 8 h
    - Ruminant Nutrition Physiology: 12 h
    - Reproduction in Ruminants: 8 h
    - Lectures held by the students: 4 h

  In summary
  - Contact hours: 58 h
  - Self-study within semester: 30 h (especially preparation for the interdisciplinary courses and the own lecture)
  - Self-study in semester break: 32 h
  - Total: 120 h

Lecture notes
Documentation, links and other materials will be provided at the start of the course

Literature
Information on books and other references will be communicated during the course.

Prerequisites / notice
The specialty of this course is that for the first time the animal science disciplines are unified. This is realised with a particular emphasis on interdisciplinary special topics and new forms of teaching. At the same time the essential basics in the central fields are communicated.

Conditions for successful participation: Background on animal science from the Bachelor is desired. In order to attend the Minor in Ruminant Science without any animal science background, a realistic self-assessment concerning the need for additional self-study is recommended (e.g. by choosing an appropriate bachelor course which then may be counted as ‘optional courses’ in the master). These efforts depend on the extent to which animal science courses have already been attended in the bachelor.

The control of performance will consist of:
- an own short lecture
- a final oral examination with focus on comprehension of the fundamental linkages rather than of specific details

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<tr>
<td>751-6001-00L</td>
<td>Forum: Livestock in the World Food System</td>
<td>W+</td>
<td>2</td>
<td>2S</td>
<td>S. Meese</td>
</tr>
</tbody>
</table>

Abstract
This forum is a platform for the critical reflection of relevant topics of livestock in the frame of the world food system comprising issues from basic knowledge to acceptance in society. The exchange is operated by scientific writing and presentation.

Objective
In the Forum "Livestock in the World Food System", a topic of significance for livestock agriculture is selected by the students and subsequently dealt with from various angles (from scientific basis to production systems, environmental aspects and to the acceptance by society).

The students learn to present a scientific subject in writing and orally to an audience and to defend the presentation in a discussion. Further, feedback is intended to improve the presentation style. Furthermore, the review process of a scientific paper will be demonstrated and applied.

Content
The Forum "Livestock in the World Food System" will take place in blocks of 2 hours each. Once the general topic has been selected, it comprises two parts:

Part 1
- Aspect 1 - Oral presentation: The students form small groups and are lecturers.
- Aspect 2 - chairperson: There are moderators which are chosen from outside of the presenting groups and they will lead the discussion and the remaining students and the lecturer are the audience and ask questions.
- Aspect 3 - feedback: At the beginning, students form teams of 2, which are not in the same group, to give each other feedback on their presentation style.

Part 2
- Aspect 1 - Scientific writing: Preparation of a critical review of a chosen publication and individual exchange with the lecturer.
- Aspect 2 - Defense: There will be a discussion in small groups on several dates to discuss the chosen publication in detail and the observations during the process.

Introductions to both presentation forms will be given by the lecturer.

Lecture notes
no scriptum

Prerequisites / notice
Requirements for allocation of the two credit points:
- oral talk with sufficient handout
- delivery of the scientific writing in sufficient quality
- active participation during all presentations (in case of absence there will be additional tasks)
- feedback on the presentation style of a student

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Autumn Semester 2024
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Political Ecology of Food and Agriculture

751-2105-00L

Number of participants limited to 25
A motivational application is required:
- presenting yourself and your studies
- stating what topic in the field of Political Ecology that you are interested in
- suggesting one paper to enrich the literature list for the course

Questions regarding the application to johanna.jacobi@usys.ethz.ch.

Abstract
In this seminar, students are introduced to the multi-disciplinary field of political ecology to investigate human-environment relationships in food and agricultural systems.

Objective
- Being able to provide an overview of the multi-disciplinary field of political ecology for investigating the relationships of humans to our environment
- Learn to identify how power and interest influence social-ecological systems and to distinguish symptoms from systemic root causes
- Become enabled to analyse complex and sometimes distant human-ecology relationships choosing from a broad range of methods

Content
We will review common narratives in agri-food systems informed by a range of different theories and assisted by different analytical tools.

Lecture notes
20.9.2024 Introduction to political ecology
27.9.2024 Ontologies and epistemologies
4.10.2024 Green revolution, industrial agriculture, and agroecology
11.10.2024 Don't blame the rain: Water management in agriculture
18.10.204 Climate justice and food systems
25.10.204 Conservation: Protecting what from what?
8.11.204 Pandemics, syndemics and the food system
15.11.204 Technology and the politics of knowledge
22.1.204 Land-sharing, land-sparing
29.11.204 Feminist (political) agroecology
6.12.204 Food: Commons or commodity?
13.12.204 Alternatives to sustainable development
20.12.204 Final session (The Hunger Banquet)

Literature
List of the literature will be provided on Moodle when the course starts.

https://moodle-app2.let.ethz.ch/course/view.php?id=20544

Competencies
Subject-specific Competencies
Concepts and Theories
Analytical Competencies
Decision-making
Problem-solving
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving

Social Competencies
Communication
Cooperation and Teamwork
Sensitivity to Diversity
Negotiation

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Self-awareness and Self-reflection
Self-direction and Self-management

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving

Social Competencies
Communication
Cooperation and Teamwork
Sensitivity to Diversity
Negotiation

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Self-awareness and Self-reflection
Self-direction and Self-management

Livestock Biology

751-6113-00L
Endocrinology and Biology of Reproduction
W+ 3 credits 2G

Abstract
Endokrinologie und Reproduktionsbiologie der Säugetiere und des Menschen (Anatomie, Morphologie, Physiologie, Regelmechanismen)
Die Systematik der Reproduktionshormone und der Hormonrezeptoren wird erläutert, die Wirkungsmechanismen (Bildung; orale Bioverfügbarkeit; Elimination) erklärt. Mit diesen Grundlagen wird das Verständnis der Regulation der Fortpflanzung umfassend erörtert.

Objective
Die Studierenden erlangen das grundlegende theoretische Verständnis und Fachwissen zur Endokrinologie der Reproduktion und zur weiblichen und männlichen Reproduktionsbiologie. Sie können darüber hinaus pathologische Situationen (Fortpflanzungsstörungen) und deren vielfältige Ursachen in den physiologischen Kontext einordnen.
### Seminar in Evolutionary Ecology of Infectious Diseases

#### Abstract
Students of this course will discuss current topics from the field of infectious disease biology. From a list of publications, each student chooses some themes that he/she is going to explain and discuss with all other participants and under supervision. The actual topics will change from year to year corresponding to the progress and new results occurring in the field.

#### Objective
This is an advanced course that will require significant student participation. Students will learn how to evaluate and present scientific literature and trace the development of ideas related to understanding the ecology and evolutionary biology of infectious diseases.

#### Content
A core set of ~10 classic publications encompassing unifying themes in infectious disease ecology and evolution, such as virulence, resistance, metapopulations, networks, and competition will be presented and discussed. Pathogens will include bacteria, viruses and fungi. Hosts will include animals, plants and humans.

#### Literature
Information about books and other references will be communicated during the course.

#### Lecture notes
The teaching slides and other materials will be provided during the course.

#### Competencies
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### Livestock Genetics

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<tr>
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<th>Lecturers</th>
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<td>751-6243-00L</td>
<td>Breeding and Conservation of Animal Genetic Resources</td>
<td>W+</td>
<td>2 credits</td>
<td>2V</td>
<td>H. Signer-Hasler, C. Flury, H. Pausch</td>
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#### Abstract
Animal genetic resources refer to the genetic and species diversity of livestock. Only a few production breeds have been further developed through breeding, while local breeds have no longer been able to survive in this competition. Without the support of endangered breeds and the sustainable breeding of productive breeds, many regionally typical breeds are threatened with extinction.

#### Objective
Learning Objectives: Part 1:
- At the end of the course, students are able to assess the importance and problems of small ruminant breeding and husbandry in Switzerland and neighbouring countries. They know the most important breeding objectives and are able to assess them in terms of production and sustainable development in small ruminants and cattle.
- The second part gives an overview of the distribution, endangerment and conservation of breed diversity of farm animals in Switzerland and internationally. The theory is illustrated with numerous examples and the knowledge is deepened in exercises.

#### Prerequisites / notice
Examination:
- Examination Part 1: Graded written examination (1 hour) on the material covered.
- Examination Part 2: Graded semester performance completed during the block course. Parts 1 and 2 contribute equally to the final grade.

### Livestock Breeding and Genomics

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<tr>
<td>751-6305-00L</td>
<td>Livestock Breeding and Genomics</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td>P. von Rohr</td>
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#### Abstract
Swiss routine breeding value estimation/genetic evaluation systems of cattle, pig, sheep and goats are presented with methods and evaluated traits. Examples will be demonstrated using the statistical software R.

#### Objective
The students know the theoretical and practical application of breeding value estimation in Switzerland for cattle, pig, sheep and goats. The students are able to interpret estimated breeding values.
Methodology Competences

Methods for Scientific Research

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
---|---|---|---|---|---
751-3801-00L | Experimental Design and Applied Statistics in Agroecosystem Science | W | 3 credits | 2G | A. Hund, C. Grieder, R. Kölker

**Abstract**
Different experimental designs will be discussed and various statistical tools will be applied to research questions in agroecosystem sciences. Statistical methods range from simple analysis of variance to mixed-models and multivariate statistics. Surveys and manipulative field and laboratory experiments are addressed and students learn to analyse data using a hands-on approach.

**Objective**
Students will know various statistical analyses and their application to science problems in their study area as well as a wide range of experimental design options used in environmental and agricultural sciences. They will practice to use statistical software packages (R), understand pros and cons of various designs and statistics, and be able to statistically evaluate their own results as well as those of published studies.

**Content**
The course program uses a learning-by-doing approach ("hands-on minds-on"). The topics are introduced as short lectures, but most of the work is done on the computer using different packages of R – a software for statistical computing and graphics. In addition to contact hours exercises must be finalized and handed in for grading. The credit points will be given based on successful assessments of selected exercises.

The tentative schedule contains the following topics:
- Introduction to experimental design and applied statistics in R
- Data handling and data exploration with tidyverse
- Designs of field and growth chamber experiments theory
- Design creation with DiGGer
- Fitting linear mixed-effects models with lme4
- Marginal means estimation and post-hoc tests with emmeans
- Nonlinear regression fits
- Statistical learning techniques
- Principle component analysis, canonical correspondence analysis (CCA), cluster analysis
- Random forest

This course does not provide the mathematical background that students are expected to bring along when signing up to this course. Alternatively, students can consider some aspects of this course as a first exposure to solutions in experimental design and applied statistics and then deepen their understanding in follow-up statistical courses.

**Lecture notes**
Handouts will be available (in English)

**Prerequisites / notice**
A selection of suggested additional literature, especially for German speaking students will be presented in the introductory lecture.

**Competencies**

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751-6003-00L | Training Course in Research Groups (Large) | W+ | 6 credits | 13P | S. M. Bernal Ulloa, S. Neuenschwander, M. Niu, H. Pausch, M. Saenz de Juan Ribes, S. E. Ulbrich

**Abstract**
The students will learn the conceptual and methodological background of research in the animal science groups of the Institute of Plant, Animal and Agroecosystem Sciences. In addition to teaching the theoretical background, the major aim of the course is to integrate the students into the research groups (on job training) and, hence, to focus on the practical application of the knowledge.

**Objective**
- Introduction into the conceptual and methodological basis of research
- Integration of the students into the research groups (on job training)
- Application of the gained knowledge

**Content**
The students will be integrated into the research groups day-to-day work and will thus deal with all aspects of scientific work. This comprises the planning (conceptually and logistically), execution (data collection, laboratory analyses) and evaluation (statistics, data presentation) of experiments as well as the basics of scientific writing (aim: later publication, Master thesis). The research topics and the range of methodologies vary between the animal science research groups in the Institute of Plant, Animal and Agroecosystem Sciences.

**Lecture notes**
None

**Literature**
Specific readings after enlisting in a particular research group.
The number of training slots in the various groups is limited. It is therefore highly recommended to contact the group leaders early enough (first come first serve). The full integration in a research group often means to work on weekends. The total time budget is equivalent to about 180 hours. Active participation in group meetings (discussion, presentation) and short written reports about the work conducted are required for the 6 credit points. There are no grades, it is only pass or fail.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

#### Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

#### Social Competencies
- Communication
- Cooperation and Teamwork

#### Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-direction and Self-management

### Prerequisites / notice

The number of training slots in the various groups is limited. It is therefore highly recommended to contact the group leaders early enough (first come first serve).

The full integration in a research group often means to work on weekends. The total time budget is equivalent to about 90 hours. Active participation in group meetings (discussion, presentation) and short written reports about the work conducted are required for the 3 credit points. There are no grades, it is only pass or fail.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

#### Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

#### Social Competencies
- Communication
- Cooperation and Teamwork

#### Personal Competencies
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- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-direction and Self-management

### Project Management for Scientific Research

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<td>2S</td>
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**Abstract**

This forum is a platform for the critical reflection of relevant topics of livestock in the frame of the world food system comprising issues from basic knowledge to acceptance in society. The exchange is operated by scientific writing and presentation.

**Objective**

In the Forum "Livestock in the World Food System", a topic of significance for livestock agriculture is selected by the students and subsequently dealt with from various angles (from scientific basis to production systems, environmental aspects and to the acceptance by society).

The students learn to present a scientific subject in writing and orally to an audience and to defend the presentation in a discussion. Further, feedback is intended to improve the presentation style. Furthermore, the review process of a scientific paper will be demonstrated and applied.
The Forum "Livestock in the World Food System" will take place in blocks of 2 hours each. Once the general topic has been selected, it comprises two parts:

Part 1
Aspect 1 - Oral presentation: The students form small groups and are lecturers.
Aspect 2 - chairperson: There are moderators which are chosen from outside of the presenting groups and they will lead the discussion and the remaining students and the lecturer are the audience and ask questions.
Aspect 3 - feedback: At the beginning, students form teams of 2, which are not in the same group, to give each other feedback on their presentation style.

Part 2.
Aspect 1 - Scientific writing: Preparation of a critical review of a chosen publication and individual exchange with the lecturer.
Aspect 2 - Defense: There will be a discussion in small groups on several dates to discuss the chosen publication in detail and the observations during the process.

Introductions to both presentation forms will be given by the lecturer.

Lecture notes
no scriptum

Prerequisites / notice
Requirements for allocation of the two credit points:
- oral talk with sufficient handout
- delivery of the scientific writing in sufficient quality
- active participation during all presentations (in case of absence there will be additional tasks)

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Communication</td>
<td>Negotiation</td>
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<tr>
<td>Analytical Competencies</td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
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751-5201-10L Tropical Cropping Systems, Soils and Livelihoods (with Excursion) W+ 5 credits 10G J. Six, K. Benabderrazik

IMPORTANT: Students who enroll for this course are strongly recommended to verify with lecturers from other courses whether their absence of two weeks may affect their performance in the respective courses.

Abstract
This course guides students in analyzing and comprehending tropical agroecosystems and food systems. Students gain practical knowledge of field methods, diagnostic tools and survey methods for tropical soils and agroecosystems. An integral part of the course is the two-week field project in the Mount Kenya Region, which is co-organized with the University of Embu (Kenya).

Objective
(1) Overview of the major land use systems in Tropical agroecosystems in several contexts Africa
(2) Interdisciplinary analysis of agricultural production systems
(3) Knowledge on methods to assess agroecological performance of a tropical agroecosystems
(4) Hands-on training on the use of field methods, diagnostic tools and survey methods.
(5) Gain practical knowledge on how to assess to climate resilience and farming systems.
(6) Collaboration in international students and stakeholders

Content
This course guides students in analyzing and comprehending tropical agroecosystems. Students of ETH Zürch will work together with the students from Embu University (Kenya) in an interdisciplinary and intercultural team. Students will focus on the Agroecological performance and climate resilience of diverse farming systems in the Mount Kenya Region.

From October 28th to November 11th, The students will take part in a field course in the Mount Kenya Region. Students will then gain practical knowledge on field, meeting several stakeholders of the agricultural and food systems and conducting various assessments related to climate resilience and farming systems.

Prerequisites / notice
We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 18rd 2023, justifying your motivation to enroll to this class. A selection of 20 students will be done on the basis of the letters.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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<td>Self-direction and Self-management</td>
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Assessment:
- Concepts and Theories: assessed
- Techniques and Technologies: assessed
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: fostered
- Project Management: assessed
- Communication: assessed
- Cooperation and Teamwork: assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered
- Adaptability and Flexibility: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed
### Major in Plant Sciences

#### Disciplinary Competences

#### Agronomy and Plant Breeding

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>751-4104-00L</td>
<td>Alternative Crops</td>
<td>W+</td>
<td>2</td>
<td>2V</td>
<td>A. Walter, K. Berger Büter</td>
</tr>
<tr>
<td>Abstract</td>
<td>Few crops dominate the crop rotations worldwide. Following the goal of an increased agricultural biodiversity, species such as buckwheat but also medicinal plants might become more important in future. The biology, physiology, stress tolerance and central aspects of the value-added chain of the above-mentioned and of other alternative crops will be depicted.</td>
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<tr>
<td>Objective</td>
<td>During this course, students learn to assess the potential of different minor or alternative crops compared to the dominant major crops based on their biological and agronomical features. Each student will assess and present a specific alternative crop of his or her choice based on information from scientific articles and Wikipedia. Wikipedia-entries will be generated.</td>
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</tbody>
</table>
| Competencies | Subject-specific Competencies: Concepts and Theories (fostered)  
Method-specific Competencies:  
- Media and Digital Technologies (fostered)  
- Problem-solving (fostered)  
- Project Management (fostered)  
Social Competencies:  
- Communication (assessed)  
- Cooperation and Teamwork (assessed)  
- Self-presentation and Social Influence (fostered)  
- Sensitivity to Diversity (fostered)  
Personal Competencies:  
- Creative Thinking (assessed)  
- Critical Thinking (assessed)  
- Integrity and Work Ethics (fostered)  
- Self-awareness and Self-reflection (assessed)  
- Self-direction and Self-management (fostered) |
| 751-3603-00L | Current Challenges in Plant Breeding | W+   | 2    | 2G    | B. Studer, A. Hund, R. Kölliker |
| Abstract     | The seminar 'Current Challenges in Plant Breeding' aims to bring together national and international experts in plant breeding to discuss current activities, latest achievements and future prospective of a selected topic/area in plant breeding. |
| Objective    | The educational objectives cover thematic, methodic as well as social and personal competencies:  
Thematic/methodic competencies:  
- Deepening of scientific knowledge in plant breeding  
- Critical evaluation of current challenges and new concepts in plant breeding  
- Promotion of collaboration and Master thesis projects with practical plant breeders  
Social/personal competencies:  
- Independent literature research to get familiar with the selected topic  
- Critical evaluation and consolidation of the acquired knowledge in an interdisciplinary team  
- Establishment of a scientific presentation in an interdisciplinary team  
- Presentation and discussion of the teamwork outcome  
- Establishing contacts and strengthening the network to national and international plant breeders and scientist |
| Content      | Interesting topics related to plant breeding will be selected in close collaboration with the working group for plant breeding of the Swiss Society of Agronomy (SSA). |
| Literature   | Peer-reviewed research articles, selected according to the topic. |
| Prerequisites / notice | Participation in the BSc course 'Pflanzenzüchtung' is strongly recommended, a completed course in 'Molecular Plant Breeding' is advantageous. |
| Competencies | Subject-specific Competencies: Concepts and Theories (assessed)  
Techniques and Technologies (assessed)  
Analytical Competencies (assessed)  
Decision-making (assessed)  
Media and Digital Technologies (assessed)  
Problem-solving (assessed)  
Project Management (assessed)  
Social Competencies:  
- Communication (assessed)  
- Cooperation and Teamwork (assessed)  
- Customer Orientation (assessed)  
- Leadership and Responsibility (fostered)  
- Self-presentation and Social Influence (fostered)  
- Sensitivity to Diversity (assessed)  
- Negotiation (assessed)  
Personal Competencies:  
- Adaptability and Flexibility (fostered)  
- Creative Thinking (assessed)  
- Critical Thinking (assessed)  
- Integrity and Work Ethics (assessed)  
- Self-awareness and Self-reflection (fostered)  
- Self-direction and Self-management (fostered) |
| 751-4704-00L | Weed Science                       | W+   | 3    | 2G    | B. Streit, U. J. Haas          |
| Abstract     | Modern weed management comprises competent knowledge of weed biology, weed ecology, population dynamics, crop-weed-interactions and different measures to control weeds. Weeds are understood to be rather part of a habitat or a cropping system than just unwanted plants in crops. |
| Objective    | At the end of the course the students are qualified to develop sustainable solutions for weed problems in agricultural and natural habitats. |
| Content      | Modern weed management comprises competent knowledge of weed biology, weed ecology, population dynamics, crop-weed-interactions and different measures to control weeds. Weeds are understood to be rather part of a habitat or a cropping system than just unwanted plants in crops. Accordingly, this knowledge will be imparted during the course and will be required to understand the mechanisms of integrated weed control strategies. |
Crop Health

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-5121-00L</td>
<td>Insect Ecology</td>
<td>W+</td>
<td>2</td>
<td>2V</td>
<td>C. De Moraes, N. Stanczyk</td>
</tr>
<tr>
<td>Abstract</td>
<td>This is an introductory class on insect ecology. During the course you will learn about insect interactions with, and adaptations to, their environment and other organisms, and the importance of insect roles in our ecosystems. This course includes in-person lectures, small group discussions and outside readings.</td>
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<tr>
<td>Objective</td>
<td>The aim of the course is for you to be able to describe examples of insect interactions and evaluate their impact on broader ecosystems. Important topics include: insect-plant interactions, chemical ecology, predator-prey interactions, vectors of disease, social insects, mutual and parasitic interactions, and examining insect ecology in an evolutionary context.</td>
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<tr>
<td>Lecture notes</td>
<td>Provided to students through Moodle</td>
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<tr>
<td>Literature</td>
<td>Selected required readings (peer reviewed literature). Optional recommended readings with additional information.</td>
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<td>Competencies</td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
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<td>Communication</td>
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<tr>
<td>751-4811-00L</td>
<td>Alien Organisms in Agriculture</td>
<td>W+</td>
<td>2</td>
<td>2G</td>
<td>J. Collatz, M. Meissle</td>
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<tr>
<td>Abstract</td>
<td>The course focuses on alien organisms in agriculture as well as the scientific assessment and regulatory management of their effects on the environment and agricultural production.</td>
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<td>Objective</td>
<td>Students will understand the consequences arising from the unintentional or deliberate introduction of alien organisms into agricultural systems. They will be able to understand the concept of environmental risk assessment and be able to evaluate risk management options.</td>
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<tr>
<td>Content</td>
<td>Alien organisms in agriculture is a topic that receives an increasing awareness among farmers, agricultural scientists, regulators and the general public. Students of this course will learn about the nature of alien organisms such as invasive species, biocontrol organisms and genetically modified organisms. With a particular focus is understanding plants and their interactions we will look at how potential threats the novel organisms pose, the benefits they provide and how both of these effects can be scientifically assessed. Students will learn how the topic of alien organisms in agriculture is intrinsically tied to policy making and regulation and get to know current examples and future challenges in research. In the last part of the course students will be able to apply the acquired knowledge in a practical exercise (case study).</td>
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<td>Lecture notes</td>
<td>Material will be distributed during the course</td>
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<td>Prerequisites / notice</td>
<td>A part of the course will take place in flipped classroom mode, i.e. some lectures will be available as podcasts.</td>
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<td>Self-direction and Self-management</td>
<td>fostered</td>
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<tr>
<td>701-0263-01L</td>
<td>Seminar in Evolutionary Ecology of Infectious Diseases</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>R. R. Regös, S. Bonhoeffer</td>
</tr>
<tr>
<td>Abstract</td>
<td>Students of this course will discuss current topics from the field of infectious disease biology. From a list of publications, each student chooses some themes that he/she is going to explain and discuss with all other participants and under supervision. The actual topics will change from year to year corresponding to the progress and new results occurring in the field.</td>
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<td>Objective</td>
<td>This is an advanced course that will require significant student participation. Students will learn how to evaluate and present scientific literature and trace the development of ideas related to understanding the ecology and evolutionary biology of infectious diseases.</td>
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<td>Content</td>
<td>A core set of ~10 classic publications encompassing unifying themes in infectious disease ecology and evolution, such as virulence, resistance, metapopulations, networks, and competition will be presented and discussed. Pathogens will include bacteria, viruses and fungi. Hosts will include animals, plants and humans.</td>
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<tr>
<td>Lecture notes</td>
<td>Publications and class notes can be downloaded from a web page announced during the lecture.</td>
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<tr>
<td>Literature</td>
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<tr>
<td>751-4506-00L</td>
<td>Plant Pathology III</td>
<td>W+</td>
<td>2</td>
<td>2G</td>
<td>M. Maurhofer Bringolf</td>
</tr>
<tr>
<td>Abstract</td>
<td>Identification based on host, symptoms and micro-morphology, completed with life cycles and related control measures of the most important fungal diseases and their causal pathogens of annual and perennial crops with agricultural significance.</td>
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<tr>
<td>Objective</td>
<td>The students will learn and train preparation skills for microscopy, acquire knowledge of selected diseases (identification, biology of pathogen, epidemiology and systematics) and understand the corresponding integrated control measures practiced in Swiss agriculture.</td>
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<tr>
<td>Content</td>
<td>One exercise will be based on computer and ocular camera, also to prepare the students for the final e-exam.</td>
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<tr>
<td>Lecture notes</td>
<td>A script will be used on annual and perennial crops and their most important diseases. It will be updated stepwise</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The course will be in German (spec. nomenclature)</td>
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</table>
The CNNAP course discusses the mechanistic relationships between nutrient speciation in fertilizer and nutrient uptake by plants using
methods of plant nutrition studies. At the end of the CNNAP course, participants will obtain a mechanistic understanding of why and how the speciation of phosphorus in fertilizer can affect its release to the soil solution and subsequent uptake by plants. Students will be able to use this information for the development of fertilization schemes that maximize the nutrient uptake and fertilizer efficiency of crops or pastures. During the course, participants will become familiar with the use of radioisotopes and nuclear magnetic resonance as approaches to measure nutrient availability and forms, respectively and they will know the limits of these techniques. Students will also have the opportunity to improve their laboratory, presentation, discussion and writing skills.

The CNNAP lecture will take place at the ETH experimental station in Eschikon Lindau every second year. The next course will be organized in autumn 2024. The CNNAP course will take place if and only if 6 or more students are registered one week before the start. See the location of the station at: http://www.plantnutrition.ethz.ch/the-group/how-to-find-us.html

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 33 of 2653
This course provides an overview about the applicability of stable isotopes (carbon 13C, nitrogen 15N, oxygen 18O and hydrogen 2H) to process-oriented ecological research. Topics focus on stable isotopes as indicators for the origin of pools and fluxes, partitioning of composite fluxes as well as to trace and integrate processes. In addition, students carry out a small project during lab sessions.

Objective
Students will be familiar with basic and advanced applications of stable isotopes in studies on plants, soils, water and trace gases, know the relevant approaches, concepts and recent results in stable isotope ecology, know how to combine classical and modern techniques to solve ecophysiological or ecological problems, learn to design, carry out and interpret a small IsoProject, practice to search and analyze literature as well as to give an oral presentation.

Content
The analyses of stable isotopes often provide insights into ecophysiological and ecological processes that otherwise would not be available with classical methods only. Stable isotopes proved useful to determine origin of pools and fluxes in ecosystems, to partition composite fluxes and to integrate processes spatially and temporally.

This course will provide an introduction to the applicability of stable isotopes to ecological research questions. Topics will focus on carbon (13C), nitrogen (15N), oxygen (18O) and hydrogen (2H) at natural isotope abundance and tracer levels. Lectures will be supplemented by intensive laboratory sessions, short presentations by students and computer exercises.

Abstract
This course provides an overview about the applicability of stable isotopes (carbon 13C, nitrogen 15N, oxygen 18O and hydrogen 2H) to process-oriented ecological research. Topics focus on stable isotopes as indicators for the origin of pools and fluxes, partitioning of composite fluxes as well as to trace and integrate processes. In addition, students carry out a small project during lab sessions.

Methodology Competences

Seminar in Plant Sciences

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>751-5115-00L</td>
<td>Current Aspects of Nutrient Cycle in Agro-</td>
<td>W+</td>
<td>2</td>
<td>1S</td>
<td>E. Frossard, A. Oberson Dräyer</td>
</tr>
</tbody>
</table>

Abstract
The seminar concerns current aspects and research related to nutrient cycles in agro-ecosystems. The theme of the next seminar is "Integrated Nutrient Management to maximize nutrient use efficiency in productive agricultural systems: Insights from long-term field experiments".

Objective
Analyze publications and/or data records on long-term field experiments regarding their content on integrated nutrient management and derive the nutrient use efficiency; link this information, write it up in a report and present the results in an oral presentation; work in a group; ask questions and contribute to the discussion following the oral presentations; link the information to answer overarching questions and recommendations; expand the knowledge on nutrient cycles and nutrient management in the agro-ecosystem; learn about the importance of long-term field experiment to answer questions on the sustainability of agricultural systems.

Content
The seminar concerns current aspects and research related to nutrient cycles in agro-ecosystems. The theme of the next seminar is "Integrated Nutrient Management to maximize nutrient use efficiency in productive agricultural systems: Insights from long-term field experiments". The students will analyze and connect the results published (or from data records) for selected field experiments in a group work. They will present their analysis in a report and in an oral presentation. The seminar is composed by presentations of experts and of the students. The presentations will be synthesized during a final discussion.
### Analytical Competencies
Research results in agro- and forest ecosystem sciences will be presented by experienced researchers as well as by doctoral and graduate students. Citation classics as well as recent research results will be discussed. Topics will range from plant ecophysiology, biodiversity and biogeochemistry to management aspects in agro- and forest ecosystems.

- Students will be able to understand and evaluate experimental design and data interpretation of on-going studies.
- Students will be able to critically analyze published research results, practice to present and discuss results in the public, and gain a broad knowledge of recent research and current topics in agro- and forest ecosystem sciences.

### Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

### Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

### Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Media and Digital Technologies</th>
<th>Problem-solving</th>
<th>Project Management</th>
<th>Communication</th>
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<th>Self-direction and Self-management</th>
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<td><strong>Concepts and Theories</strong></td>
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### Current Topics in Grassland Sciences (autumn)

**Current Topics in Grassland Sciences (autumn) 751-4003-01L**

**W+ 2 credits 2S**

**N. Buchmann**

**Abstract**
Research results in agro- and forest ecosystem sciences will be presented by experienced researchers as well as by doctoral and graduate students. Citation classics as well as recent research results will be discussed. Topics will range from plant ecophysiology, biodiversity and biogeochemistry to management aspects in agro- and forest ecosystems.

**Objective**
- Students will be able to understand and evaluate experimental design and data interpretation of on-going studies, be able to critically analyze published research results, practice to present and discuss results in the public, and gain a broad knowledge of recent research and current topics in agro- and forest ecosystem sciences.

**Content**
Research results in agro- and forest ecosystem sciences will be presented by experienced researchers as well as by doctoral and graduate students. Citation classics as well as recent research results will be discussed. Topics will range from plant ecophysiology, biodiversity and biogeochemistry to management aspects in agro- and forest ecosystems.

**Lecture notes**
- none

**Prerequisites / notice**
- Prerequisites: Basic knowledge of plant ecophysiology, terrestrial ecology and management of agro- and forest ecosystems. Course will be taught in English.

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories: assessed
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### Political Ecology of Food and Agriculture

**Political Ecology of Food and Agriculture 751-2105-00L**

**W+ 3 credits 2G**

**J. Jacobi**

**Abstract**
In this seminar, students are introduced to the multi-disciplinary field of political ecology to investigate human-environment relationships in food and agricultural systems.

**Objective**
- Being able to provide an overview of the multi-disciplinary field of political ecology for investigating the relationships of humans to our environment.
- Learn to identify how power and interest influence social-ecological systems and to distinguish symptoms from systemic root causes.
- Become enabled to analyse complex and sometimes distant human-ecology relationships choosing from a broad range of methods.

**Content**
We will review common narratives in agri-food systems informed by a range of different theories and assisted by different analytical tools. For this purpose, we will start from different concepts of nature, power and interests, explore different ontologies and epistemologies through a set of topics such as hunger, obesity, agrobiodiversity and seeds, forests and deforestation, climate change and food production. Students will explain one concept in each course to the groups and practice their argumentative and writing skills in a final essay, applying the acquired tools to a topic of their choice. While specific inputs from external lecturers broaden our perspective, enough time for critical discussion and reflection will be granted.

**Lecture notes**
- 20.9.2024 Introduction to political ecology
- 27.9.2024 Ontologies and epistemologies
- 4.10.2024 Green revolution, industrial agriculture, and agroecology
- 11.10.2024 Don't blame the rain: Water management in agriculture
- 18.10.2024 Climate justice and food systems
- 25.10.2024 Conservation: Protecting what from what?
- 1.11.2024 Deforestation: Root causes and alternatives
- 8.11.2024 Pandemics, syndemics and the food system
- 15.11.2024 Technology and the politics of knowledge
- 22.11.2024 Land-sharing, land-sparing
- 29.11.2024 Feminist (political) agroecology
- 6.12.2024 Food: Commons or commodity?
- 13.12.2024 Alternatives to sustainable development
- 20.12.2024 Final session (The Hunger Banquet)

**Literature list**
List of literature provided on Moodle when the course starts.

https://moodle-app2.let.ethz.ch/course/view.php?id=20544
### Design, Analysis and Communication of Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>751-3801-00L</td>
<td>Experimental Design and Applied Statistics in Agroecosystem Science</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>A. Hund, C. Grieder, R. Kölliker</td>
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</tbody>
</table>

#### Abstract
Different experimental designs will be discussed and various statistical tools will be applied to research questions in agroecosystem sciences. Statistical methods range from simple analysis of variance to mixed-models and multivariate statistics. Surveys and manipulative field and laboratory experiments are addressed and students learn to analyze data using a hands-on approach.

#### Objective
Students will know various statistical analyses and their application to science problems in their study area as well as a wide range of experimental design options used in environmental and agricultural sciences. They will practice to use statistical software packages (R), understand pros and cons of various designs and statistics, and be able to statistically evaluate their own results as well as those of published studies.

#### Content
The course program uses a learning-by-doing approach ("hands-on minds-on"). The topics are introduced as short lectures, but most of the work is done on the computer using different packages of R – a software for statistical computing and graphics. In addition to contact hours exercises must be finalized and handed in for grading. The credit points will be given based on successful assessments of selected exercises.

The tentative schedule contains the following topics:
- Introduction to experimental design and applied statistics in R
- Data handling and data exploration with tidyverse
- Designs of field and growth chamber experiments theory
- Design creation with DIGGer
- Fitting linear mixed-effects models with lme4
- Marginal means estimation and post-hoc tests with emmeans
- Nonlinear regression fits
- Statistical learning techniques
- Principle component analysis, canonical correspondance analysis (CCA), cluster analysis
- Random forest

This course does not provide the mathematical background that students are expected to bring along when signing up to this course. Alternatively, students can consider some aspects of this course as a first exposure to solutions in experimental design and applied statistics and then deepen their understanding in follow-up statistical courses.

#### Lecture notes
Handouts will be available (in English)

#### Literature
A selection of suggested additional literature, especially for German speaking students will be presented in the introductory lecture.

#### Prerequisites / notice
This course is based on the course Mathematik IV: Statistik, passed in the 2nd year and the Bachelor's course "Wissenschaftliche Datenauswertung und Datenpräsentation" (751-0441-00L) This course does not provide the mathematical background that students are expected to bring along when signing up to this course. Alternatively, students can consider some aspects of this course as a first exposure to solutions in experimental design and applied statistics and then deepen their understanding in follow-up statistical courses.

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<td>Self-presentation and Self-management</td>
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</tbody>
</table>

#### Prerequisites / notice
We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 18rd 2023, justifying your motivation to enroll to this class. A selection of 20 students will be done on the basis of the letters.

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### Tropical Cropping Systems, Soils and Livelihoods (with Excursion)

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<tr>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-5201-10L</td>
<td>Tropical Cropping Systems, Soils and Livelihoods (with Excursion)</td>
<td>W+</td>
<td>5</td>
<td>10G</td>
<td>J. Six, K. Benabderrazik</td>
</tr>
</tbody>
</table>

**IMPORTANT:** Students who enroll for this course are strongly recommended to verify with lecturers from other courses whether their absence of two weeks may affect their performance in the respective courses.

#### Abstract
This course guides students in analyzing and comprehending tropical agroecosystems and food systems. Students gain practical knowledge of field methods, diagnostic tools and survey methods for tropical soils and agroecosystems. An integral part of the course is the two-week field project in the Mount Kenya Region, which is co-organized with the University of Embu (Kenya).

#### Objective
1. Overview of the major land use systems in Tropical agroecosystems in several contexts Africa
2. Interdisciplinary analysis of agricultural production systems
3. Knowledge on methods to assess agroecological performance of a tropical agroecosystems
4. Hands-on training on the use of field methods, diagnostic tools and survey methods.
5. Gain practical knowledge on how to assess to climate resilience and farming systems.
6. Collaboration in international students and stakeholders

#### Content
This course guides students in analyzing and comprehending tropical agroecosystems. Students of ETH Zürich will work together with the students from Embu University (Kenya) in an interdisciplinary and intercultural team. Students will focus on the Agroecological performance and climate resilience of diverse farming systems in the Mount Kenya Region.

From October 28th to November 11th, The students will take part in a field course in the Mount Kenya Region. Students will then gain practical knowledge on field, meeting several stakeholders of the agricultural and food systems and conducting various assessments related to climate resilience and farming systems.

#### Prerequisites / notice
We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 18rd 2023, justifying your motivation to enroll to this class. A selection of 20 students will be done on the basis of the letters.
Major in Agriculture Economics

Disciplinary Competences

Decision Making and Management

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<tr>
<td>363-0403-00L</td>
<td>Introduction to Marketing</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>F. von Wangenheim, P. Bachmann</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>This course provides an overview on essential perspectives of marketing and how marketing adds value to a business. It will teach concepts, frameworks and methods for marketing decision making. The course will also look at issues related to marketing implementation. Thereby, a particular focus will be on how data and data analytics can help to support marketers in their decision making.</td>
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<td>Objective</td>
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<td>After taking the class, students will be able to</td>
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<td></td>
<td>1) Understand how marketing adds value to a business.</td>
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<td>2) Provide an overview of key concepts in marketing that are applicable to any business.</td>
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<td>3) Understand how consumers behave and how this impacts marketing</td>
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<td>4) Learn how analytics and quantitative methods can help to improve decision making in marketing.</td>
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<td>5) Get to know the elements that shape a firm’s marketing strategy (segmentation, targeting, positioning) and marketing tactics (product, price, promotion, place)</td>
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<td>Content</td>
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<td>The class will center on the importance of marketing as an activity that creates long-term value for the benefit of organizations and their customers. It will teach concepts, frameworks and methods for marketing decision making. Specifically, the course is aims to provide students with a) an overview on the role of marketing within a business, b) details on strategic marketing management decisions and tools, c) a profound knowledge on the individual elements of the marketing mix (product, price, promotion, place), d) an awareness of specific contexts of marketing, and e) first-hand experience on data-driven techniques to support marketers' decision making. Thus, this course will introduce key analytical tools to help solving respective managerial tasks. This is a lecture with integrated exercises. Access to a laptop is required for the exercises. The the class might be thought in an in-person, remote or in a hybrid format. Students might also be taught via pre-recorded videos and assigned material for self-study.</td>
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<td>Competencies</td>
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<td>The course might comprise mandatory and supplemental reading material. Other literature may be assigned in class.</td>
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<td>Subject-specific Competencies</td>
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<td>Concepts and Theories assessed</td>
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<td>Techniques and Technologies assessed</td>
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<td>Leadership and Responsibility fostered</td>
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<td>Self-direction and Self-management</td>
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<td>751-2205-00L</td>
<td>Management for Enterprises in the Agri-Food-Chain II</td>
<td>W+</td>
<td>2</td>
<td>2G</td>
<td>M. Weber</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>Advanced Management in the Agri-Food Chain: Framework and models for management of organizations in the Agri-Food Chain in a complex environment</td>
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<td>Objective</td>
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<td>After the lecture the students ...</td>
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<td>... know the characteristics and consequences of complexity in the organizational world,</td>
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<td>... know and can apply selected comprehensive models for managing in complex situations,</td>
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<td>... know possible practical applications and examples of the treated contents to organizations in the Agri-Food Chain and</td>
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<td>... are able to deepen the relevant topics in an autonomous way.</td>
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<td>Content</td>
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<td>In the lecture the following contents will be treated:</td>
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<td>- State, reasons and effects of complexity in the organizational world.</td>
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<td>- A basic framework for shaping and governing intelligent organizations.</td>
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<td>- Selected contemporary models for managing in the complex organizational world.</td>
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<td>- Transfer and adaption of the models to organizations in the Agri-Food Chain.</td>
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<td></td>
<td>Lecture notes</td>
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<td>Reader with selected contents.</td>
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</tbody>
</table>
The course addresses environmental policies, focusing on new steering approaches, which are generally summarized as environmental governance. The course also provides students with tools to analyze environmental policy processes and assesses the key features of environmental governance by examining various practical environmental policy examples.

To analyze the evolution as well as the key elements of environmental governance.

To understand how an environmental problem may (not) become a policy and explain political processes, using basic concepts and techniques from political science.

To be able to identify the main challenges and opportunities for environmental governance and to critically discuss them with reference to various practical policy examples.
Improvements in environmental quality and sustainable management of natural resources cannot be achieved through technical solutions alone. The quality of the environment and the achievement of sustainable development strongly depend on human behavior and specifically the human uses of nature. To influence human behavior, we rely on public policies and other societal rules, which aim to steer the way humans use natural resources and their effects on the environment. Such steering can take place through government intervention alone. However, this often also involves governance, which includes the interplay between governmental and non-governmental actors, the use of diverse tools such as emission standards or financial incentives to steer actors' behavior and can occur at the local, regional, national or international level.

In this course, we will address both the practical aspects of as well as the scientific debate on environmental governance. The course gives future environmental experts a strong basis to position themselves in the governance debate, which does not preclude government but rather involves a spectrum from government to governance.

Key questions that this course seeks to answer: What are the core characteristics of environmental challenges from a policy perspective? What are key elements of 'environmental governance' and how legitimate and effective are these approaches in addressing persistent environmental challenges?

Furthermore, we encourage the development of soft skills by engaging students in activities such as moderating discussions in class, presenting own proposals, giving regular peer feedback, as well as critically reflecting on various relevant publications in the environmental governance domain.

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Furthermore, we encourage the development of soft skills by engaging students in activities such as moderating discussions in class, presenting own proposals, giving regular peer feedback, as well as critically reflecting on various relevant publications in the environmental governance domain.

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Furthermore, we encourage the development of soft skills by engaging students in activities such as moderating discussions in class, presenting own proposals, giving regular peer feedback, as well as critically reflecting on various relevant publications in the environmental governance domain.
This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined.

The objectives in this course are to (1) gain an overview of important questions pertaining to international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions in this policy area and how to address them in a conceptually and methodologically meaningful and insightful way; (3) gain an overview of important global and regional environmental problems and how they are or could be solved.

The course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined, for example international efforts to reduce air pollution, manage international water resources, mitigate and adapt to global warming, protect the stratospheric ozone layer, address biodiversity challenges, deal with plastic waste, and prevent pollution of the oceans.

This course will take place on campus (ETH Main Building, HG F.3). There will be no live-streaming, and the course is NOT in hybrid (on-campus plus online) format. However, the lecture will be recorded and the recordings will be made available via the Moodle platform for this course a few days after the respective lecture for students who are unable to attend in person. All electronic correspondence will take place via the ETH mystudies system and Moodle, so please make sure you are properly registered there with a functioning email address/account.

Credits and Exam

After passing a written test at the end of the course (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test). Visiting students (e.g., from the University of Zurich, exchange students) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory. Students who obtain a grade of < 4.0 for the test will have a second chance (see table below). Students who did not participate in the test on 18 December 2023 will not have access to the repeat test unless they submit compelling and documented (e.g. medical, other exam in parallel at ETH) reasons for why they were unable to participate in the first test. It covers all contents of the lectures and the reading assignments. Visiting students (e.g., from the University of Zurich or other universities) are subject to the same conditions. Registration for the course in the mystudies system of ETH is compulsory. No separate registration for the exam is required, registration for the course as such covers everything. The exam will take place on campus, either in the F3 lecture hall or in a computer room. That is, you must be present in person at ETH Zurich on the exam date/time.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Problem-solving

Method-specific Competencies
- Critical Thinking

Personal Competencies
- Creative Thinking

Questions regarding the application to joanna.jacob@usys.ethz.ch.

Abstract

In this seminar, students are introduced to the multi-disciplinary field of political ecology to investigate human-environment relationships in food and agricultural systems.

Objective

- Being able to provide an overview of the multi-disciplinary field of political ecology for investigating the relationships of humans to our environment
- Learn to identify how power and interest influence social-ecological systems and to distinguish symptoms from systemic root causes
- Become enabled to analyse complex and sometimes distant human-ecology relationships choosing from a broad range of methods

Content

We will review common narratives in agri-food systems informed by different ontologies and epistemologies, through a set of topics such as hunger, obesity, agrobiodiversity and seeds, forests and deforestation, climate change and food production. Students will explain one concept in each course to the groups and practice their argumentative and writing skills in a final essay, applying the acquired tools to a topic of their choice. While specific inputs from external lecturers broaden our perspective, enough time for critical discussion and reflection will be granted.

Lecture notes

20.9.2024 Introduction to political ecology
27.9.2024 Ontologies and epistemologies
4.10.2024 Green revolution, industrial agriculture, and agroecology
11.10.2024 Don't blame the rain: Water management in agriculture
18.10.2024 Climate justice and food systems
25.10.2024 Conservation: Protecting what from what?
1.11.2024 Deforestation: Root causes and alternatives
8.11.2024 Pandemics, syndemics and the food system
15.11.2024 Technology and the politics of knowledge
22.11.2024 Land-sharing, land-sparing
29.11.2024 Feminist (political) agroecology
6.12.2024 Food: Commons or commodity?
13.12.2024 Alternatives to sustainable development
20.12.2024 Final session (The Hunger Banquet)
The aim of the course is to discuss different econometric models and their empirical applications. We will cover cross-sectional linear and non-linear regression models, models for estimating treatment effects, and linear panel data models. Therefore, this class introduces problems and key concepts of empirical research, which might form a basis of their managerial decision-making. We recommend the lecture also to students without basic statistical skills, who plan to attend more advanced lectures in the field of artificial intelligence such as Marketing Analytics.

Concerning qualitative research, students learn how to conduct and evaluate interviews. In the area of quantitative research, we recommend the lecture also to students without basic statistical skills, who plan to attend more advanced lectures in the field of artificial intelligence such as Marketing Analytics.

The lecture will empower students to critically assess the quality and outcomes of studies published in the media and scientific journals, which might form a basis of their managerial decision-making. We recommend the lecture also to students without basic statistical skills, who plan to attend more advanced lectures in the field of artificial intelligence such as Marketing Analytics.

The course includes out-of-class assignments to give students some hands-on experience in conducting empirical research in management. Projects will focus on one particular aspect of empirical research, like the formulation of a research question or the design of a study. Assignments will be graded and need to be turned in on time as they will be shown and discussed in class. Class participation is encouraged and can greatly improve students’ learning. In this spirit, students are expected to attend class regularly and come to class prepared.

The course will consist of both theoretical and practical components. In the theoretical part, we will discuss each estimation approach in practice using STATA. In the empirical part, we will look at simulation results using artificial data. Furthermore, we will investigate a particular research question using STATA.

The course will tentatively cover the following subjects:
- review of ordinary least squares (OLS) estimation
- instrumental variable estimation and two-stage least squares estimation
- seemingly unrelated regression models
- simultaneous equation models
- maximum likelihood estimation
- binary response models
- count data models
- censored and truncated regression models
- sample selection models
- treatment effect models
- static linear panel data models (random effects and fixed effects estimation)
For the theoretical portions of the lectures, we will prepare slides for in-class discussion. The format of the course is in-person. Slides will be distributed electronically before each lecture.

For the applied portion of the lectures, we will provide STATA do files, log files, and data sets.

Problem sets will also be made available after every lecture. These problem sets will not be collected or graded, but students can use them in order to prepare for the final exam. Solutions will be made available in the following lecture.

While there is no required textbook for the course, we draw from the following texts, which are also recommend for the preparation of the exam:


**Literature**


**Prerequisites / notice**

Prior basic knowledge of matrix algebra and probability theory is strongly recommended.
Communication

The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.

The subsequent lectures then introduce different one- and two-dimensional nonlinear models with applications in economics, such as models of supply and demand, business cycles, growth and competition.

Emphasis is on the formal analysis of these models using methods from applied mathematics and tools for solving coupled differential equations.

Weekly self-study tasks are used to apply the concepts introduced in the lectures.

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.

This book can also be used for the course "Mathematical Optimization", which is a more advance lecture covering similar topics. Compared to "Mathematical Optimization", this course has a stronger focus on modeling and applications.

This course is meant for students who did not already attend the course "Mathematical Optimization", which is a more advance lecture covering similar topics. Compared to "Mathematical Optimization", this course has a stronger focus on modeling and applications.

This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to every-day economic problems.

The subsequent lectures then introduce different one- and two-dimensional nonlinear models with applications in economics, such as models of supply and demand, business cycles, growth and competition.

Emphasis is on the formal analysis of these models using methods from applied mathematics and tools for solving coupled differential equations.

Weekly self-study tasks are used to apply the concepts introduced in the lectures.

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

363-1017-00L Risk and Insurance Economics

W 3 credits 2G H. Schernberg

Abstract
The course covers the economics of risk and insurance, in particular the following topics will be discussed:
1) individual decision making under risk
2) models of insurance demand, risk sharing, insurance supply
3) information issues in insurance markets
4) advanced topics in microeconomics and behavioral economics
5) the macroeconomic role of insurers and insurance regulation

Objective
The course introduces students to basic microeconomic models of risk attitudes and highlight the role insurance can – or cannot – play for individuals facing risks.

Content
Everyday, we take decisions involving risks. These decisions are driven by our perception of and our appetite for risk. Insurance plays a significant role in people's risk-management strategies.

In the first part of this lecture, we discuss a normative decision concept, Expected Utility theory, and compare it with empirically observed behaviour.

Students then learn about the rationale for individuals to purchase insurance, and for companies to offer it. We derive the optimal level of insurance demand and discuss how it depends on our model's underlying assumptions.

We then discuss the consequences of information asymmetries in insurance markets and the consequences for insurance supply.

Finally, we discuss refinements in decision theory that help account for observed behaviours that don't fit with the basic models of microeconomic theory. For example, we'll explore how behavioural economics can be leveraged by the insurance industry.

Literature
Main literature:
- Handbook of the Economics of Risk and Uncertainty, Volume 1
Further readings:

References will be given on a topic-by-topic basis during the course.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

Personal Competencies
- Critical Thinking: assessed
- Self-direction and Self-management: fostered

363-1137-00L Applied Econometrics in Environmental and Energy Economics

W 3 credits 2V

Abstract
The course introduces to the most common empirical methods for the analysis of issues in environmental, energy, and resource economics. The course includes computer laboratory sessions, and covers the following broad topics: demand models, discrete choice models, empirical methods in policy evaluation, field- and quasi-experiments.

Objective
At the end of the course, the students will be able to: understand the most common empirical methodologies used in environmental, energy, and resource economics; understand the problems the methodologies learnt in class aim to address; appreciate the importance of causal inference in empirical economics; read and understand the research papers in the literature; apply the empirical methods learnt in class using the software R.

Autumn Semester 2024
The course introduces students to empirical statistical methods that have wide application in environmental, energy, and resource economics and it is divided in four blocks. The first block is a quick review of the basic econometric methodology and concepts (OLS, standard errors, logit/probit models); the second block introduces demand models like the Almost Ideal Demand System, discrete choice models, and their evolutions; the third block explores causal inference in empirical economics and the main reduced-form econometric techniques used in policy evaluation, such as difference-in-differences, regression discontinuity and synthetic control; the fourth block introduces field experiments and instrumental variables, and their characteristics.

At the end of each block there will be a computer laboratory class in which the student will learn to apply the methodologies learnt in class using the statistical open-source software R. Throughout the course, students will have the chance to work on actual data used for analysis in economics papers.

The lectures will make use of current research papers in the literature to illustrate practical examples in which the methodologies learnt in class have been used. Students will be expected to read in advance the paper that will be explained during the lecture. The evaluation policy has the aim to allow students to get practical experience on the econometric methodologies learnt in class. Thus, beyond a final open-book computer exercise exam (60% of the grade), the course includes short takehome computer exercises (40% of the grade).

As the course will be centered on econometric methods, it is recommended that students have taken 363-0570-00L Principles of Econometrics first, or have otherwise a solid knowledge of basic econometric methodologies as detailed in Part 1 of Wooldridge, Jeffrey M. (2018) Introductory Econometrics: A Modern Approach. Seventh ed. ISBN: 978-1-337-55886-0. Knowledge of statistical software R is helpful, but not required and will be taught in the computer laboratory sessions.

From October 28th to November 11th, The students will take part in a field course in the Mount Kenya Region. Students will then gain practical knowledge on field, meeting several stakeholders of the agricultural and food systems and conducting various assessments of their performance in the respective courses.

### Prerequisites / notice

It is highly recommended to take 363-0570-00L Principles of Econometrics first.

### Project Management and Communication of Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>751-5201-10L</td>
<td><strong>Tropical Cropping Systems, Soils and Livelihoods</strong> <em>(with Excursion)</em></td>
<td>W+</td>
<td>5 credits</td>
<td>10G</td>
<td>J. Six, K. Benabderrazik</td>
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</tbody>
</table>

**Abstract**

This course guides students in analyzing and comprehending tropical agroecosystems and food systems. Students gain practical knowledge of field methods, diagnostic tools and survey methods for tropical soils and agroecosystems. An integral part of the course is the two-week field project in the Mount Kenya Region, which is co-organized with the University of Embu (Kenya).

**Objective**

1. Overview of the major land use systems in Tropical agroecosystems in several contexts Africa
2. Interdisciplinary analysis of agricultural production systems
3. Knowledge on methods to assess agroecological performance of a tropical agroecosystems
4. Hands-on training on the use of field methods, diagnostic tools and survey methods.
5. Gain practical knowledge on how to assess climate resilience and farming systems.
6. Collaboration in international students and stakeholders

**Content**

This course guides students in analyzing and comprehending tropical agroecosystems. Students of ETH Zürich will work together with the students from Embu University (Kenya) in an interdisciplinary and intercultural team. Students will focus on the Agroecological performance and climate resilience of diverse farming systems in the Mount Kenya Region.

### Prerequisites / notice

We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 18rd 2023, justifying your motivation to enroll to this class. A selection of 20 students will be done on the basis of the letters.

### Professional Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>751-0210-00L</td>
<td><strong>Professional Internship</strong></td>
<td>O</td>
<td>30 credits</td>
<td></td>
<td>B. Dorn</td>
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</table>
Students primarily work on a defined task or internship project in a professional environment within the field of Agricultural Sciences. By doing so, they apply the subject-specific, method-specific, social, and personal competencies acquired during their studies in their daily work and further develop and deepen them. Additionally, they reflect upon and present their internship experiences. The students will set their own learning and working goals, and reflect on learning and work performance within the framework of their internship provider.

The course Professional Internship consists of:
- a preparatory phase, which includes an information event, the attendance of Agro Day II as well as seeking a suitable internship position.
- the placement period, preferably in the 3rd semester of the master's programme, but necessarily before the master's thesis, lasting at least 16 weeks. During placement period, additional written assignments will be completed.
- a follow-up phase, which includes presenting a "1-minute presentation" and discussing a poster on Agro-Day II.

The course has four major learning objectives: 1) Students know the conceptual background of evaluations and can relate concepts in agricultural economics to the evaluation of policies. 2) They know the basics of how to design and implement a policy evaluation study. 3) Students can transfer their methodological knowledge from other agricultural economics courses to the context of agricultural policy evaluations (econometrics, modelling etc.). They make hands-on experiences of methodological challenges. 4) They can critically assess the science-policy interface of policy evaluations.

Students are able to deepen the relevant topics in an autonomous way. They know possible practical applications and examples of the treated contents to organizations in the Agri-Food Chain and they know and can apply selected comprehensive models for managing in complex situations. Students can transfer their methodological knowledge from other agricultural economics courses to the context of agricultural policy evaluations (econometrics, modelling etc.). They make hands-on experiences of methodological challenges. 4) They can critically assess the science-policy interface of policy evaluations.

Falls in einem Semester nur die Lehrveranstaltung Berufspraktikum belegt wird, kann man sich in ein Urlaub einschreiben. Genaue Informationen finden sich im Moodle Kurs.

### Minors

#### Agricultural Economics and Policy

<table>
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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-2903-00L</td>
<td>Evaluation of Agricultural Policies</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>R. Huber, R. Finger, C. Schader</td>
</tr>
</tbody>
</table>

**Abstract**
In this course, students get an overview of agricultural policy evaluations and their societal and political relevance. They learn to understand and apply the principles of scientific based evaluations of agricultural policies.

**Objective**
The course has four major learning objectives: 1) Students know the conceptual background of evaluations and can relate concepts in agricultural economics to the evaluation of policies. 2) They know the basics of how to design and implement a policy evaluation study. 3) Students can transfer their methodological knowledge from other agricultural economics courses to the context of agricultural policy evaluations (econometrics, modelling etc.). They make hands-on experiences of methodological challenges. 4) They can critically assess the science-policy interface of policy evaluations.

**Content**
The course consists of two blocks: First, students will learn the basics of how to design, implement and interpret agricultural policy evaluations. In this block, the conceptual embedding, the design and methodological tools as well as case studies are presented. Secondly, the students make hands-on experience using econometric and modelling tools in the context of agricultural policy evaluations. They apply their theoretical and empirical knowledge to Swiss case studies.

**Lecture notes**
Handouts and reading assignments

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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-2205-00L</td>
<td>Management for Enterprises in the Agri-Food-Chain II</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>M. Weber</td>
</tr>
</tbody>
</table>

**Abstract**
Advanced Management in the Agri-Food Chain: Framework and models for management of organizations in the Agri-Food Chain in a complex environment

**Objective**
After the lecture the students ...
... know the characteristics and consequences of complexity in the organizational world,
... know and can apply selected comprehensive models for managing in complex situations,
... know possible practical applications and examples of the treated contents to organizations in the Agri-Food Chain and ... are able to deepen the relevant topics in an autonomous way.

**Content**
In the lecture the following contents will be treated:
- State, reasons and effects of complexity in the organizational world.
- A basic framework for shaping and governing intelligent organizations.
- Selected contemporary models for managing in the complex organizational world.
- Transfer and adaption of the models to organizations in the Agri-Food Chain.

**Lecture notes**
Reader with selected contents.

**Prerequisites / notice**
- Vorlesung "Management für Unternehmen der Agrar- & Ernährungswirtschaft I" in D-USYS

Vorlesung wird in deutscher Sprache abgehalten
**Competencies**

**Subject-specific Competencies**
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed

**Social Competencies**
- Communication: assessed

**Personal Competencies**
- Critical Thinking: assessed

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**751-2103-00L** Socioeconomics of Agriculture

- **W 2 credits 2V**
- **S. Mann**

**Abstract**
The main part of this lecture will examine constellations where hierarchies, markets or cooperation have been observed and described in the agricultural sector. On a more aggregated level, different agricultural systems will be evaluated in terms of main socioeconomic parameters like social capital or perceptions.

**Objective**
Students should be able to describe the dynamics of hierarchies, markets and cooperation in an agricultural context.

**Content**
- Introduction to Sociology
- Introduction to Socioeconomics
- Agricultural Administration: Path dependencies and efficiency issues
- Power in the Chain
- The farming family
- Occupational Choices
- Market segregation
- The issue of meat demand
- Common Resource Management in Alpine Farming
- Agricultural Cooperatives
- Societal perceptions of agriculture
- Perceptions of farming from within
- Varieties of agricultural systems and policies

**Literature**
see script

**Prerequisites / notice**
Basic economic knowledge is expected.

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**751-1073-00L** Dynamic Simulation in Agricultural and Regional Economics

- **W 3 credits 2V**
- **B. Kopainsky**

**Abstract**
In this class, students learn the basics of system dynamics and its application to agricultural and regional economic questions. In the second half of the class, students develop their own simulation model, with which they evaluate potential interventions for improving the economic as well as the ecological sustainability of food systems.

**Objective**
- Students learn the basic theory and practice of dynamic simulation
- Students can develop, analyze and extend a dynamic simulation model and interpret its results.
- By applying the developed simulation model, students gain insights into food system issues. They also learn to recognize the benefits and pitfalls of dynamic simulation, both from a theoretical and an applied perspective.

**Lecture notes**
slides (will be provided during the class)

**Literature**
articles and papers (will be provided during the class)

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**751-0423-00L** Risk Analysis and Risk Management in Agriculture

- **W 3 credits 2G**
- **R. Finger**

**Abstract**
Agricultural production is exposed to various risks and risk management is indispensable. This course introduces modern concepts on farmers’ decision making under risk and risk management. We present innovative insights, empirical example from European agriculture. You gain hands-on experience using R.

**Objective**
- to develop a better understanding of decision making under uncertainty and risk;
- gain hands-on experience in risk analysis and management using R;
- to gain experience in different approaches to analyze risky decisions;
- to develop an understanding for different sources of risk in agricultural production;
- to get an overview on risk management in the agricultural sector, with a particular focus on insurance solutions

**Content**
- Quantification and measurement of risk
- Risk preferences, Expected Utility Theory, Cumulative Prospect Theory
- Production and input use decisions under risk
- Portfolio Theory and Farm Diversification
- Forwards, Futures, Crop Insurance
- Weather Index Insurance and Satellite Imagery
- Empirical Applications using R

**Lecture notes**
Handouts will be distributed in the lecture and available on the moodle.

**Prerequisites / notice**
knowledge of basic concepts of probability theory and microeconomics


In this class, students learn how to understand and conduct empirical research. It will enable them to manage a business based on evidence-based decision-making. The class includes assignments related to the lecture content.

The general objective of the course is to enable students to understand the basic principles of empirical studies. After successfully passing the class, they will be able to formulate research questions, design empirical studies, and analyze data by using basic statistical approaches.

Data has become an important resource in today’s business environment, which can be used to make better management decisions. However, evidence-based decision-making comes along with challenges and requires a basic understanding of statistical approaches. Therefore, this class introduces problems and key concepts of empirical research, which might be qualitative or quantitative in nature. Concerning qualitative research, students learn how to conduct and evaluate interviews. In the area of quantitative research, they learn how to apply measurement and scaling methods and conduct experiments. In addition, basic statistical analyses like a variance analysis and how to conduct it in a standard statistical software package like SPSS or R are also part of the lecture. The lessons learned from the lecture will empower students to critically assess the quality and outcomes of studies published in the media and scientific journals, which might form a basis of their managerial decision-making. We recommend the lecture also to students without basic statistical skills, who plan to attend more advanced lectures in the field of artificial intelligence such as Marketing Analytics.

The lecture will be taught in presence. There will be individual assignments that students have to solve throughout the lecture. In addition to that, there will be some non-mandatory online exercises as an additional opportunity to prepare for the exam.

Literature and readings will be announced. For a basic understanding we recommend the Handbook of Good Research by Jürgen Brock and Florian von Wangenheim.

The course includes out-of-class assignments to give students some hands-on experience in conducting empirical research in management. Projects will focus on one particular aspect of empirical research, like the formulation of a research question or the design of a study. Assignments will be graded and need to be turned in on time as they will be shown and discussed in class. Class participation is encouraged and can greatly improve students’ learning. In this spirit, students are expected to attend class regularly and come to class prepared.

The course gives economic and empirical foundations for a sound understanding of the instruments, prospects and limitations of international development aid.

Students have a theoretically and empirically sound understanding of the prospects and limitations of international development aid. Students are able to critically discuss the various aid instruments of bi- and multilateral donors and NGOs.

Introduction to the Determinants of Underdevelopment; History of Aid; Aid and Development: Theories and Empirics; Political Economy of Aid; Experience and Impact of Aid; New Instruments of Aid: e.g. Micro-Finance, Budget-Support; Fair-Trade.

Articles and book abstracts will be uploaded to a course website.

Animal Sciences

This forum is a platform for the critical reflection of relevant topics of livestock in the frame of the world food system comprising issues from basic knowledge to acceptance in society. The exchange is operated by scientific writing and presentation.

In the Forum “Livestock in the World Food System”, a topic of significance for livestock agriculture is selected by the students and subsequently dealt with from various angles (from scientific basis to production systems, environmental aspects and to the acceptance by society).

The students learn to present a scientific subject in writing and orally to an audience and to defend the presentation in a discussion. Further, feedback is intended to improve the presentation style. Furthermore, the review process of a scientific paper will be demonstrated and applied.
The Forum "Livestock in the World Food System" will take place in blocks of 2 hours each. Once the general topic has been selected, it comprises two parts:

Part 1
Aspect 1 - Oral presentation: The students form small groups and are lecturers.
Aspect 2 - chairperson: There are moderators which are chosen from outside of the presenting groups and they will lead the discussion and the remaining students and the lecturer are the audience and ask questions.
Aspect 3 - feedback: At the beginning, students form teams of 2, which are not in the same group, to give each other feedback on their presentation style.

Part 2.
Aspect 1 - Scientific writing: Preparation of a critical review of a chosen publication and individual exchange with the lecturer.
Aspect 2 - Defense: There will be a discussion in small groups on several dates to discuss the chosen publication in detail and the observations during the process.

Introductions to both presentation forms will be given by the lecturer.

Lecture notes: no scriptum

Requirements for allocation of the two credit points:
- oral talk with sufficient handout
- delivery of the scientific writing in sufficient quality
- active participation during all presentations (in case of absence there will be additional tasks)
- feedback on the presentation style of a student

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity

Personal Competencies
- Negotiation
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

751-6501-00L Ruminant Science W+ 4 credits 4G M. Niu, M. Terranova, U. Witschi

Abstract
The course provides the scientific basis of the central aspects of reproduction and nutrition physiology of ruminants, and of the implications for animal health, product quality, and breeding programs. Means of knowledge transfer include interdisciplinary approaches, disciplinary parts, web-based learning and self-study.

Objective
At the end of the course the students are able to apply, by a comprehensive understanding of the underlying mechanisms, their knowledge in various fields of ruminant science. They will be able to develop and recommend best strategies for breeding programs, feed formulation, improving forage quality, and increasing animal health. They will be trained to carry out interdisciplinary and disciplinary research at the highest level.

Content
- Fields (contact hours)
  - Introduction: 2 h
  - Special topics: 20 h
  - Rumen Anatomy
  - Hohenheim Gas Test
  - Calf health
  - Reproduction Techniques
  - Fertility in Cows
  - Disciplinary topics: 32 h
  - Ruminal Digestion: 8 h
  - Ruminant Nutrition Physiology: 12 h
  - Reproduction in Ruminants: 8 h
  - Lectures held by the students: 4 h

In summary
- Contact hours: 58 h
- Self-study within semester: 30 h (especially preparation for the interdisciplinary courses and the own lecture)
- Self-study in semester break: 32 h
- Total: 120 h

Lecture notes
- Introductions to both presentation forms will be given by the lecturer.
- Lectures held by the students: 4 h

Literature
- Information on books and other references will be communicated during the course.

Prerequisites / notice
- The specialty of this course is that for the first time the animal science disciplines are unified. This is realised with a particular emphasis on interdisciplinary special topics and new forms of teaching. At the same time the essential basics in the central fields are communicated.

Conditions for successful participation:
- Background on animal science from the Bachelor is desired. In order to attend the Minor in Ruminant Science without any animal science background, a realistic self-assessment concerning the need for additional self-study is recommended (e.g. by choosing an appropriate bachelor course which then may be counted as 'optional courses' in the master). These efforts depend on the extent to which animal science courses have already been attended in the bachelor.
- The control of performance will consist of:
  - an oral short lecture
  - a final oral examination with focus on comprehension of the fundamental linkages rather than of specific details

751-6243-00L Breeding and Conservation of Animal Genetic Resources W+ 2 credits 2V H. SignerHASLER, C. Flury, H. Pausch

Abstract
Animal genetic resources refer to the genetic and species diversity of livestock. Only a few production breeds have been further developed through breeding, while local breeds have no longer been able to survive in this competition. Without the support of endangered breeds and the sustainable breeding of productive breeds, many regionally typical breeds are threatened with extinction.
Objective

Learning Objectives: Part 1:
At the end of the course, students are able to assess the importance and problems of small ruminant breeding and husbandry in Switzerland and neighbouring countries. They know the most important breeding objectives and are able to assess them in terms of production and sustainable development in small ruminants and cattle.

Learning objectives part 2:
The second part gives an overview of the distribution, endangerment and conservation of breed diversity of farm animals in Switzerland and internationally. The theory is illustrated with numerous examples and the knowledge is deepened in exercises.

The students:
- have an overview of the national and international distribution of animal genetic resources and are familiar with the database DAD-IS (Domestic Animal Diversity Information System).
- can name the national and international efforts to conserve agricultural livestock breeds.
- know how to describe genetic diversity.
- can point out what is important in the management of small populations.
- can describe different conservation measures, especially in situ and ex situ conservation.
- can describe current national and international conservation programmes for different livestock breeds.

Prerequisites / notice
Examination:
Examination Part 1: Graded written examination (1 hour) on the material covered.
Examination Part 2: Graded semester performance completed during the block course.
Parts 1 and 2 contribute equally to the final grade.

Crop- and Grassland Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-4104-00L</td>
<td>Alternative Crops</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>A. Walter, K. Berger Büter</td>
</tr>
</tbody>
</table>

Abstract
Few crops dominate the crop rotations worldwide. Following the goal of an increased agricultural biodiversity, species such as buckwheat but also medicinal plants might become more important in future. The biology, physiology, stress tolerance and central aspects of the value-added chain of the above-mentioned and of other alternative crops will be depicted.

Objective
During this course, students learn to assess the potential of different minor or alternative crops compared to the dominant major crops based on their biological and agronomical features. Each student will assess and present a specific alternative crop of his or her choice based on information from scientific articles and Wikipedia. Wikipedia-entries will be generated.

Competencies
Subject-specific Competencies: Concepts and Theories
Method-specific Competencies: Media and Digital Technologies
Project Management: Problem-solving
Social Competencies: Communication
Self-presentation and Social Influence: Cooperation and Teamwork
Sensitivity to Diversity: Self-presentation and Social Influence

Personal Competencies
Creative Thinking: fostered
Critical Thinking: fostered
Integrity and Work Ethics: fostered
Self-awareness and Self-reflection: fostered
Self-direction and Self-management: fostered

751-3603-00L | Current Challenges in Plant Breeding        | W    | 2    | 2G    | B. Studer, A. Hund, R. Kölliker |

Abstract
The seminar ‘Current Challenges in Plant Breeding’ aims to bring together national and international experts in plant breeding to discuss current activities, latest achievements and future prospective of a selected topic/area in plant breeding.

Objective
The educational objectives cover thematic, methodic as well as social and personal competencies:
Thematic/methodic competencies:
- Deepening of scientific knowledge in plant breeding
- Critical evaluation of current challenges and new concepts in plant breeding
- Promotion of collaboration and Master thesis projects with practical plant breeders
Social/personal competencies:
- Independent literature research to get familiar with the selected topic
- Critical evaluation and consolidation of the acquired knowledge in an interdisciplinary team
- Establishment of a scientific presentation in an interdisciplinary team
- Presentation and discussion of the teamwork outcome
- Establishing contacts and strengthening the network to national and international plant breeders and scientist

Content
Interesting topics related to plant breeding will be selected in close collaboration with the working group for plant breeding of the Swiss Society of Agronomy (SSA).

Lecture notes
None

Literature
Peer-reviewed research articles, selected according to the topic.

Prerequisites / notice
Participation in the BSc course ‘Pflanzenzüchtung’ is strongly recommended, a completed course in ‘Molecular Plant Breeding’ is advantageous.
Agroecosystems play a major role in all landscapes, either for production purposes, ecological areas or for recreation. The human impact on the environment is mainly driven by effects on biogeochemical cycles and thus ecosystem functioning, but also about feedback mechanisms of terrestrial ecosystems. Students will gain profound knowledge about biogeochemical cycles and greenhouse gas fluxes in managed grassland and/or cropland ecosystems as well as expand their computational competences. Responses of agroecosystems to the environment, i.e., to climate and weather events, but also to management will be studied. Two flipped classroom exercises include the assessment of an ecosystem disturbance and the experimental design of an own study. Data loggers will be programmed, and a small weather station will be set up. Different meteorological and greenhouse gas flux data will be analysed (using R) and assessed in terms of production, greenhouse gas budgets, and carbon sequestration. Thus, students will learn how to collect, analyse and interpret data about the complex interactions of a coupled human-environmental system.

Students will work in groups (3-4 persons per group) with data from a small weather station (dedicated to the course), as well as data from the long-term measurement network Swiss FluxNet and from global databases. Data from the intensively managed grassland site Charmau will be used to investigate the biosphere-atmosphere exchange of CO2, H2O, N2O and CH4. Functional relationships will be identified, greenhouse gas budgets will be calculated for different time periods and in relation to management over the course of a year. A part of the course will take place in flipped classroom mode, i.e., some lectures will be available as podcasts.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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**Method-specific Competencies**

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<th>Analytical Competencies</th>
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<tr>
<td>Decision-making</td>
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<tr>
<td>Media and Digital Technologies</td>
<td>Assessed</td>
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<td>Problem-solving</td>
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<td>Project Management</td>
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**Social Competencies**

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<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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**Personal Competencies**

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<th>Adaptability and Flexibility</th>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
<td>Assessed</td>
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<tr>
<td>Self-direction and Self-management</td>
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</table>

**Prerequisites / notice**

- A part of the course will take place in flipped classroom mode, i.e. some lectures will be available as podcasts.
- Material will be distributed during the course.
- Lecture notes will be available in moodle.
- Students will understand the consequences arising from the unintentional or deliberate introduction of alien organisms into agricultural systems. They will be able to understand the concept of environmental risk assessment and be able to evaluate risk management options.
- The course focuses on alien organisms in agriculture, as well as the scientific assessment and regulatory management of their effects on the environment and agricultural production.

**751-5101-00L Biogeochemistry and Sustainable Management**

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<th>Competencies</th>
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<td>Subject-specific Competencies</td>
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<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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</table>

**Objective**

Students will analyse and understand the complex and interacting processes of ecology, biogeochemistry and management of agroecosystems. They will use their theoretical knowledge in two flipped classroom exercises, but also set up a small weather station and program a data logger to collect meteorological variables, analyze large meteorological and flux data sets, and evaluate the impacts of weather events and management practices on the ecosystem greenhouse gas exchange. Thus, students will expand their computational competences. Moreover, students will be able to coordinate and work successfully in small (interdisciplinary) teams.

**Content**

Students will understand the consequences arising from the unintentional or deliberate introduction of alien organisms into agricultural systems. They will be able to understand the concept of environmental risk assessment and be able to evaluate risk management options.

**751-4811-00L Alien Organisms in Agriculture**

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<th>Competencies</th>
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<tr>
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<td>Techniques and Technologies</td>
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</table>

**Objective**

Students will understand the consequences arising from the unintentional or deliberate introduction of alien organisms into agricultural systems. They will be able to understand the concept of environmental risk assessment and be able to evaluate risk management options.

**Content**

The course focuses on alien organisms in agriculture, as well as the scientific assessment and regulatory management of their effects on the environment and agricultural production.
The seminar concerns current aspects and research related to nutrient cycles in agro-ecosystems. The theme of the next seminar is "Integrated Nutrient Management to maximize nutrient use efficiency in productive agricultural systems: Insights from long-term field experiments".

Analyze publications and/or data records on long-term field experiments regarding their content on integrated nutrient management and derive the nutrient use efficiency; link this information, write it up in a report and present the results in an oral presentation; work in a group; ask questions and contribute to the discussion following the oral presentations; link the information to answer overarching questions and recommendations; expand the knowledge on nutrient cycles and nutrient management in the agro-ecosystem; learn about the importance of long-term field experiment to answer questions on the sustainability of agricultural systems.

The seminar concerns current aspects and research related to nutrient cycles in agro-ecosystems. The theme of the next seminar is "Integrated Nutrient Management to maximize nutrient use efficiency in productive agricultural systems: Insights from long-term field experiments". The students will analyze and connect the results published (or from data records) for selected field experiments in a group work. They will present their analysis in a report and in an oral presentation. The seminar is composed by presentations of experts and of the students. The presentations will be synthesized during a final discussion.

Research results in agro- and forest ecosystem sciences will be presented by experienced researchers as well as by doctoral and graduate students. Citation classics as well as recent research results will be discussed. Topics will range from plant ecophysiology, biodiversity and biogeochemistry to management aspects in agro- and forest ecosystems.

Students will be able to understand and evaluate experimental design and data interpretation of on-going studies, be able to critically analyze published research results, practice to present and discuss results in the public, and gain a broad knowledge of recent research and current topics in agro- and forest ecosystem sciences.

The students will learn and train preparation skills for microscopy, acquire knowledge of selected diseases (identification, biology of pathogen, epidemiology and systematics) and understand the corresponding integrated control measures practiced in Swiss agriculture. One exercise will be based on computer and ocular camera, also to prepare the students for the final e-exam. The course will be in German (spec. nomenclature).
Modern weed management comprises competent knowledge of weed biology, weed ecology, population dynamics, crop-weed-interactions and different measures to control weeds. Weeds are understood to be rather part of a habitat or a cropping system than just unwanted plants in crops. Accordingly, this knowledge will be imparted during the course and will be required to understand the mechanisms of integrated weed control strategies.

### Data Science and Technology for Agricultural Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-3001-00L</td>
<td>Environmental Systems Data Science: Data Processing</td>
<td>W+</td>
<td>2</td>
<td>2G</td>
<td>L. Pellissier, C. P. Albouy, M. Volpi</td>
</tr>
<tr>
<td>401-6215-00L</td>
<td>Using R for Data Analysis and Graphics (Part I)</td>
<td>W+</td>
<td>1.5</td>
<td>1G</td>
<td>A. Hauser</td>
</tr>
<tr>
<td>401-6217-00L</td>
<td>Using R for Data Analysis and Graphics (Part II)</td>
<td>W+</td>
<td>1.5</td>
<td>1G</td>
<td>M. Mächler</td>
</tr>
</tbody>
</table>

The students will be able to use the software R for simple data analysis and graphics. The course provides the first part of an introduction to the statistical software R for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.

The course focuses on practical work at the computer with R. We will make use of the graphical user interface RStudio: www.rstudio.org

Note: Part I of UsingR is complemented and extended by Part II, which is offered during the second part of the semester and which can be taken independently from Part I.


The course resources will be provided via the Moodle web learning platform. Subscribing via Mystudies "automatically" makes you a student participant of the Moodle course of this lecture, which is at https://moodle-app2.let.ethz.ch/course/view.php?id=20847

Competencies

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

- **Method-specific Competencies**
  - Analytical Competencies
  - Media and Digital Technologies
  - Problem-solving

- **Social Competencies**
  - Cooperation and Teamwork

- **Personal Competencies**
  - Creative Thinking
Robots are becoming a key technology in the transition to smart farming and in supporting the agricultural needs of the 21st century. For example, robots enable site-specific fertilization, automated weeding, or livestock herding. The course gives an overview of robotic systems, beginning with their fundamental components (e.g., sensors, actuators, locomotion strategies) and gradually scaling up to the system level, illustrating the concepts of perception, robot control, obstacle avoidance and navigation. Exercises performed with an educational robot (Thymio) will complement the theoretical lectures providing a hands-on practical experience of the challenges of using these machines.

During the course, students will gradually apply the theoretical and practical knowledge they are learning. To this end, students will work in teams to develop a robotic solution for an agricultural task of their choice. Students will learn to translate the task into meaningful requirements for a robotic system and critically select the most appropriate components to achieve the required robotic functions. Students will periodically present and discuss the development of this "robot design" exercise during presentations and in a journal report.
701-0951-00L  GIST - Introduction into Geoinformation Science and Technology

Abstract
Theoretical basics and fundamental concepts of Geographic Information Science are imparted and subsequently further elaborated with the software ArcGIS.

Objective
Students are able to
- elucidate the theoretical and conceptional foundations of geographic information systems (GIS)
- independently perform normal GIS work using commercial software and practical examples

Content
The course covers the following topics:
- What is GIS? What are spatial data?
- The representation of reality by means of spatial data models: vector, raster, TIN
- The four phases of data modelling: Spatial, conceptual, logical and physical model
- Possibilities of data collection
- Transition of reference frame
- Spatial Analysis I: query and manipulation of vector data
- Spatial Analysis II: operators and functions with raster data
- Digital elevation models and derived products
- Process modelling with vector and raster data
- Presentation possibilities of spatial data

One Friday is reserved for a field trip or guest speaker;

Literature

Prerequisites / notice
Aufgrund der Grösse des verfügbaren EDV-Schulungsraumes ist die Teilnehmerzahl auf 50 Studierende beschränkt! Für die Übungen werden die Studierenden auf zwei, max. drei Zeitfenster aufgeteilt. Pro Zeitfenster können maximal 25 Studierende betreut werden.

651-4031-00L  Geographic Information Systems

Abstract
Introduction to the fundamental concepts and data processing capabilities of Geographic Information Systems (GIS). Practical application of geospatial data management and analysis functions based on a selected geoscience project.

Objective
Students can
- explain the basic principles of GIS
- solve a complex, real-world GIS problem in the field of Earth Science
- apply the principles of data modelling and geoprocessing with ArcGIS Pro: data design and modelling, data acquisition, data integration of different data types (including LiDAR data), spatial analysis of vector and raster data, special functions for digital terrain modelling and hydrology, map production and 3D visualisation.

Content
Theoretical introduction to the concepts, spatial data types and spatial data handling functions of Geographic Information Systems (GIS). Application of data modeling principles and geoprocessing capabilities using ArcGIS Pro: data design and modeling, data acquisition, data acquisition and integration, spatial analysis of vector and raster data, particular functions for digital terrain modeling and hydrology, map generation and 3D-visualization.

Lecture notes
Lecture Script: Introduction to Geographic Information Systems, Tutorial: Introduction to ArcGIS Pro. All lecture materials are provided digitally.

Literature
L. Pellissier

The seminar concerns current aspects and research related to nutrient cycles in agro-ecosystems. The theme of the next seminar is "Integrated Nutrient Management to maximize nutrient use efficiency in productive agricultural systems: Insights from long-term field experiments". The students will analyze and connect the results published (or from data records) for selected field experiments in a group work. They will present their analysis in a report and in an oral presentation. The seminar is composed by presentations of experts and of the students. The presentations will be synthesized during a final discussion.

Competencies

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Media and Digital Technologies
  - Problem-solving
  - Project Management
- Social Competencies
  - Cooperation and Teamwork
- Personal Competencies
  - Creative Thinking
  - Critical Thinking
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

701-3003-00L Environmental Systems Data Science: Machine Learning

Abstract

Students are introduced to advanced data science where environmental data are analyzed using state of the art machine learning methods. Starting from known statistical approaches, they learn the principle of more advanced machine learning methods with practical application. The course enables students to plan their own data science project in their specialization and to apply machine learning models to real-world problems.

Objective

The students are able to:
- select an appropriate model related to a research question and dataset
- describe the steps from data preparation to running and evaluating models
- prepare data for running machine learning with dependent and independent variable
- build and validate regressions and neural network models
- understand convolution and deep learning models
- access online resources to keep up with the latest data science methodology and deepen their understanding

Content

- The data science workflow
- Data preparation for running and validating machine learning models
- Get to know machine learning approaches including regression, random forest and neural network
- Model complexity and hyperparameters
- Model parameterization and loss
- Model evaluations and uncertainty
- Deep learning with convolutions

Literature

Building on existing data science resources

Prerequisites / notice

- Math IV, VI (Statistics); R, Python; ESDS I

Number Title Type ECTS Hours Lecturers

751-5115-00L Current Aspects of Nutrient Cycle in Agro-Ecosystems W 2 credits 1S E. Frossard, A. Oberson Dräyer

Abstract

The seminar concerns current aspects and research related to nutrient cycles in agro-ecosystems. The theme of the next seminar is "Integrated Nutrient Management to maximize nutrient use efficiency in productive agricultural systems: Insights from long-term field experiments". The students will analyze and connect the results published (or from data records) for selected field experiments in a group work. They will present their analysis in a report and in an oral presentation. The seminar is composed by presentations of experts and of the students. The presentations will be synthesized during a final discussion.

Competencies

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management
- Social Competencies
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
  - Negotiation
- Personal Competencies
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

751-3405-00L Chemical Nature of Nutrients and their Availability to Plants: The Case of Phosphorus

Abstract

The CNNAP course discusses the mechanistic relationships between nutrient speciation in fertilizer and nutrient uptake by plants using phosphorus as an example. The course involves theoretical aspects of nutrient cycling, laboratory work, data analysis and presentation, and the use of advanced methods in plant nutrition studies.
Objective

At the end of the CNNAP course, participants will obtain a mechanistic understanding of why and how the speciation of phosphorus in fertilizer can affect its release to the soil solution and subsequent uptake by plants. Students will be able to use this information for the development of fertilization schemes that maximize the nutrient uptake and fertilizer efficiency of crops or pastures. During the course, participants will become familiar with the use of radioisotopes and nuclear magnetic resonance as approaches to measure nutrient availability and forms, respectively and they will know the limits of these techniques. Students will also have the opportunity to improve their laboratory, presentation, discussion and writing skills.

Lecture notes

Documents will be distributed during the lecture.

Literature

Documents will be distributed during the lecture.

Prerequisites / notice

The CNNAP lecture will take place at the ETH experimental station in Eschikon Lindau every second year. The next course will be organized in autumn 2024. The CNNAP course will take place if and only if 8 or more students are registered one week before the start. See the location of the station at: http://www.plantnutrition.ethz.ch/the-group/how-to-find-us.html

We strongly advise students who are planning to be absent for more than one week during the semester NOT to visit this course. Students should have visited the plant nutrition lectures in the 3rd and 6th semesters and the lecture pedosphere in the 3rd semester of the agricultural study program of the ETH. If students do not have visited these courses they will have to acquire the necessary information by themselves as this knowledge is indispensable for the CNNAP course.

As the CNNAP course does not take place in autumn 2023, we recommend students interested in integrated assessment of nutrient cycling in soil plant systems to visit the 8th semester lecture 751-3404-00L (Nutrient Fluxes in Soil-Plant Systems: The Case of Nitrogen) organized in spring 2024 by Oberson et al.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Problem-solving assessed
Project Management fostered

Social Competencies

Communication assessed

Personal Competencies

Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

751-5125-00L

Stable Isotope Ecology of Terrestrial Ecosystems

W 2 credits 2G R. A. Werner, N. Buchmann, A. Geissler, M. Lehmann

Abstract

This course provides an overview about the applicability of stable isotopes (carbon 13C, nitrogen 15N, oxygen 18O and hydrogen 2H) to process-oriented ecological research. Topics focus on stable isotopes as indicators for the origin of pools and fluxes, partitioning of composite fluxes as well as to trace and integrate processes. In addition, students carry out a small project during lab sessions.

Objective

Students will be familiar with basic and advanced applications of stable isotopes in studies on plants, soils, water and trace gases, know the relevant approaches, concepts and recent results in stable isotope ecology, know how to combine classical and modern techniques to solve ecophysiological or ecological problems, learn to design, carry out and interpret a small IsoProject, practice to search and analyze literature as well as to give an oral presentation.

Content

The analyses of stable isotopes often provide insights into ecophysiological and ecological processes that otherwise would not be available with classical methods only. Stable isotopes proved useful to determine origin of pools and fluxes in ecosystems, to partition composite fluxes and to integrate processes spatially and temporally.

This course will provide an introduction to the applicability of stable isotopes to ecological research questions. Topics will focus on carbon (13C), nitrogen (15N), oxygen (18O) and hydrogen (2H) at natural isotope abundance and tracer levels. Lectures will be supplemented by intensive laboratory sessions, short presentations by students and computer exercises.

Lecture notes

Handouts will be available on the webpage of the course.

Literature

Will be discussed in class.

Prerequisites / notice

This course is based on fundamental knowledge about plant ecophysiology, soil science, and ecology in general. Course will be taught in English.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Problem-solving assessed
Project Management fostered

Social Competencies

Communication assessed

Personal Competencies

Creative Thinking fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management assessed

701-0533-00L

Soil and Water Chemistry

W 3 credits 2G R. Kretzschmar, D. I. Christl, L. Winkel

Abstract

This course covers chemical and biogeochemical processes in soils and water and their influence on the behavior and cycling of nutrients and pollutants in terrestrial and aquatic systems. Approaches for quantitative modeling of the processes are introduced and applied in selected examples.

Objective

1. Understanding of important chemical properties and processes of soils and water and their influence on the behavior (e.g., chemical speciation, bioavailability, mobility) of nutrients and pollutants.
2. Quantitative applications of chemical equilibria to processes in natural systems.

Content

The course "Soil and Water Chemistry" teaches, applies and examines the competences process understanding, systems understanding, and modelling.

Chemical equilibria in aqueous solutions, gas equilibria, precipitation and dissolution of mineral phases, silicate weathering, weathering kinetics, formation of secondary minerals (clay minerals, oxides, sulfides), redox processes in natural systems, pH buffering and acidification, salinity and salinization, environmental behavior of selected essential and toxic trace elements.

Lecture notes

Lecture slides on Moodle

Literature

--Chapters 1, 3, 4, 6, 7 and 11 in Sigg/Stumm – Aquatische Chemie, 6. Auflage, vdf, 2016.
The lecture courses Pedosphere and Hydrosphere are highly recommended.

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies
- **Method-specific Competencies**
  - Analytical Competencies
  - Problem-solving
- **Social Competencies**
  - Communication
- **Personal Competencies**
  - Critical Thinking

### Prerequisites / notice

The lecture courses Pedosphere and Hydrosphere are highly recommended.

### 701-0535-00L Environmental Soil Physics/Vadose Zone Hydrology

- **Credits:** 3
- **ECTS:** 2V+1U
- **Lecturers:** A. Carminati, P. U. Lehmann Grunder

### Abstract

The course provides theoretical and practical foundations for understanding and characterizing physical soil properties and processes and their relevance for terrestrial ecosystems, plant growth, hydrological processes and atmospheric-land gas exchange, across all relevant scales.

### Objective

Students are able to:
- Characterize the different soils based on their key textural and structural properties.
- Simulate and predict soil water retention and flow under varying environmental conditions and understand the key driving forces (capillarity, gravity, friction) and related water properties (surface tension and viscosity).
- Predict soil hydraulic properties for varying soil textural classes.
- Predict solute transport in soils for varying environmental conditions.
- Predict energy balance and temperature dynamics in soils.
- Predict conditions for plant water stress
- Estimate the impact of soil properties on the hydrological cycle and on plant growth.

### Content

#### INTRODUCTION

- Week 1 (September 18)
  - Presentation of the role of soil physics in environmental sciences and terrestrial ecosystems: soils in the water cycle; soils and vegetation; soils and solute transport. Survey on students' interests and expectations. Presentation of course structure and learning objectives.

#### BASIC SOIL PROPERTIES

- Week 2 (September 25) and Week 3 (October 02)
  - soil texture, particle size distribution, soil structure, soil surface area, porosity and bulk density
  - Pore scale consideration (water in a single pore), pore sizes and shapes; surface tension; Young-Laplace equation; capillary rise; contact angle
  - Friction and laminar flow; Hagen-Poiseuille’s law; Washburn equation; numerical lab (REPORT 1)

#### SOIL HYDRAULIC PROPERTIES

- Week 4 (October 09) and Week 5 (October 16)
  - Soil water content and soil water potential - The energy state of soil water; total water potential and its components; volumetric and gravimetric water contents; field capacity and wilting point
  - Soil water characteristics and pore size distribution
  - Saturated water flow in soils - Laminar flow in tubes (Poiseuille’s Law); Darcy’s Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts; effective conductivity; unsaturated hydraulic conductivity; Buckingham law.
  - Unsaturated water flow in soils - Unsaturated hydraulic conductivity models and applications

#### TOOLBOX – MEASUREMENTS AND MODELING

- Week 6 (October 23) and Week 7 (October 30)
  - Measuring soil hydraulic properties, fitting and interpretation; Lab tour - demonstration of soil physical methods; lecture on HYPROP method; report on Hyprop data (REPORT 2)
  - Modelling unsaturated water flow based on Richards equation - Using Hydrus1D for simulation of unsaturated flow; simulating HYPROP measurements (REPORT 3)

#### SOIL IN THE WATER CYCLE

- Week 8 (November 06) and Week 9 (November 13)
  - Water infiltration - steady state solutions for infiltration; approximate solutions to infiltration (Green-Ampt, Philip); infiltration rate and ponding; outlook to preferential flow
  - Water evaporation - Energy balance and land atmosphere interactions - potential and actual evaporation, evaporation stages;

#### SOIL PLANT INTERACTIONS

- Week 10 (November 20) and Week 11 (November 27)
  - Root water uptake and transpiration – Theory and mechanisms controlling root water uptake; hydraulic properties of rhizosphere; plant and stomatal conductance.
  - Modelling root water uptake and transpiration; analytical approaches and modeling using Hydrus (REPORT 4)

#### SOLUTE TRANSPORT

- Week 12 (December 04) and Week 13 (December 11)
  - Transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application
  - Transport of reactive substances, preferential flow, simulations with Hydrus

#### CLOSURE

- Week 14 (December 18)
  - Summary, course synthesis, connections between the different topics, questions, exam preparation

### Literature

Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel
This course guides students in analyzing and comprehending tropical agroecosystems and food systems. Students gain practical knowledge of field methods, diagnostic tools and survey methods for tropical soils and agroecosystems. An integral part of the course is the two-week field project in the Mount Kenya Region, which is co-organized with the University of Embu (Kenya).

**Abstract**

This course guides students in analyzing and comprehending tropical agroecosystems and food systems. Students gain practical knowledge of field methods, diagnostic tools and survey methods for tropical soils and agroecosystems. An integral part of the course is the two-week field project in the Mount Kenya Region, which is co-organized with the University of Embu (Kenya).

**Objective**

(1) Overview of the major land use systems in Tropical agroecosystems in several contexts Africa
(2) Interdisciplinary analysis of agricultural production systems
(3) Knowledge on methods to assess agroecological performance of a tropical agroecosystems
(4) Hands-on training on the use of field methods, diagnostic tools and survey methods.
(5) Gain practical knowledge on how to assess climate resilience and farming systems.
(6) Collaboration in international students and stakeholders

**Content**

The students will take part in a field course in the Mount Kenya Region. Students will then gain practical knowledge on field, meeting several stakeholders of the agricultural and food systems and conducting various assessments related to climate resilience and farming systems.
We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 18th 2023, justifying your motivation to enroll to this class. A selection of 20 students will be done on the basis of the letters.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Assessed</th>
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<tbody>
<tr>
<td></td>
<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td>Decision-making</td>
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<td>Problem-solving</td>
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</table>

| Social Competencies | Communication | assessed |
|                     |               |          |
|                     | Cooperation and Teamwork | assessed |
|                     | Leadership and Responsibility | assessed |

| Personal Competencies | Adaptable and Flexibility | assessed |
|                      | Critical Thinking          | assessed |
|                      | Integrity and Work Ethics  | assessed |
|                      | Self-awareness and Self-reflection | assessed |
|                      | Self-direction and Self-management | assessed |

### Safety and Quality in Agri-Food Chain

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>752-2122-00L</td>
<td>Food and Consumer Behaviour</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>M. Siegrist, F. Michel</td>
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<tr>
<td></td>
<td>This course focuses on food consumer behavior, consumer's decision-making processes and consumer's attitudes towards food products.</td>
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<td>Students will be able to...</td>
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<td>- to describe heuristics that influence consumer behavior in the food domain</td>
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<td>- to explain the consumer led food product development</td>
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<td>- to summarise how consumers perceive the environmental impact and the healthiness of foods</td>
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<td>- to assess the cultural, the environmental and the food policy impact on consumer behavior</td>
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<td>- to explain psychological factors influencing eating behavior</td>
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<td></td>
<td>Problem-solving</td>
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| Social Competencies | Communication | fostered |
|                     | Customer Orientation | assessed |
|                     | Sensitivity to Diversity | assessed |

| Personal Competencies | Critical Thinking | assessed |

<table>
<thead>
<tr>
<th>752-2307-00L</th>
<th>Nutritional Aspects of Food Composition and Processing</th>
<th>W</th>
<th>3</th>
<th>2V</th>
<th>B. E. Baumer, J. M. Sych</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Lecture type course with an interdisciplinary approach for the evaluation of nutritional aspects of changes in food composition due to processing.</td>
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<tr>
<td>Objective</td>
<td>Students should be able to...</td>
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<td></td>
<td>- describe and compare the major concepts /criteria used for the evaluation of the nutritional quality of food</td>
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<td>- apply these criteria when assessing the effects of selected processing technologies on nutritional quality.</td>
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<td></td>
<td>- evaluate recent formulation strategies aimed to achieve additional physiological benefits for targeted population groups (i.e. functional foods),</td>
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<tr>
<td>Content</td>
<td>The course gives inputs on compositional changes in food due to processing (with focus on thermal/chilling, enzymatic, chemical, separation and emerging technologies) or new formulation strategies. New approaches for evaluating these changes (e.g. nutritional profiles) and how these are communicated to consumers are also discussed.</td>
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<tr>
<td>Lecture notes</td>
<td>There is no script. Powerpoint presentations and relevant scientific articles will be available on-line for students. A selection of recommended readings will be given at the beginning of the course.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The course is open to Master and MAS students in food and science and nutrition or related. Basic knowledge of food chemistry and nutrition is expected, as well as an understanding of food processing.</td>
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<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>fostered</td>
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<td></td>
<td>Decision-making</td>
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| Social Competencies | Fostered |
|                     | Customer Orientation | assessed |
|                     | Sensitivity to Diversity | assessed |

| Personal Competencies | Fostered |
|                      | Critical Thinking | assessed |

<table>
<thead>
<tr>
<th>751-7310-00L</th>
<th>Bioactive Food and Feed Components</th>
<th>W+</th>
<th>2</th>
<th>2V</th>
<th>to be announced</th>
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</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The course provides students with the basic knowledge to understand the connection between the structure of nutritive and non-nutritive bioactive food and feed components and their effects on the nutrient supply and health of humans and livestock as well as on the quality of animal-derived foods.</td>
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<tr>
<td>Objective</td>
<td>At the end of this course, the students are aware of food and feed as sources of different bioactive compounds. By a comprehensive understanding of the connection between bioavailability, molecular mechanisms and biological effects, they are able to apply their knowledge on beneficial and detrimental effects of bioactive food and feed components in the fields of human and animal nutrition.</td>
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<td>Content</td>
<td>The course gives an introduction into different classes of bioactive components present in food and feed including fatty acids and secondary plant compounds such as carotenoids, polyphenols, phytoestrogens, glucosinolates, protease inhibitors and monoterpenes.</td>
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<td>Topics include:</td>
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<td></td>
<td>- sources of bioactive food and feed components</td>
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<td></td>
<td>- bioavailability and modification in the gastrointestinal tract</td>
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<td></td>
<td>- beneficial and detrimental effects</td>
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<tr>
<td></td>
<td>- molecular mechanisms of biological effects</td>
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<td></td>
<td>- species differences concerning metabolism and biological effects</td>
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</table>
The teaching slides and other materials will be provided during the course.

Information about books and other references will be communicated during the course.

**751-4104-00L Alternative Crops**

**Abstract**

Few crops dominate the crop rotations worldwide. Following the goal of an increased agricultural biodiversity, species such as buckwheat but also medicinal plants might become more important in future. The biology, physiology, stress tolerance and central aspects of the value-added chain of the above-mentioned and of other alternative crops will be depicted.

**Objective**

During this course, students learn to assess the potential of different minor or alternative crops compared to the dominant major crops based on their biological and agronomical features. Each student will assess and present a specific alternative crop of his or her choice based on information from scientific articles and Wikipedia. Wikipedia-entries will be generated.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: fostered
  - Project Management: fostered

- **Method-specific Competencies**
  - Communication: assessed
  - Cooperation and Teamwork: assessed
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered

- **Social Competencies**
  - Communication: assessed
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered

- **Personal Competencies**
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered
  - Self-awareness and Self-reflection: assessed
  - Self-direction and Self-management: fostered

**Literature**

Information about books and other references will be communicated during the course.

**751-2105-00L Political Ecology of Food and Agriculture**

**Abstract**

In this seminar, students are introduced to the multi-disciplinary field of political ecology to investigate human-environment relationships in food and agricultural systems.

**Objective**

- Being able to provide an overview of the multi-disciplinary field of political ecology for investigating the relationships of humans to our environment
- Learn to identify how power and interest influence social-ecological systems and to distinguish symptoms from systemic root causes
- Become enabled to analyse complex and sometimes distant human-ecology relationships choosing from a broad range of methods

**Content**

We will review common narratives in agri-food systems informed by a range of different theories and assisted by different analytical tools. For this purpose, we will start from different concepts of nature, power and interests, explore different ontologies and epistemologies through a set of topics such as hunger, obesity, agrobiodiversity and seeds, forests and deforestation, climate change and food production. Students will explain one concept in each course to the groups and practice their argumentative and writing skills in a final essay, applying the acquired tools to a topic of their choice. While specific inputs from external lecturers broaden our perspective, enough time for critical discussion and reflection will be granted.

**Lecture notes**

- 20.9.2024 Introduction to political ecology
- 27.9.2024 Ontologies and epistemologies
- 4.10.2024 Green revolution, industrial agriculture, and agroecology
- 11.10.2024 Don't blame the rain: Water management in agriculture
- 18.10.2024 Climate justice and food systems
- 25.10.2024 Conservation: Protecting what from what?
- 1.11.2024 Deforestation: Root causes and alternatives
- 8.11.2024 Pandemics, syndemics and the food system
- 15.11.2024 Technology and the politics of knowledge
- 22.1.2024 Land-sharing, land-sparing
- 29.11.2024 Feminist (political) agroecology
- 6.12.2024 Food: Commons or commodity?
- 13.12.2024 Alternatives to sustainable development
- 20.12.2024 Final session (The Hunger Banquet)

**Literature**

Literature list provided on Moodle when the course starts.

https://moodle-app2.let.ethz.ch/course/view.php?id=20544
The course gives economic and empirical foundations for a sound understanding of the instruments, prospects and limitations of international development aid. Students have a theoretically and empirically sound understanding of the prospects and limitations of international development aid.

Subject-specific Competencies
- Concepts and Theories: assessed
- Analytical Competencies: fostered
- Decision-making: fostered
- Problem-solving: fostered

Social Competencies
- Cooperation and Teamwork: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

751-5003-00L Sustainable Agroecosystems II

Objective
1. Systematically analyse and discuss case studies from ongoing agroecological and food system research.
2. Learn and experiment on methods for field and laboratory investigations in agroecology.
3. Engage with positive and empowering frameworks that motivate critical reflection and action on the types of transformative responses needed to adapt and thrive within agricultural and food systems.
4. Reflect critically on agricultural and food system transformation tools and methods from the perspective of a food system stakeholder.
5. Identify and describe institutions in the context of sustainable agricultural development (for Bachelor and Master thesis and internships).

Content
The course will address a wide range of agricultural and food system challenges (e.g. food security, climate crisis, soil degradation, etc.) in both temperate and tropical contexts. In class we will address topics like building food system resilience through innovative measures, improving soil fertility management or understanding the effects of agroforestry systems.

Case studies from the on-going research in the Sustainable Agroecosystems Group (sae.ethz.ch) will be presented, covering different scales (e.g. food value-chains, farm dynamics and soil management).

The class is complemented by practical group work conducted with the CSA Meh Als Gmues in Zürich on Measuring and monitoring Agroecological performance.

Students will gain an overview on institutions and actors’ roles in the field of sustainable agricultural development. Throughout the group work, students will learn to engage directly with various stakeholders, monitor agroecological transition and communicate their research to a wider audience. Ultimately, this class should provide an overview on methods, tools, innovations and platforms that support a sustainable food transformation.


851-0626-01L International Development Cooperation

Objective
Students are able to critically discuss the various aid instruments of bi- and multilateral donors and NGOs.

Content
Introduction to the Determinants of Underdevelopment; History of Aid; Aid and Development: Theories and Empirics; Political Economy of Aid; Experience and Impact of Aid; New Instruments of Aid: e.g. Micro-Finance, Budget-Support; Fair-Trade.

Literature
Articles and book abstracts will be uploaded to a course website.

751-6001-00L Forum: Livestock in the World Food System

Objective
In the Forum "Livestock in the World Food System", a topic of significance for livestock agriculture is selected by the students and subsequently dealt with from various angles (from scientific basis to production systems, environmental aspects and to the acceptance by society).

The students learn to present a scientific subject in writing and orally to an audience and to defend the presentation in a discussion. Further, feedback is intended to improve the presentation style. Furthermore, the review process of a scientific paper will be demonstrated and applied.
The Forum "Livestock in the World Food System" will take place in blocks of 2 hours each. Once the general topic has been selected, it comprises two parts:

Part 1
Aspect 1 - Oral presentation: The students form small groups and are lecturers.
Aspect 2 - chairperson: There are moderators which are chosen from outside of the presenting groups and they will lead the discussion and the remaining students and the lecturer are the audience and ask questions.
Aspect 3 - feedback: At the beginning, students form teams of 2, which are not in the same group, to give each other feedback on their presentation style.

Part 2.
Aspect 1 - Scientific writing: Preparation of a critical review of a chosen publication and individual exchange with the lecturer.
Aspect 2 - Defense: There will be a discussion in small groups on several dates to discuss the chosen publication in detail and the observations during the process.

Introductions to both presentation forms will be given by the lecturer.

Lecture notes
no scriptum
Prerequisites / notice
Requirements for allocation of the two credit points:
- oral talk with sufficient handout
- delivery of the scientific writing in sufficient quality
- active participation during all presentations (in case of absence there will be additional tasks)
- feedback on the presentation style of a student

Competencies

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<tr>
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<td>Cooperation and Teamwork</td>
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<tr>
<td>Sensitivity to Diversity</td>
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<tr>
<td>Personal Competencies</td>
<td>Negotiation</td>
<td>fostered</td>
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<tr>
<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<tr>
<td>Critical Thinking</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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751-5201-10L Tropical Cropping Systems, Soils and Livelihoods (with Excursion) W+ 5 credits 10G J. Six, K. Benabderrazik

IMPORTANT: Students who enroll for this course are strongly recommended to verify with lecturers from other courses whether their absence of two weeks may affect their performance in the respective courses.

Abstract
This course guides students in analyzing and comprehending tropical agroecosystems and food systems. Students gain practical knowledge of field methods, diagnostic tools and survey methods for tropical soils and agroecosystems. An integral part of the course is the two-week field project in the Mount Kenya Region, which is co-organized with the University of Embu (Kenya).

Objective
(1) Overview of the major land use systems in Tropical agroecosystems in several contexts Africa
(2) Interdisciplinary analysis of agricultural production systems
(3) Knowledge on methods to assess agroecological performance of a tropical agroecosystems
(4) Hands-on training on the use of field methods, diagnostic tools and survey methods.
(5) Gain practical knowledge on how to assess to climate resilience and farming systems.
(6) Collaboration in international students and stakeholders

Content
This course guides students in analyzing and comprehending tropical agroecosystems. Students of ETH Zürch will work together with the students from Embu University (Kenya) in an interdisciplinary and intercultural team. Students will focus on the Agroecological performance and climate resilience of diverse farming systems in the Mount Kenya Region.

From October 28th to November 11th, The students will take part in a field course in the Mount Kenya Region. Students will then gain practical knowledge on field, meeting several stakeholders of the agricultural and food systems and conducting various assessments related to climate resilience and farming systems.

Prerequisites / notice
We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 18rd 2023, justifying your motivation to enroll to this class. A selection of 20 students will be done on the basis of the letters.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
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<tr>
<td>Method-specific Competencies</td>
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<tr>
<td>Decision-making</td>
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<tr>
<td>Problem-solving</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
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<tr>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<tr>
<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
<td>fostered</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<tr>
<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<tr>
<td>Self-direction and Self-management</td>
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</table>

751-2107-00L Agrarian and Environmental Values: Tensions, W+ 5 credits 3G M. Chapman, J. Jacobi

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 63 of 2653
Abstract

In politics, society, and science, it can seem that the values and practices of agricultural production and environmental protection are in conflict. This tension is often described as “protection versus use” of natural resources. We will explore ways to move beyond the apparent conflict. We will apply this learning to field trips and transdisciplinary projects.

Objective

Students are able to:

- Define different kinds and categories of values.
- Relate value concepts to their own studies, life, and experiences through reflective journaling.
- Infer the underlying values in a text or policy about agri-environmental topics.
- Collaboratively develop a transdisciplinary project for an agri-environmental case study from the field trips.

Content

The course consists of interactive seminars alongside field trips to farms that have found innovative solutions to balancing protection and production.

Seminars will cover topics such as the relationship between values and behavior and how people perceive value trade-offs. We will also discuss environmental ethics, environmental valuation and its critiques, the interplay of facts and values in agri-environmental decision-making, cultural ecosystem services, and relational values.

This class requires active participation. Learning is based on in-class activities, group work and field trips.

Literature

Literature will draw from political ecology, value theory and environmental values, as well as case studies and primary texts, such as the following (not all will be required reading; we will read 1 or 2 papers or book chapters each week).

- Environmental Values, by O’Neill, Holland and Light, 2008

IPBES Values Assessment 2023


Autonomous robots are quickly becoming a key player in the transition to precision agriculture. In this course, students will learn theoretical

**Method-specific Competencies**

- Analytical Competencies
- Problem-solving
- Decision-making
- Project Management

**Social Competencies**

- Communication
- Leadership and Responsibility
- Sensitivity to Diversity

**Personal Competencies**

- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics

**Electives Courses**

Elective courses can be chosen from the entire course programme of the ETH Zurich as well as from the course programme of the University of Zurich.

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---
701-3001-00L | Environmental Systems Data Science: Data Processing | W+ | 2 credits | 2G | L. Pellissier, C. P. Albouy, M. Volpi

**Abstract**

Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

**Objective**

- The students are able to
  - frame a data science problem and build a hypothesis
  - describe the steps of a typical data science project workflow
  - conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
  - critically think about the limits and implications of a method
  - visualise data and results throughout the workflow
  - access online resources to keep up with the latest data science methodology and deepen their understanding

**Content**

- The data science workflow
- Prepare and clean data
- Access and handle (large) datasets
- Analysis: data exploratory steps
- Analysis: machine learning and computational methods
- Evaluate results and analyse uncertainty
- Visualisation and communication

**Prerequisites / notice**

- 252-0840-02L Anwendungsbares Programmieren mit Python
- 401-0624-00L Mathematik IV: Statistik
- 401-6215-00L Using R for Data Analysis and Graphics (Part I)
- 401-6217-00L Using R for Data Analysis and Graphics (Part II)
- 701-0105-00L Mathematik VI: Angewandte Statistik für Umwelt- und Naturwissenschaften

751-5510-00L | Introduction to Agricultural Robotics | W+ | 3 credits | 2G | S. Mintchev

**Abstract**

Autonomous robots are quickly becoming a key player in the transition to precision agriculture. In this course, students will learn theoretical and practical aspects of robotics. Lectures will introduce how robots operate and analyse their application to precision agriculture. In hands-on laboratories, students will apply concepts learned in class on educational robots to simulate a weeding task.

**Objective**

- After the course, students will be able to critically examine and select appropriate robotic solutions for agricultural applications.
- The learning objectives of the course are: (i) illustrate the principle of operation of the main components of a robotic system, (ii) analyse how the different robotic components are integrated and contribute to the functioning of a robotic system, and (iii) solve problems in the field of agriculture using robotic principles.

**Content**

- Robots are becoming a key technology in the transition to smart farming and in supporting the agricultural needs of the 21st century. For example, robots enable site-specific fertilization, automated weeding, or livestock herding.
- The course gives an overview of robotic systems, beginning with their fundamental components (e.g., sensors, actuators, locomotion strategies) and gradually scaling up to the system level, illustrating the concepts of perception, robot control, obstacle avoidance and navigation. Exercises performed with an educational robot (Thymio) will complement the theoretical lectures providing a hands-on practical experience of the challenges of using these machines.
- During the course, students will gradually apply the theoretical and practical knowledge they are learning. To this end, students will work in teams to develop a robotic solution for an agricultural task of their choice. Students will learn to translate the task into meaningful requirements for a robotic system and critically select the most appropriate components to achieve the required robotic functions. Students will periodically present and discuss the development of this "robot design" exercise during presentations and in a journal report.

**Lecture notes / Literature**


**Prerequisites / notice**

- No mandatory prerequisites, but it is preferable that students have a basic knowledge of computer programming.
- Class size limitation to 30 students.
Agroecology is a discipline, an agricultural practice, and a political-social movement. Students will attend public lectures by experts from different fields and will reflect on agroecology and its principles. Moreover, students will expand their knowledge with case studies and discuss about the role of agroecology to support sustainable agriculture and food systems.

Students will be able to transfer their disciplinary and interdisciplinary knowledge about the thirteen principles as guiding principles for policymakers, practitioners, and other stakeholders across the food system in planning, managing, and evaluating agroecological transformation. Students are part of small groups focusing on selected principles of the HLPE. During the course, students discuss the potential and limitations of agroecology and learn about scientific contributions to agroecology. Students form an opinion on the role of agroecology, reflect and argue on the different facets and develop recommendations for real-world applications of agroecology in supporting a transition towards sustainable food systems.

The course is designed as a combination of public lectures/webinars on "Agroecology and the Transformation to Sustainable Food Systems" delivered by national and international experts and scientists as well as sessions in which students reflect on the topics addressed in the lecture series in a group work format. The public lectures bring different perspectives to the discussion and are intended as inputs for the students' sessions. In the student sessions, the student groups deepen their knowledge of the 13 principles of agroecology proposed by the High-Level Panel of Experts (HLPE) of the Committee on World Food Security. They identify "unknows" and link to other closely related principles. The groups also work out the perspective of a chosen stakeholder. Finally, the groups will take part in a scientific discussion representing their stakeholder perspective. All groups will synthesize their discussions in a short report.

Lecture notes

Handouts will be available on the webpage of the course.

Literature


Report of HLPE on agroecology:

Prerequisites / notice

This course is based on fundamental knowledge about plant ecophysiology, soil science, biogeochemistry, crop and forage science, and ecology in general. The course will be taught in English. The course is only offered in fall.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

Personal Competencies
- Negotiation: fostered
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Master's Thesis

Only students who fulfill the following criteria are allowed to begin with their master thesis:

A. successful completion of the bachelor programme;
B. fulfilling of any additional requirements necessary to gain admission to the master programme.

The Master thesis is an independent scientific work. Normally the subject is selected among the topics of the core subject. It is written under the guidance of a agricultural science professor.

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: assessed

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-direction and Self-management: assessed
Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<td>Anatomy and Physiology of Humans and Animals I+II Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
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<td>4R</td>
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<tr>
<td>751-7002-AAL</td>
<td>Basics in Animal Nutrition Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
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<td>M. Niu</td>
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<tr>
<td>751-3401-AAL</td>
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<td>E-</td>
<td>2</td>
<td>4R</td>
<td>E. Frossard</td>
</tr>
</tbody>
</table>

Abstract

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective

The course enables students to describe basic knowledge of human and animal anatomy and physiology, to understand basic functions of the organism, to understand connections between morphology and function of organ systems, to describe the development of organ systems and to be able to understand pathophysiological connections.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Sensitivity to Diversity
- Critical Thinking

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Self-awareness and Self-reflection

Literature

A detailed bibliography is included in the lecture notes.

Prerequisites / notice

Calculation exercises are part of the course. A calculator is required for this.

Content

We study the following chapters of the book Marschner’s Mineral Nutrition of Plants Fourth Edition 2023 chapters 1, 2, 3, 6, 7, 9, 11, 12 and 16

Lecture notes

We study the following chapters of the book Marschner’s Mineral Nutrition of Plants Fourth Edition 2023 chapters 1, 2, 3, 6, 7, 9, 11, 12 and 16

Literature


Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Communication
- Sensitivity to Diversity
- Self-direction and Self-management

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Self-awareness and Self-reflection

ECTS

2 credits

Prerequisites

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective

At the end of the course, students know how mineral nutrients are taken up through roots and circulate in the plants and what their roles in plants are. They understand the importance of nutrients for yield formation and for crop product quality.

Content

We study the following chapters of the book Marschner’s Mineral Nutrition of Plants Fourth Edition 2023 chapters 1, 2, 3, 6, 7, 9, 11, 12 and 16

Lecture notes

We study the following chapters of the book Marschner’s Mineral Nutrition of Plants Fourth Edition 2023 chapters 1, 2, 3, 6, 7, 9, 11, 12 and 16

Literature


Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Communication
- Sensitivity to Diversity
- Self-direction and Self-management

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Self-awareness and Self-reflection

ECTS

2 credits

Prerequisites

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective

Imparts a basic understanding of physiology an anatomy in man and domestic animals, focusing on the interrelations between morphology and function of the organism, in particular of domestic animals. This is fostered by discussing all subjects from a functional point of view. The lecture consists of two consecutive parts.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Sensitivity to Diversity
- Critical Thinking

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Self-awareness and Self-reflection

ECTS

2 credits

Prerequisites

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective

The aim of this course is to present processes controlling the uptake and transport of nutrients by the plant, the assimilation of nutrients in the plant, the effect of nutrients on crop yield and quality, and the role of the soil as a source of nutrients for crops.

Content

We study the following chapters of the book Marschner’s Mineral Nutrition of Plants Fourth Edition 2023 chapters 1, 2, 3, 6, 7, 9, 11, 12 and 16

Lecture notes

We study the following chapters of the book Marschner’s Mineral Nutrition of Plants Fourth Edition 2023 chapters 1, 2, 3, 6, 7, 9, 11, 12 and 16

Literature


Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Communication
- Sensitivity to Diversity
- Self-direction and Self-management

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Self-awareness and Self-reflection

ECTS

2 credits

Prerequisites

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective

Students know how mineral nutrients are taken up through roots and circulate in the plants and what their roles in animals are. They understand the importance of nutrients for yield formation and for crop product quality.

Content

We study the following chapters of the book Marschner’s Mineral Nutrition of Plants Fourth Edition 2023 chapters 1, 2, 3, 6, 7, 9, 11, 12 and 16

Lecture notes

We study the following chapters of the book Marschner’s Mineral Nutrition of Plants Fourth Edition 2023 chapters 1, 2, 3, 6, 7, 9, 11, 12 and 16

Literature


Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Communication
- Sensitivity to Diversity
- Self-direction and Self-management

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Self-awareness and Self-reflection

ECTS

2 credits

Prerequisites

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective

The course builds on knowledge of nutritional sciences by translating the information on nutrition to individual farm animal species and purposes. The emphasis is on the principles of utilisation of and requirements for energy and nutrients and the resulting feed evaluation systems as applied for the relevant forms of livestock nutrition (e.g., cattle, pig, poultry).

Content

Turnover and utilisation of nutrients and energy in the animal (definition of terms, turnover in the animal body, balances, utilisation), Feed evaluation in cattle, pigs and poultry (energetic feed evaluation, evaluation of nitrogenous feed substance) Nutrition of cattle, pigs and poultry (basics of feeding, physiological characteristics, demand and demand coverage, feeding standards, ration design) Feed science (individual feedstuffs, farm-produced feed)

Lecture notes

Lecture notes are available and can be obtained by moodle.

Literature

A detailed bibliography is included in the lecture notes.

Prerequisites / notice

Calculation exercises are part of the course. A calculator is required for this.
### Introduction to Crop and Forage Production

**Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.**

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**
This course provides an introduction into crop and forage sciences - with a focus on sustainable management methods in Switzerland and Europe.

**Objective**
The students know the basic processes and management methods of arable and forage production in Switzerland and Central Europe. They know the most relevant arable crops. Students can assess the influence of environmental factors and management not only on individual plants, but also on meadow and pasture plant communities and on their yields. They understand the relevance of crop rotation measures and can make recommendations for the establishment of land management methods. The students are familiar with sustainable, climate-friendly and biodiversity-conserving or biodiversity-enhancing management measures and understand the value of species-rich vegetation for the provision of ecosystem services.

**Content**
The part 'Arable Crop Production' deals with the most relevant arable crops and with basic steps of arable field management such as soil tillage, sowing and plant protection. Effects on soil structure, different tillage measures for different crops as well as differences in the intensity of intervention in comparison of conventional and soil-conserving tillage (e.g. no-till) are explained. The most important differences between conventional, integrated and organic production are addressed. Special emphasis is placed on the establishment of crop rotations taking into account the farm context.

In the part 'Forage Production', important plant functional groups and representative plant species as well as different types of grassland systems, i.e., most important mixtures as well as natural plant communities in Central Europe are presented (ward assessment). Based on the ecophysiology of individual plants, the reactions of plant stands to changing environmental conditions are elaborated. Different types of management are presented (e.g. fertilisation, grazing, cutting) and their effects on stand composition and yields are discussed.

Feedback mechanisms between environment and grassland systems are addressed. The role of biodiversity is addressed.

**Lecture notes**
Available on moodle.

**Competencies**

<table>
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<td>fostering</td>
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<td>Project Management</td>
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<td>Self-direction and Self-management</td>
<td>assessed</td>
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</tbody>
</table>

### Animal Breeding

**Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.**

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**
Introduction to basics of animal breeding. Importance of animal production. Species of livestock and their products, performance recording, functional traits, genetic diversity, breeding goals. Qualitative and quantitative traits. Basic knowledge of breeding methods: genetic and environmental variation, heritability, genetic correlation, estimation of breeding values, selection, mating systems.

**Objective**
Show the importance of animal production for Swiss and international agriculture. Name the livestock species, their products, systematic classification and breeding and production goals. Describe methods to measure animal performance (performance recording) and functional traits. Define the most important parameters and methods in animal breeding.

**Content**

**Lecture notes**
Transparencies and single chapters of textbook are made available on homepage.

**Literature**
Tierzucht (Willam/Simianer) UTB 3526 (2011)
Additional literature to be announced in the lecture.

**Competencies**

<table>
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<th>assessed</th>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Social Competencies</td>
<td>Cooperation and Teamwork</td>
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### Key for Hours

<table>
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<tbody>
<tr>
<td>V</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

### ECTS

- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
Applied Geophysics Master

Courses at ETH Zurich only take place in Spring Semester.

<table>
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<th>Key for Type</th>
<th>Type</th>
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<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<table>
<thead>
<tr>
<th>Key for Hours</th>
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<tbody>
<tr>
<td>V</td>
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ECTS (European Credit Transfer and Accumulation System)

- Special students and auditors need special permission from the lecturers.
## Architecture Bachelor

### First Year Examinations

#### Examination Block 1

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<th>Number</th>
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<td>052-0603-00L</td>
<td>Structural Design I</td>
<td>O</td>
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</table>

**Abstract**
The courses Structural Design I and II explain the fundamentals of how structures function. These courses put great emphasis on studying the relationship between the form of a structure and the internal forces within it by means of graphic statics.

**Objective**
At the end of the courses Structural Design I and II, students will be able to:

1. visualize the internal forces within structural elements.
2. understand the relationship between the form of a structure and the internal forces within it.
3. modify the design of a structure in order to improve it.
4. identify the most important structural typologies.
5. use graphic statics for the form-finding and analysis of structures.
6. carry out basic dimensioning of structural elements.
7. respond to structural problems in a creative manner.

**Content**

<table>
<thead>
<tr>
<th>Structural Design I:</th>
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</thead>
<tbody>
<tr>
<td>- Fundamentals of static equilibrium</td>
</tr>
<tr>
<td>- Introduction to graphic statics</td>
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<tr>
<td>- Basic dimensioning of structural elements</td>
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<tr>
<td>- Cables and stiffening schemes of cables</td>
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<td>- Arches and stiffening schemes of arches</td>
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<td>- Arch-cables structures</td>
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<th>Structural Design II:</th>
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<td>- Trusses</td>
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<td>- Beams</td>
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<td>- Frames</td>
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<tr>
<td>- Plates</td>
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<tr>
<td>- Buckling of compression elements</td>
</tr>
</tbody>
</table>

**Literature**

- "Faustformel Tragwerksentwurf" (Philippe Block, Christoph Gengangel, Stefan Peters, DVA Deutsche Verlags-Anstalt 2013, ISBN: 978-3-421-03904-0)

### Sociology I

<table>
<thead>
<tr>
<th>052-0703-00L</th>
<th>Sociology I</th>
<th>O</th>
<th>2 credits</th>
<th>2V</th>
<th>C. Schmid</th>
</tr>
</thead>
</table>

**Abstract**
Sociology I investigates the relation between social developments and the production of the built environment from a macro-sociological point of view. It examines central aspects of social change, historical and contemporary forms of urbanization, and typical examples of models of urbanization.

**Objective**
This series of lectures should enable students to comprehend architecture in its social context.

**Content**
Sociology I deals with the macro-sociological point of view, and investigates the relation between social developments and the production of the built environment. In the first part central aspects of social change are examined, in particular the transition from Fordism to Neoliberalism and the interlinked processes of globalization and regionalization. The second part deals with historical and current forms of urbanization. Among other aspects, it focuses on the changed significance of the urban-rural contradiction, the processes of suburbanization, periurbanization, and planetary urbanization; the formation of global cities and metropolitan regions; the development of new urban configurations in centres (gentrification) and in urban peripheries (edge city, exopolis, new urban intensity). In the third part these general processes are illustrated by typical models of urbanization: Manchester, Chicago, Los Angeles, Paris and Zürich.

**Literature**
A detailed collection of original texts will be distributed.

### Building History I

<table>
<thead>
<tr>
<th>052-0901-00L</th>
<th>Building History I</th>
<th>O</th>
<th>2 credits</th>
<th>2V</th>
<th>J. Schäfer</th>
</tr>
</thead>
</table>

**Abstract**
History of building from classical antiquity to modernity: building types, constructions, forms, with particular reference to functional issues such as flexibility of use, statics, durability. This is not a mere history lecture, but an important part of the basic introduction into construction.

**Objective**
Participants know the fundamentals of building history, including landmark monuments of each era, key historic constructions and forms. They are able to "read" a historic building and to relate it to building history. They are aware of the variety of historic building constructions.
Building history I covers the period from classical Greek antiquity to medieval architecture. The principal topics include construction issues such as Greek megalithic building, Roman mortar-and-rubble construction, and vaulting.

Within the Vitruvian and Albertian triad of firmitas, utilitas and venustas, we focus on the first two topics, whereas the last topic (deciphering the "meaning" of architecture) stands at the heart of the "architectural history" lectures. The present lecture contributes essentially to deepening knowledge about historic constructions, an indispensable precondition for building within existing fabric.

- buildings of Greek antiquity as examples of construction with huge stone blocks
- Roman buildings as examples of building with small materials, strict functional disposition, and evolution of the art of vaulting
- late antique and early Christian buildings: discovering interior space, developing new paradigms for religious architecture, construction wide-span roofs
- early and high medieval construction, continuing antique traditions, revival of dressed stone and vaulting
- small buildings, notably rural housing
- the medieval monastery

Lecture notes
Please keep a tight record of manuscript notes yourself. pdfs of lecture slides will be on line before each lecture. Lecture notes for exam preparation are provided and should be used in conjunction with the pictures from the lecture slides.

The exam will be held at the end of the first year. It is a computer-based multiple choice test. It calls for precise knowledge of the examples presented in the lecture, including the specifics of the architecture and construction of the buildings. Terminology is in GERMAN.

Prerequisites / notice
Due to professor Holzer's sabbatical, this lecture will be given by Dr. Jasmin Schäfer, in Fall Term 2024. However, the contents will be identical to the lecture delivered by professor Holzer in the Fall Term of 2023. This includes the topics, slides, lecture notes. Professor Holzer's lecture of Fall Term 2023 is available as a recording on video.ethz.ch. The lecture of Dr. Schäfer in Fall Term 2024 will NOT be recorded. Please refer to the recording of Fall Term 2023 under video.ethz.ch.

You may either listen to the fall 2023 recordings, to Dr. Schäfer's live lecture, or to both, to be prepared for the spring term of 2025 and the exam.

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<th>Method-specific Competencies</th>
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<td>Concepts and Theories</td>
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<td>Analytical Competencies</td>
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**Examination Block 2**

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<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Lecturers</th>
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<tr>
<td>052-0803-00L</td>
<td>History and Theory of Architecture I</td>
<td>O</td>
<td>2</td>
<td>2+2U</td>
<td>T. Avermaete, C. Rachele,</td>
</tr>
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<td>L. Stalder, P. Ursprung</td>
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</table>

**Abstract**
Introduction and overview of the history and theory of architecture from the Renaissance to the nineteenth century. The course covers the chronology and key works, protagonists and discourses of early modern European architecture, Fundamentals for the History and Theory of Architecture II-II provides a practical introduction to the methods and instruments of the history of art and architecture.

**Objective**
1. Acquiring basic knowledge of the history and theory of architecture during the early modern period, of its key protagonists and discourses and of the methods and instruments of architectural research.
2. Identifying the main architectural issues and debates of the period and recognising the places and architectural works covered in the course.
3. Acquiring the tools to develop a historically informed reading of the built environment, recognising debates, styles, ideas and problems which drive and inform architectural production.
4. Developing the tools to draw on historical, theoretical and critical research to the benefit to one's own architectural culture.

**Content**
The course History and Theory of Architecture II-I offers a chronological and thematic overview of the architecture and architectural theory produced in Europe from the 15th to the 19th centuries. Thematic lectures about key questions at play during the period will be combined with in-depth analysis of historical buildings, texts and iconographies.

Themes will cover the emergence and development of Vitruvian design theory and practice up to the 19th century and related issues such as the emergence of the architect; the development of original design practices and of divergent theories of architectural composition and design; the media of architectural design and practice (drawings, models, building materials); patterns and media of dissemination and influence (books, imagery, micro-architecture); building types (the palazzo and the villa); questions of beauty and ornament; questions of patronage (e.g., the Roman papacy) and the formation of religious and political symbolism through architecture; the relation of buildings to the city (e.g., the development of European capitals); attitudes towards history (origin myths, historicism); the question of the monument.

The exercises Fundamentals of the History and Theory of Architecture II-II aim to explore and develop basic methods and strategies to research the history of art and architecture. They consist of four parts, each developed under one of the four gta Chairs and each dealing with a particular area of study in the field of architecture and art history.

(1) The historiography of architecture (M. Delbeke)
(2) Architectural media (L. Stalder)
(3) Architecture and art (P. Ursprung)
(4) Urbanism and the Commons (T. Avermaete)
Literature

Course scripts, PowerPoints and lecture recordings for History and Theory of Architecture I-II will be available to download from the course page. Printed copies of the course scripts will also be available for purchase.

Prerequisites / notice

For the course History and Theory of Architecture I-II students will rely on assisted self-study to acquire basic knowledge of the history of architecture in Europe.

Competencies

Subject-specific Competencies
Methods-specific Competencies
Personal Competencies

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>credits</th>
<th>V</th>
<th>Instructor(s)</th>
</tr>
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<tbody>
<tr>
<td>052-0601-00L</td>
<td>Building Materials I</td>
<td>O</td>
<td>2V</td>
<td>J. Pauli</td>
</tr>
</tbody>
</table>

Abstract

Building Materials - Introduction to the most common building materials
- Raw materials + Production
- Properties + Application
- Ecological footprint + Recycling

Objective

The lecture introduces the most common building materials concrete, steel, masonry and timber, but also clay, glass and polymers in a historical context. The fabrication processes are described and the most important properties regarding construction explained. A special focus is on the ecological aspects such as availability of raw materials, effort for production, emission of hazardous substances, disposal and recycling.

Lecture notes

Lecture slides as pdf

Competencies

Subject-specific Competencies

<table>
<thead>
<tr>
<th>Techniques and Technologies</th>
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<tbody>
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<td>Analytical Competencies</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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Method-specific Competencies

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Social Competencies

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Personal Competencies

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<td>Creative Thinking</td>
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<td>Self-direction and Self-management</td>
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</table>

Computational Design I

Title of this course before HS22: “Mathematical Thinking and Programming I”

Abstract

This course introduces computational design and teaches how design can be modeled and materialized using digital technology. Participants learn to use the computer strategically, thoughtfully, and sensitively within the design process. With the “digital literacy” acquired in this course, they develop an understanding of the potential of a digital building culture.

Objective

To systematically harvest the potential of the computer in their work processes, architects need an insight into the fundamental principles of information technology. In this course, students learn the concepts, methods, and instruments of computational design. By the end of the two semesters, students will have mastered the basics of 3D modeling techniques, parametric design, programming code for Computer-aided-design (CAD), and digital prototyping. The acquired knowledge qualifies students to use the computer as a unique instrument to model their designs. Participants also learn to apply CAD and programming code creatively and productively in planning, design, and construction.

Specifically, the learning goals are:

- Critical understanding of the possibilities of information technology in design
- Acquiring an overview of the mechanisms and types of CAD systems and digital building models
- Gaining knowledge of the basic principles of computational geometry
- Applying visualization techniques and creatively using various digital media
- Learning concepts and application of parametric design.
- Being able to integrate computer-aided analysis and optimization methods in design-process
- Understanding the principles of digital process chains from design to production
- Strategically using visual programming code
- Reading, understanding, and adapting programming code within CAD software.
Architecture is no longer conceivable without information technology. The planning, construction, operation, and ultimately the nature of buildings are increasingly influenced by digital technology. The digital is omnipresent both in the work of architects and in our built environment itself.

The courses Computational Design 1 and 2 offer an introduction to the character, challenges, and possibilities of digital technology in architectural design. The lectures will discuss the topics of digital building models and data, computational geometry, digital fabrication, machine intelligence, and mixed reality.

In this course, students will practice digital modeling processes and related techniques. The spectrum of exercises includes manual modeling, visual programming, and programming code within CAD software. Students learn to read, understand and adapt this code. In addition, the courses will provide insights into the nature and handling of different digital media formats, from real-time rendering to mixed reality.

Topics discussed within the lectures:
- CAD - background, and developments
- On the nature of digital models and data
- Architectural geometry
- Computational geometry
- Parametric and generative creation of models
- Computer-aided analysis and optimization of models
- Artificial intelligence and architectural models
- Materialization of digital models
- Mixed reality

Course Structure
The course consists of theoretical lectures, practical tutorials introducing technical concepts, and exercises supported by tutors. Participants can find updated and detailed information on Moodle, which is the learning platform for the course.

<table>
<thead>
<tr>
<th>052-0709-00L</th>
<th>Perspectives on Landscape and Urban Transformation I</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>In this course we will collectively explore the different actions and actors, as well as the roles and professional practices that represent and collectively shape our environment. This is the first course which is collectively organized by the Institute of Landscape and Urban Studies (LUS), with the NEWROPE chair taking up the coordination. It will span two semesters.</td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>Through the different Perspectives on Landscape and Urban Transformation, students will learn to understand the complexity of the (urban) landscape. The various perspectives, readings and key terms will enrich and expand the vocabulary and theoretical knowledge of students. Tools for observation and activation will give students agency to observe and intervene in processes of urban transformation.</td>
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<tr>
<td><strong>Content</strong></td>
<td>At the end of the course students will be able to perceive and identify a multitude of actors and professional roles and recognize how they are overlapping, entangled and ever-shifting. Students will practice to textually and visually illustrate complex processes, including the many different stakeholders involved and the notion of time. Students will learn to reflect about and formulate their possible personal positions in relation to others. The formulated learning goals are aligned with the teaching activities, the exercises, and the final evaluation.</td>
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</table>

This course presents designers as facilitators of complex urban transformation processes. This position requires both an understanding of a great diversity of perspectives and positions constituting a city, and of the different professional roles one can take up to detect and utilize this diversity of – specific and often conflicting – needs, wishes, ambitions and actions. In each lecture one of these perspectives is presented. The list of different perspectives presented in both semesters is deliberately left incomplete, leaving space for students to think of other perspectives, needs and desires that one could take into account when working on a design or (redevelopment) of a space.

**Lecture notes**
Students will be provided with a reader at the first lecture. The reader for the course Perspectives on Landscape and Urban Transformation I-II is a container which holds together a collection of different hand-outs, brochures, and materials. All in all, it is a 'bag' and a personal organizer which invites students to fill over the course of the year. It allows them to individually structure and curate the content of the course. It is deliberately designed to be open-ended and to be individually extended and adapted. Towards the end of the semester, students will get a glossary where all key terms and concepts, presented in the various lectures, are combined. Each week students will receive a small leaflet that gives an overview of the individual lecture, as well as an additional reading.

All documents can be downloaded via Moodle.

**Literature**
Weekly handout of readings. All documents can be downloaded via Moodle. The course takes place at the Fokushalle, E7, ONA Building from 18:15h-20:15h.

The course will be under the formal responsibility of Prof. Freek Persyn and collectively coordinated by a core team consisting of Freek Persyn, Michiel van Iersel, Lukas Fink and Charlotte Schaeben.

Students can contact:
Charlotte (schaeben@arch.ethz.ch) for organisational, technical and personal questions
Lukas (fink@arch.ethz.ch) for questions regarding the reader, weekly exercises and the final exam
Michiel (mvaniersel@arch.ethz.ch) for questions regarding guests and literature
Competencies

Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies

- Communication: fostered
- Cooperation and Teamwork: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

Personal Competencies

- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-presentation and Social Influence: fostered
- Self-direction and Self-management: fostered

Subjects with Semester Grade

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>052-0501-00L</td>
<td>Design and Construction I</td>
<td>O</td>
<td>8</td>
<td>4V+10G+2U</td>
<td>A. Deplazes, D. Mettler, D. Studer</td>
</tr>
</tbody>
</table>

- **Abstract**: Designing and constructing will be understood to be a complementary offer. The content and methodical foundations of design and construction are taught and deepened through lectures and exercises.

- **Objective**: Understanding and dominating the methodology of designing and constructing.

- **Content**: Lectures and exercises to achieve the methodology and ability of designing and constructing.


- **Literature**:
  - Book recommendation *Construccion I - IV: "Construction"; A reference work on contemporary construction*, German or English
  - 360 pages, 171 images, 20 color images, texts
  - ISBN 978-3-0356-2225-6
  - Online reference source: https://www.hochparterre-buecher.ch/ Konstruktions.html

- **Prerequisites / notice**: 100% of interest and engagement!

- Participation in the seminar week of the Deplazes chair ("Hybrid Modeling") from DATE is compulsory!
Art in Space and Time I

Project grading at semester end is based on the list of enrolments on x.xx.2024 (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

8 credits 5G+4U R. Barba, H. E. Franzen, M. Narula

Abstract
Attendance in the lecture and exercise “Art in Space and Time I” and in the course “Introduction to Free and Perspective Drawing”. Submission of artistic exercise works. The semester grade results from participation in the lecture and exercise “Art in Space and Time I” as well as the “Introduction to Free and Perspective Drawing”, and the submission of artistic exercise works.

Objective
Students engage in experimental concepts in the arts as well as free and perspective drawing. In addition to acquiring extended artistic thought processes and practices, they each develop their own artistic exercise works.

Content
“Art in Space and Time” encompasses diverse and multi-disciplinary research fields, ranging from urban anthropology to artistic practices: film, sculpture, sound, writing, digital arts, and performance. These fields include and intersect with language, political discourses, and investigations of the human environment. Concrete theoretical as well as speculative, practical procedures are being tested to open up new horizons of perception and to reflect on them.

Examination Blocks

Examination Block 1

Number Title Type ECTS Hours Lecturers
052-0607-00L Structural Design III O 2 credits 3G J. Pauli

Abstract
The course Structural Design III complements the courses Structural Design I and II by introducing building materials and construction techniques.

Objective
After a successful conclusion of the course, students will be able to:

1. Understand the structural behaviour of a building and of its main components
2. Conceive and control design parameters as part of the design process
3. Design structural systems in compliance with diverse performance criteria including architectural, structural, constructive, and environmental aspects altogether.
4. Design structural systems consistent with the material used
5. Dimension structural elements using different building materials
6. Develop construction details in compliance to a specific static scheme
The course intends to stimulate a holistic approach to the design of structures that integrates the notions of static equilibrium learned in previous semesters, with systematic investigations related to mechanical properties of the main structural materials and related construction techniques.

The course explores the relationship between architecture and structure by introducing and discussing design parameters and their implications with respect to different performance criteria. In addition to those related to statics, performance criteria also include aspects related to use of material and energy resources, which is directly connected to questions of environmental footprint. The objective of the course is to show that structural design tasks must consider a number of aspects belonging to different disciplines simultaneously. This results in a level of complexity that very rarely can be reduced to a univocal “right” answer. Critical thinking and technical knowledge must support each other. The course aims at giving the tools for developing these skills.

After a brief review of the key aspects taught in Structural Design I and II, the course Structural Design III will examine different load-bearing elements, how they relate to each other, and their possible relationships with the architectural space. Starting from 2D spanning structures, a series of 5 lectures will illustrate the functioning of the main load-bearing elements of a building by means of graphic statics as well as analytical methods. Implications at the level of structural performance, spatial performance, material use, and environmental footprint will be thoroughly discussed throughout the entire course by analysing buildings of exemplary quality. The content of the lectures will be strengthened through 5 exercise sessions during which students will have the opportunity to apply the knowledge gained during the lectures and refine their design skills through dedicated design exercises under the supervision of a tutoring team.

**Objectives**

- To introduce students to the history and theory of architecture, the course has three objectives.

- First, students will be able to identify the “things” that transformed architecture in modernity, and the crucial events, buildings, theories, and actors that characterize their history.

- Second, students will be able to describe how these “things” operated at different scales, focusing less on the formal level, and naming instead the different forms of expertise that constituted them historically, as well as the processes within which they were embedded.

- Third, students will be able to reflect on a series of apparatuses, devices, and building parts that are in fact micro-architectures which have often been neglected, despite their pivotal role in shaping the daily lives of modern societies.

**Content**

The course proposes a new approach to the study of the history and theory of architecture in Europe during modernity. It focuses less on single architects or their buildings, and more on those “things” that have brought profound transformations in the built environment and daily life over the last 200 years, such as the revolving door, the clock, and the curtain.

The notion of “thing” includes both the concrete building parts and the concerns associated with them, such as material performance, social synchronization, and individual expression. To understand buildings as assemblages of “things,” therefore, does not mean to diminish their significance, but on the contrary to add reality to them, to understand them in terms of the complex, historically situated, and diverse concerns within which they were designed.

Each lecture introduces one “thing” through a genealogy that shaped it, from patents and scientific discoveries and technological advancement, to cinema, the visual arts, and literature. A set of renowned projects as well as lesser-known buildings from all around Europe offers a variety of case studies to describe these “things,” to understand how they operated in relation with one another, and to identify the theories and tactics that architects mobilized to make sense of them.

**Lecture notes**

http://www.stalder.arch.ethz.ch/courses

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### Literature

“The art of structures, Introduction to the functioning of structures in architecture”  

“Faustformel Tragwerksentwurf”  
(Philippe Block, Christoph Gengangel, Stefan Peters, DVA Deutsche Verlags-Anstalt 2013, ISBN: 978-3-421-03904-0)

“Form and Forces: Designing Efficient, Expressive Structures”  

### Prerequisites / notice

To take part in this course, it is recommended to first complete the courses Structural Design I and II or to have knowledge of graphic statics.

### Competencies

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### Prerequisites

- **052-0805-00L History and Theory of Architecture III**
  - **O 2 credits 2V L. Stalder, A. Kalpakci**

### Abstract

This two-semester course is an introduction to the history of architecture from the Second Industrial Revolution in the 1850s to the Oil Crisis in the 1970s in Europe. Students will be able to identify the “things”—technical objects and ensembles—that transformed architecture, and to relate them to the technical, scientific, and cultural concerns that introduced them as key features of modernity.

### Objective

To introduce students to the history and theory of architecture, the course has three objectives.

- First, students will be able to identify the “things” that transformed architecture in modernity, and the crucial events, buildings, theories, and actors that characterize their history.

- Second, students will be able to describe how these “things” operated at different scales, focusing less on the formal level, and naming instead the different forms of expertise that constituted them historically, as well as the processes within which they were embedded.

- Third, students will be able to reflect on a series of apparatuses, devices, and building parts that are in fact micro-architectures which have often been neglected, despite their pivotal role in shaping the daily lives of modern societies.

### Content

The course proposes a new approach to the study of the history and theory of architecture in Europe during modernity. It focuses less on single architects or their buildings, and more on those “things” that have brought profound transformations in the built environment and daily life over the last 200 years, such as the revolving door, the clock, and the curtain.

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Each lecture introduces one “thing” through a genealogy that shaped it, from patents and scientific discoveries and technological advancement, to cinema, the visual arts, and literature. A set of renowned projects as well as lesser-known buildings from all around Europe offers a variety of case studies to describe these “things,” to understand how they operated in relation with one another, and to identify the theories and tactics that architects mobilized to make sense of them.
### Computational Design III

**Title of this course before HS22: "Mathematical Thinking and Programming III"**

**Abstract**
This class builds on the digital literacy foundations taught in the previous year and expands the acquired competence in the use of computers in design. At the core stands the question of how to use digital architectural design methods in a creative, purposeful and self-confident manner.

**Objective**
The course consists of lectures and exercises. The lectures convey an insight into strategies for the implementation of algorithmic techniques in architectural design by presenting and discussing the research and the build work of the professorship. This pragmatic view on the computational design process helps demystifying algorithmic techniques and developing a critical understanding for their potentials in the architectural praxis. Programming is an extension of traditional design tools. While this powerful cultural technique allows us to handle complexity in a previously unknown way, the question of its meaning, relevance and potential needs to be negotiated on a context specific base for every single project. In order to be able to do this, we shall develop a conceptual understanding for the methods as well as familiarity with the practice of programming. While the works discussed in the lectures sharpen the conceptual understanding, the tutored exercises will train the programming practice. In these sessions, we will implement simplified yet powerful versions of the discussed projects by using Rhinoceros 3D as a modeler and Grasshopper as a visual programming interface, both environments that have been introduced in the previous semesters. Up-to-date and detailed information on the lectures and exercises is announced on MOODLE, which will serve as the teaching platform for this course.

The specific learning goals are:
- To develop a critical awareness for the potentials of algorithmic design methods.
- Learn to deploy parametric design strategies.
- Become familiar with the practice of visual programming.
- Understand the concepts and potentials of digital fabrication.

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed

**Personal Competencies**
- Creative Thinking: assessed
- Critical Thinking: assessed

#### Examination Block 2

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<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<tr>
<td>151-8009-00L</td>
<td>Building Physics II</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>J. Carmeliet, M. Ettlin, A. Rubin</td>
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</table>

**Abstract**
Moisture related problems are common in buildings leading to costly damage and uncomfortable indoor environments. This course aims at providing the necessary theoretical background and training in order to foresee and avoid these problems.

**Objective**
- to develop a basic understanding of mass transport and buffering
- to become aware of potential moisture-related damage and health risks
- to learn how to (i) design building components and (ii) assess their hygrothermal performance

**Content**
- hygrothermal loads
- conservation of mass (dry air, water vapor, liquid water)
- moist air: constitutive behavior, transport, potential problems and solutions
- liquid water: constitutive behavior, transport, potential problems and solutions
- exercises

**Lecture notes**
Handouts, supporting material and exercises are provided online via Moodle.

**Prerequisites / notice**
Prior knowledge of "BP I: heat" is required.

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<tr>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>052-0801-00L</td>
<td>Global History of Urban Design I</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>T. Avermaete</td>
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</table>

**Abstract**
This course focuses on the history of the design of cities, as well as on the ideas, processes and actors that engender and lead their development and transformation. The history of urban design will be approached as a cross-cultural field of knowledge that integrates scientific, economic and technical innovation as well as social and cultural advances.

**Objective**
The lectures deal mainly with the definition of urban design as an independent discipline, which maintains connections with other disciplines (politics, sociology, geography) that are concerned with the transformation of the city. The aim is to make students conversant with the multiple theories, concepts and approaches of urban design as they were articulated throughout time in a variety of cultural contexts, thus offering a theoretical framework for students’ future design work.

**Content**
In the first semester the genesis of the objects of study, the city, urban culture and urban design, are introduced and situated within their intellectual, cultural and political contexts.

01. The History and Theory of the City as Project
02. Of Rituals, Water and Mud: The Urban Revolution in Mesopotamia and the Indus
03. The Idea of the Polis: Rome, Greece and Beyond
04. The Long Middle Ages and their Counterparts: From the Towns of Tuscany to Delhi
05. Between Ideal and Laboratory: Of Middle Eastern Grids and European Renaissance Principles
06. Of Absolutism and Enlightenment: Baroque, Defense and Colonization
07. The City of Labor: Company Towns as Cross-Cultural Phenomenon
08. Garden Cities of Tomorrow: From the Global North to the Global South and Back Again
09. Civilized Wilderness and City Beautiful: The Park Movement of Olmsted and The Urban Plans of Burnham
10. The Extension of the European City: From the Viennese Ringstrasse to Amsterdam Zuid

**Lecture notes**
Prior to each lecture a chapter of the reader (Skript) will be made available through the webpage of the Chair. These chapters will provide an introduction to the lecture, the basic visual references of each lecture, key dates and events, as well as references to the compulsory and additional reading.

**Literature**
There are three books that will function as main reference literature throughout the course:


These books will be reserved for consultation in the ETH Baubibliothek, and will not be available for individual loans.

A list of further recommended literature will be found within each chapter of the reader (Skript).
Students are required to familiarize themselves with the conventions of architectural drawing (reading and analyzing plans at various scales).

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<th>Competencies</th>
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<tr>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories assessed</td>
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How can students of architecture become active agents of change? What does it take to go beyond a building's scale, making design-relevant decisions to the city rather than a single client? How can we design in cities with a lack of land, tax base, risk, and resilience, understanding that Zurich is the exception and these other cities are the rule? How can we discover, set rather than follow trends and understand existing urban phenomena activating them in a design process? The lecture series produces a growing catalog of operational urban tools across the globe, considering Governance, Social, and Environmental realities. Instead of limited binary comparing of cities, we are building a catalog of change, analyzing what design solutions cities have been developing informally incrementally over time, why, and how.

How did cities develop into the cities we live in now? Urban plans, instruments, visions, political decisions, economic reasonings, cultural inputs, and social organization have been used to operate in urban settlements in specific moments of change. We have chosen cities that exemplify how these instruments have been implemented and how they have shaped urban environments. We transcribe these instruments into urban operational tools that we have recognized and collected within existing tested cases in contemporary cities across the globe.

052-0707-00L Urban Design III

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<tr>
<td>052-0807-00L</td>
<td>History and Theory of Architecture V</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>P. Ursprung</td>
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</table>

How did cities develop into the cities we live in now? Urban plans, instruments, visions, political decisions, economic reasonings, cultural inputs, and social organization have been used to operate in urban settlements in specific moments of change. We have chosen cities that exemplify how these instruments have been implemented and how they have shaped urban environments. We transcribe these instruments into urban operational tools that we have recognized and collected within existing tested cases in contemporary cities across the globe.

This lecture series will introduce urban knowledge and the way it has introduced urban models and operational modes within different concrete realities, therefore shaping cities. The lecture series translates urban knowledge into operational tools, extracted from cities where they have been tested and become exemplary samples, most relevant for understanding how the urban landscape has taken shape. The tools are clustered in twelve thematic clusters and three tool scales for better comparability and cross-reflection.

The Tool case studies are compiled into a global urbanization toolbox, which we use as typological models to read the city and critically reflect upon it. The presented contents are meant to serve as inspiration for positioning in future professional life and provide instruments for future design decisions.

In an interview with a local designer, we measure our insights against the most pressing design topics in cities today, including inclusion, affordable housing, provision of public spaces, and infrastructure for all.

The learning material, available via https://moodle-app2.let.ethz.ch/ is comprised of:

- Toolbox 'Reader' with an introduction to the lecture course and tool summaries
- Weekly exercise tasks
- Infographics with basic information of each city
- Quiz question for each tool
- Additional reading material
- Interviews with experts
- Archive of lecture recordings
- Reading material will be provided throughout the semester.

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Building Process I

Objective
Alongside a discussion of the basic principles, trends and terminologies, a closer look will be taken at each topic using case studies that investigate current structures as well as those relevant in terms of architecture and urban design. Active participation as well as interdisciplinary and process-oriented thinking on the part of students is a prerequisite.

Content
The building process is the main focus of this lecture series. The process is understood as a sequence of criteria in time. Topics: Acquisition and building law, building economics and sustainability strategies, participants and their services, construction and planning organization.

Process thinking and a look at neighbouring countries complement the series.

Lecture notes
https://map.arch.ethz.ch

Prerequisites / notice
The ungraded semester performance consists of participation in the two exercises and the feedback.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management
Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation
Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Landscape Architecture I

Objective
The lecture series not only analyzes the results of anthropogenic nature design, but also discusses its various causes, contexts and consequences. Active participation as well as interdisciplinary and process-oriented thinking on the part of students is a prerequisite.

Content
The lectures in the fall semester course “History and Theory of Gardens and Landscape Architecture” provide an overview of the cultural history of nature, the landscape and the garden from its origins to the present day. An in-depth understanding of change as well as the design strategies and characteristics of the most important epochs and their current relevance will be discussed.

Lecture notes
Handouts and a bibliography will be provided

Prerequisites / notice
Bachelor students: The knowledge taught in the lecture and the exam-relevant literature provided by the lecturer serve as the basis for exam preparation. The course is designed as an annual program. As the written session exam tests knowledge from both the Landscape Architecture I and II lecture series, it is strongly recommended that you attend the course over two semesters. The examination topics will be announced shortly before the end of the semester. The lecturer will provide texts on the examination topics as pdf files for download. These serve to deepen understanding of the lecture.

Mobility students or students from other departments: Students who only attend the lecture for one semester complete the lecture with an end-of-semester oral examination. Here too, the lecturer provides literature relevant to the examination as a download.

Students registered for the exam will receive further information on the exam procedure by email shortly before the end of the semester.

Literature

Philip Ursprung, Der Wert der Oberfläche, Essays zu Kunst, Architektur und Ökonomie, Zürich, gta Verlag, 2017.
The lecture series does not provide instructions or recipes on general constructive topics. The description of distinctive, spatial experiences is fostered at the end of this one-year course, students will be able to estimate the impact of energy, GHG emissions and climate on a building. You will be able to independently apply the steps of an integrated design process to your own project and master selected tools from the A/S knowledge platform (https://moodle-app2.let.ethz.ch/course/view.php?id=11917). Future own designs can be supplemented and enriched with potentials from energy and climate analyses.

This annual course focuses on physical principles, concepts and methods for the efficient and sustainable heating, cooling and ventilation of buildings. Interactions of energy, GHG emissions and climate with architectural and urban design will be investigated.

Construction is the prerequisite for making an architectural, spatial idea tangible in the first place. The lecture series is fostered by showing countless possibilities of how an architectural, spatial idea can be understood and further developed through its material, its component of a holistic, coherent architecture and is derived from its architectural, spatial context on the basis of a broad selection of buildings.

Architectural Technology V

Construction is the prerequisite for making an architectural, spatial idea tangible in the first place. In this lecture series, it is understood as a component of a holistic, coherent architecture and is derived from its architectural, spatial context on the basis of a broad selection of buildings.

The lecture series does not provide instructions or recipes on general constructive topics. The description of distinctive, spatial experiences and the constructive measures used to achieve them, is rather intended to sharpen the students' awareness, for their own design work and to show countless possibilities of how an architectural, spatial idea can be understood and further developed through its material, its construction method and its supporting structure.

The buildings, which are described and explained in the lectures, differ fundamentally from each other in their time of origin, their urban context, as well as their geographical location and could hardly be more different in their scale and their use. These buildings are not a typical expression of their time and location, instead they are an expression of an individual creation and likewise use the constructive possibilities of their time and their environment in a distinctive way. Accordingly, each lecture is dedicated to a different architect. In addition, isolated current examples from professional practice will be shown. These lectures on new buildings, some of them unfinished, are given by an architect directly involved on site, in English, and partly online.

The slides of the lecture on the course moodle serve as lecture notes and are available as download.

The script will be made available in digital form at the end of the year to students enrolled in the lecture series.
Focusing on the theme of Shelter, the semester begins with a field trip to Rome, where we will visit and study selected historical examples. The second half of the semester will be dedicated to the design of an ideal shelter located in the Roman countryside. With these questions in mind, we will dedicate the coming studio in the series of Ideal Architecture to the development of a contemporary shelter.

But what is Shelter? Not just a protection from natural elements, a shelter also identifies the place of collective refuge in our society, a place of community and hospitality. This social value in turn influences the architectural form: be it inn or church, hut or temple, cave or hangar, the Shelter is as much primary dwelling as cultural place. The Shelter is Architecture.

But how do we protect our living space from increasingly harsh and unpredictable climatic events? How do we design resilient and durable structures? How to make the best use of the limited available resources? All these questions take us back to the roots of architecture, to the complex relationship between nature and civilization, to the human need of finding refuge in and from nature: Shelter.

In times of climate crisis and strong social transformation we find ourselves dwelling on unsettling questions: am I still safe in my place? Will there be room for everyone in the future? What is the minimum necessary to live? What does it take to foster an idea of community that is gradually disappearing? Within the discipline of architecture, such doubts and fears can be translated into fundamental design questions: how do we protect our living space from increasingly harsh and unpredictable climatic events? How do we design resilient and durable structures? How to make the best use of the limited available resources? All these questions take us back to the roots of architecture, to the complex relationship between nature and civilization, to the human need of finding refuge in and from nature: Shelter.

With these questions in mind, we will dedicate the coming studio in the series of Ideal Architecture to the development of a contemporary understating of Shelter, taking into consideration its connotation as both intimate and collective space, and its socio-cultural value: The Ideal Shelter - 7 new Types. Starting from historical examples, we will develop the basic architectural knowledge needed to tackle this challenging task in theory and practice. Primary questions of space, structure and tectonics, as well as the fundamental issues of proportion, form and meaning will be at the center of our design debate.

We will begin the design process for a new contemporary shelter with a field trip to Rome. We will visit, analyze and critically reflect on 7 shelters from different time periods. This will be followed by a visit to 7 sites outside of Rome. Here in the ideal (-ized) landscape of the Roman Campagna, the Ideal Shelter will find its place. As a studio we will collectively develop a culture of representation where multi-layered drawings and models, as well as the handling of historical references, will form the methodological basis for the design, which will primarily focus on typological, tectonic, and formal aspects.

The overall topic of the lecture series is “Construction – Elements of Architecture”. The lecture series gives the students an insight into different construction and design methods. The lectures are held by four different professorships in a block of 5 lectures in a row and showcasing their individual approach on design and architecture in general.
**Literature**

Lecture "Construction III":
Momoyo Kajjima:

Jan De Vylder:
Free to consult / not limited
- BRAVOURE SCARCITY BEAUTY – 9789082122572
- UNLESS EVER PEOPLE – ISBN 9789492567079
- GALLERY MAGAZINE N° 1 – ISBN 9789493146495
- PARTTIMEAMATEURTOURIST - INSTAGRAM

Emanuel Christ and Christoph Gantenbein:
- "Remaking Cities: Techning at ETH Zurich 2010 - 2013. Review No. II", Park Books, Zurich, 2022

Roger Boltshauser:
- Tschanz, Martin (2021): Roger Boltshauser, Monografie, Triest Verlag, Zurich.
- Höniger, Christian; Menti, Urs-Peter; et al. (2009): Das Klima als Entwurfsfaktor, Quart Verlag, Luzern.

**Prerequisites / notice**

Design Studio "Architectural Design III":
Group work.
Introduction:
Intermediate crits:
Final crits:

Lecture "Construction III":

**Competencies**

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**052-0543-24L Architectural Design III: House Behaviorology in Switzerland (M.Kajjima)**

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Students who do not wish to change the design class must not enrol.

Project grading at semester end is based on the list of enrolments on 30.10.2024 (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

**Abstract**

The overall topic of the lecture series is "Construction – Elements of Architecture". The lecture series gives the students an insight into different construction and design methods. The lectures are held by four different professorships in a block of 5 lectures in a row and showcasing their individual approach on design and architecture in general.
In the 2nd Year curriculum, three courses are related in design theory and design practice: "Konstruktion III" is design theory, "Konstruktion BUK III" is construction theory. "Architectural Design III" integrates the theories from the different courses including with them to apply architectural design in real-world problems.

Architectural Design III: House Behaviorology in Switzerland (M.Kaijima)

Typology and Research (4 weeks)
Each individual student
• is able to understand different housing typologies within their historical context. (2)
• is able to understand the principles of housing design, including topics such as Typology, Program, Usage, Privacy, Commonality, Material and Climate. (2)
• is able to independently gather information on a self-chosen topic (3)
• is able to analyze a case study house based on an individually formed question or individual interest. (4)
• is able to represent their analysis in a drawing and a short text. (3)

Structure and Space (4 weeks)
Each individual student
• is able to design a small-scale housing complex according to the above-mentioned principles. (3)
• is able to design spaces for privacy and for community. (3)
• is able to adapt a housing design to the needs of specific inhabitants with partially special needs, such as families and elderly. (3)
• is able to apply the principles of structural design to their housing design. (3)
• is able to critically evaluate a design and improve it. (5-6)
• is able to represent a design through floor plans, sections and elevations as well as with physical models (3)

Improving Design + Details and Construction (5 weeks)
Each individual student
• is able to detail a small-scale housing complex. (3)
• is able to understand the principles of construction. (2)
• is able to gather examples and evaluate them in accordance with their design (5)
• is able to evaluate and chose materials and construction in accordance with their design idea (5).
• is able draw a section of their design in scale 1:50 with all necessary details. (3)

Cognitive scale
(1) Remember
(2) Understand
(3) Apply
(4) Analyze
(5) Evaluate
(6) Create

https://ethz.ch/content/dam/ethz/main/eth-zurich/education/lehrentwicklung/files_DE/Vorlage_LernzieleFormulierenDe.pdf

Grading Criteria:
The submissions will be graded before each review. Each submission is graded according to the following criteria:
• Completeness and punctuality of submission
• Research method, the ability to find and analyze information
• Implementation of the concept of Architectural Behaviorology within the design
• Choice of Typology, Design and Expression of the project, in connection with the concept of Architectural Behaviorology
• Structural design, construction details and choice of materials in accordance with the design idea and the method of Architectural Behaviorology
• Visualization, the ability to communicate a design effectively with compelling drawings, models and text.
The final grade consists of the following partial grades:
• Mid review 1 submission (individual work): 30%
• Mid Review 2 submission (individual work): 30%
• Final Review submission (individual work): 30%
• "Construction III" submission (individual work): 10%

Lecture "Construction III":
Introducing students into different design and making approaches to find a path towards their personal approach on designing and making. Last day of lecture, students must bring construction drawing by a A5 sketchbook given at first lecture by design studio to submit the result of understanding of lectures. The presentation will be a large exhibition participated by all 2nd year students to share as exhibition by all 2nd year students. The result will be integrated in the grading of design studio.
Architectural Design III: House Behaviorology in Switzerland (M.Kaijima)

Architectural Behaviorology and Actor Network Theory are our two guiding principles to not only design architecture but also understand our current existing environment. By understanding a building, a house not as an isolated object but as a node in a vast and far reaching network, or several networks, we grow conscious of the impact, which or the city, the environment, the society. Vice-versa, analyzing and understanding the relationships, which have shaped existing buildings, helps us to better understand how and why the design of those buildings came to be. While identifying the relationship between actors within the network, we simultaneously observe the behavior of each actor as a result of their relationship. The behavior can be static or dynamic, actors can be human, non-human, animate or inanimate. How does a building behave towards its environment? What behavior do inhabitants engage in within and around a building? How do we have to design to take Behaviors of certain materials into account?

House and Housing is the base of our living environment and a diverse field in architecture. House behaviorology will set the challenge to find sustainable living condition in the city, by understanding historical examples and their geography, density, economic standing, and time period.

At first, to find the character and essence of today’s house and housing design in Ticino, we will start with analyzing existing single-family houses in and around the city. We will research and map how these basic units of housing relate to the users, to each other and to their surroundings. What kind of purposes they fulfilled and what kind of activities and behaviors do these houses enable?

Second, we will try to improve on the design by changing the single-family house into housing complexes, responding to the need of greater density, but still retaining the qualities of the original houses. Where do we find synergies, when combining houses? What kind of common spaces arise and how can we make use of them to make better neighborhoods?

Simultaneously we will have a close look on designing for inclusivity. How do we design for partially special needs groups, such as the elderly or children? How can we all live together in a house and in the urban ecology?

The course is structured as follow:

**Typology and Research (4 weeks)**
- Analyzing an existing single-family house in Ticino according to the principles of Architectural Behaviorology and the historical context of the said house.
- Defining a special interest for an element or relationship between elements of the chosen house and defining a question as a tool to better understand this field of interest.
- Representing the house and the research in a large-scale drawing and a short text.

**Structure and Space (4 weeks)**
- Designing a housing complex with a given program on the basis of the analysis of the case study single-family house.
- Evaluating and adapting the design constantly.
- Applying the principles of structural design to the design project.

**Improving Design + Details and Construction (5 weeks)**
- Constantly improving the design and sharpening the design idea.
- Detailing one section in the scale of 1:50 by applying the learned principles of construction and structural design as well as adding details in accordance with the principles of Architectural Behaviorology.

**Architectural Design III: House Behaviorology in Switzerland (M.Kaijima) Lecture Notes**

Each student will receive a printed reader, containing the basic information about the course, such as schedule, syllabus and other important information, as well as examples and references for the design task, and readings to support the theoretical framework of the course.

**Lecture "Construction III"**

Momoyo Kaijima:
- Jan De Vylder:
  - Free to consult / not limited
    - BRAVOURE SCARCITY BEAUTY – 9789082122572
    - UNLESS EVERY PEOPLE – ISBN 9789492567079
    - GALLERY MAGAZINE N° 1 – ISBN 9789493146495
    - PARTTIMEAMATEURTOURIST - INSTAGRAM
  - Emanuel Christ and Christoph Gantenbein:
- Roger Boltsbauer:
- Tschantz, Martin (2021): Roger Boltsbauer, Monografie, Triest Verlag, Zürich.
- Höniger, Christian; Menti, Urs-Peter; et al. (2009): Das Klima als Entwurfsfaktor, Quart Verlag, Luzern.

**Prerequisites / notice**

Architectural Design III: House Behaviorology in Switzerland (M.Kaijima)

To attend this course, students have to enroll through the "Enrolment in the Design Studios of D-Arch"-page: (www.einschreibung.arch.ethz.ch).

The design studio is structured as a year-long course. The submissions during the autumn semester will be individual work.

**Schedule Autumn Semester 2024:**
- Introduction:
- Mid Review 1:
- Mid Review 2:
- Final Review:

**Costs:** ca. CHF

**Location:**

Lecture "Construction III":

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 85 of 2653
Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

**Social Competencies**
- Communication: assessed
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Research and development of architectural themes resulting from energy and climatic considerations
- Practical work with models, plans and visualization programs as part of the design process

**Architectural Design III: Material and Light**

***W 14 credits 2V+14U***

(R.Boltshauser)

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Students who do not wish to change the design class don’t have to participate in the internal enrolment.

Project grading at semester end is based on the list of enrolments on 30.10.2024, 24:00 h (valuation date) only. This is also the ultimate deadline to unsubscribe or enroll for the studio.

**Abstract**

In the autumn semester, we will approach the phenomenon of space through fundamental experiences with regenerative materials and «Nordic Light» to design a cultural centre on Louis Kahn’s home island of Saaremaa in Estonia.

In the spring semester, we work on the redensification of an industrial wasteland in Brunnen (CH) and focus on the themes of structure and place.

**Objective**

Semester topic “Design III”:
- Addressing dense, sustainable, circular, simple building
- Development of a broad theoretical basic
- Holistic design of spatial atmospheres in the interplay of concept, context, construction, climate, sustainability and materiality
- Practical work with models, plans and visualization programs as part of the design process

Lecture “Construction III”:
Introducing students into different design and making approaches to find a path towards their personal approach on designing and making.

**Content**

Semester topic “Architectural Design III”:

(...)

Lecture “Construction III”:
The overall topic of the lecture series is “Construction – Elements of Architecture”. The lecture series gives the students an insight into different construction and design methods. The lectures are held by four different professorships in a block of 5 lectures in a row and showcasing their individual approach on design and architecture in general.

Lecture notes

The students will receive a reader at the beginning of the semester.

**Literature**

Semester topic “Architectural Design III”:

tbd

Lecture “Construction III”:

Momoyo Kaijima:

Jan De Vylder:
Free to consult / not limited
- 3 BOEK 789 – ISBN 978942321749
- BRAVOURE SCARCITY BEAUTY – 9789082122572
- LESSV NEVER PEOPLE – ISBN 9789492567079
- GALLERY MAGAZINE N° I – ISBN 9789493146495
- PARTTIMEAMATEURTROUS – INSTAGRAM

Emanuel Christ and Christoph Gantenbein:

Roger Boltshauser:
- Tschanz, Martin (2021): Roger Boltshauser, Monografie, Triest Verlag, Zürich.
- Boltshauser, Roger; Veillon, Cyril; Mailiard, Nadja (2020): Pié, Stampflehmbau – Tradition und Potenzial, Triest Verlag, Zürich.
- Höniger, Christian; Menti, Urs-Peter; et al. (2009): Das Klima als Entwurfsfaktor, Quart Verlag, Luzern.
Prerequisites / notice

Lecture "Construction III":
tbd

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management fostered

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection assessed
Self-direction and Self-management fostered

052-0547-24L Architectural Design III: Topic (J.De Vylder)

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).
Students who do not wish to change the design class must not enrol.

Project grading at semester end is based on the list of enrolments on 30.10.2024 (valuation date) only.
This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract
Do we live a house?
Or do we house a life?
How. Do. We. Live.
Do we know HOW we live? Do we know enough about HOW we live? HOW do things around us shape the way we live? HOW do we live the things around us? WHAT are the conditions around us? WHAT makes our habits? HOW do habits change conditions?
Objective
With sets of questions, we will question
HOW TO house a life?
HOW TO cook?
HOW TO bath?
HOW TO rest?
HOW TO move?
HOW TO eat?
HOW TO plant?
HOW TO clean?
Combined with
WHAT IS
WHAT IS wood?
WHAT IS steel?
WHAT IS stone?
WHAT IS ceramic?
WHAT IS glass?
WHAT IS earth?
WHAT IS concrete?
Lined out with
WHERE IS
WHERE IS the window?
WHERE IS the stool?
WHERE IS the tree?
WHERE IS the stove?
WHERE IS the sink?
WHERE IS the lamp?
WHERE IS the door?
And never without
WHAT ABOUT
WHAT ABOUT the norm and the normative?
WHAT ABOUT the size and the scale?
WHAT ABOUT the place and the space?
WHAT ABOUT the individual and the common?
WHAT ABOUT the culture and the society?
WHAT ABOUT the weather and the atmosphere?
WHAT ABOUT the speed and the urge?
These sets of questions will guide us through the semester and form SETTINGS, SCENOGRAPHIES and SEQUENCES.
Is the way we cook defining the space or is our space changing the way we cook? Is taking a bath a matter of physical cleaning or might it also be a matter mental health?
Do we sleep to rest or is the bedroom also a place to read, to play, to meet? Can space be more than circulation? What do you store, where do you hide? What is an office at home? What is work at all?

Content
0 + 3 + 13
This studio will be organized in 0 + 3 + 13 movements. Movement 0, 1, 2 and 3 will last 3 weeks. Movement 13 will last 1 week.
During Movement 0, students will question, travel, draw, and collect from the activities of Universum Carousel Journey.
Movements 1, 2 and 3, students will work in groups of 3. These 3 students become a practice. The practice will be assigned a set of 2x HOW TO and 1x WHILST, that they will freely combine with 1x WHAT IS, 1x WHERE IS and 1x WHAT ABOUT. They will work in the form of settings, scenographies and sequences for 3 weeks.
In the next movement group members and assigned sets of questions change again. Each movement will be another group constellation of students. We study 3 times a combination of questions. All together we will by that collect an endless series of configurations of topics. The Movement 13, will be an individual movement of questioning, connecting M0, M1, M2 and M3 all together into sets of questions that will be presented in the last week as a ground for a collective discussion.
Literature

- Momoyo Kaijima:

- Jan De Vylder:
  - Free to consult / not limited
  - BRAVOURE SCARCITY BEAUTY – 9789082122572
  - UNLESS EVER PEOPLE – ISBN 9789492567079
  - GALLERY MAGAZINE N° I – ISBN 9789493146495

- Emanuel Christ and Christoph Gantenbein:

- Roger Boltshauser:
  - Tschanz, Martin (2021): Roger Boltshauser, Monografie, Triest Verlag, Zurich.
  - Höng, Christian; Menti, Urs-Peter; et al. (2009): Das Klima als Entwurfsfaktor, Quart Verlag, Luzern.

Prerequisites / notice

Lecture "Construction III":

Competencies

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Architectural Design (from 5. Semester on)

Number | Title | Type | ECTS | Hours | Lecturers |
---|---|---|---|---|---|
052-1107-24L | Design Studio V-IX: Landscape Architecture Studio | W | 14 credits | 16U | M. Voser |

Abstract

RETHINKING LANDSCAPE STRUCTURES

Objective

DESIGNING LANDSCAPES AND PROCESSES

The primary goal of the studio is to project landscapes. This entails the constant oscillation between territorial relationships and local actions - between landscape space and place.

THINKING IN SYSTEMS

Due to the dynamics of their constituent elements such as soil, water and vegetation, landscapes change their dimensions and character with cycles and time. Designing landscape consequently means thinking in and designing systems and processes.

DEVELOPMENT OF A LANDSCAPE VOCABULARY

‘Reading’ a landscape, its space-defining elements – like water, topography and vegetation – and the processes and forces that shape them is as much a focus of teaching as designing. Thus, an intensive examination of our understanding of landscape and our relationship to nature goes hand-in-hand with the semester.

METHOD TO DESIGN FROM AND WITH PROCESSES

Because of the complexity of territory and task, the iterative design method is followed, oscillating between designing and analyzing, and between large and small scales. Developing an attitude, crystallizing the specific themes, and choosing the appropriate design tools are as much a part of the work process as designing the transformation processes.

Content

PROTOTYPICAL CASE STUDIES ON THE CLIMATE ADAPTATION OF THE SWISS LANDSCAPE

Based on specific issues such as landslide risks or planned tunnel projects, new innovative ways of dealing with natural events and infrastructure projects are designed - always in search of multi-layered added value for people, flora and fauna.

Parallel to the landscape design, the students get to know landscape architecture as one of the instruments with which today's questions can be answered. Because these increasingly demand different answers - systemic thinking, designing processes, accepting change and a differentiated landscape vocabulary are prerequisites for this.

Prerequisites / notice

Integrated Discipline: Landscape and Urban Studies (LUS)
### Competencies

#### Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Media and Digital Technologies
- Problem-solving
- Project Management

#### Method-specific Competencies
- Analytical Competencies
- Decision-making
- Project Management
- Media and Digital Technologies

#### Social Competencies
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity

#### Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

### Prerequisites / notice
- Group work only
- Introduction:
- Final crits:
- Extra costs: Approx. CHF xxx.-- per student (estimated costs, without possible seminar week costs)

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<th>16U</th>
<th>A. Fonteyne</th>
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###_notes_

- Group work only.
- Introduction:
- Final crits:
- Extra costs: Approx. CHF xxx.-- per student (estimated costs, without possible seminar week costs)

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- Introduction:
- Final crits:
- Extra costs: Approx. CHF xxx.-- per student (estimated costs, without possible seminar week costs)

###_notes_052-1131-24L

- Group work only.
- Introduction:
- Final crits:
- Extra costs: Approx. CHF xxx.-- per student (estimated costs, without possible seminar week costs)

###_notes_052-1113-24L

- Group work only.
- Introduction:
- Final crits:
- Extra costs: Approx. CHF xxx.-- per student (estimated costs, without possible seminar week costs)
the ultimate deadline to unsubscribe or enroll for the studio.

Prerequisites / notice

Group work only.

Introduction:
Intermediate crit:
Final crits:
Extra costs: Approx. CHF xxx per student.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Method-specific Competencies
- Techniques and Technologies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

052-1125-24L
Architectural Design V-IX: Topic (E.Mosayebi)

W 14 credits 16U E. Mosayebi

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrolments on 30.10.2024 (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Prerequisites / notice

Building Construction (BUK) as an integrated discipline is included in this course.

Introduction:
Intermediate crits:
Final crits:
Extra costs: CHF xxx per student. (Approximation, excl. Material for Model Building, excl. Seminar Week)

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Method-specific Competencies
- Concepts and Theories
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

052-1119-24L
Architectural Design V-IX: Topic (A.Brandlhuber)

W 14 credits 16U A. Brandlhuber

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrolments on 30.10.2024 (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Prerequisites / notice

Building Construction (BUK) as an integrated discipline is included in this course.

Introduction:
Intermediate crits:
Final crits:
Extra costs: approx. CHF xxx.--. per student (estimated costs, without possible seminar week costs)
## Competencies

### Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

### Method-specific Competencies
- Analytical Competencies fostered
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving fostered
- Project Management fostered

### Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered

### Personal Competencies
- Negotiation fostered
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered

### Competencies

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## Prerequisites / notice

### Architectural Design V-IX: Topic (H.Klumpner)
- Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).
- Project grading at semester end is based on the list of enrolments on 30.10.2024 (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

### Architectural Design V-IX: The End of...
- Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).
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W 14 credits 16U F. Persyn

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Prerequisites / notice

Introduction:
Intermediate crits:
Final crits:

CHF 150,- per student (estimated costs, without possible seminar week costs)

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W 14 credits 16U A. Holtrop

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Abstract
To be specified.

Objective
Qualification to control the design process increasingly independent and with sole responsibility and to find to an individual design methodology and attitude.

Content
To be specified.

Prerequisites / notice
To be specified.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

Personal Competencies
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- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Leadership and Responsibility: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: fostered

Abstract
"Italian may be "such children" but their tar-babies are not physical pain or coldness; they want an absence of history, they want to start fresh. When they designed those big palaces in Rome they must have known all along about hope and death, but they were so graceful they made it look easy."

Objective
METHODOLOGY
1. Conduct a survey based on the objective observation of Rome; Driven by the choice of an Agent, map out a singular path within the city; Consider the subjectivity of experience and extrapolate multiple storylines.
2. Develop a project addressing a specific problematic: formulate a critical comment onto a contemporary condition; Intensify the experience to reveal further potentials.
3. Elaborate an argumentative discourse, supported by a curated selection of multidisciplinary sources.

INCENTIVES
Drafting & Mounting
Conceptual & Critical Thinking
Argumentation & Rhetoric
Narration & Storytelling
Scenography & Atmosphere
Expression & Composition

SKILLS
Researching Contemporary Concepts & Curating multidisciplinary Sources; Articulating a discursive Argument; Mastering Visual Literacy & Storytelling, Image Mounting & Composing, Architectural Drafting & Projecting.

Content
PATHFINDER 3 is dedicated to the timeless city of Rome: its intricate history, morphology, mythology… all canonical spatial perimeters as suggested by Lefebvre: political, sociological, anthropological, economical, temporal.*

Our interest will focus both on the banal and the sublime, on habits, routines, and calendar rites as well as on individual and social rhythms setting the pace for society. As the ordinary interweaves thousands of beats, repetitive tunes and syncopated breaks, there can be no territoriality without its temporalities, may it be that of urbanisation, of experience, or of dreams.

The critical consideration of these paragons, further endowed with the lure of fiction, shall initiate alternate (hi)stories and cityscapes.

The design studio will be carried out in collaboration with the Faculty of Game Design of the Zurich University of the Arts (ZHdK). Together we will draft, mount, design, discuss, play… confront our perspectives onto contemporaneity and ultimately imagine audacious yet playful architectural and territorial fictions.

A series of lectures by experts from a variety of fields will enrich our investigations.

*see: Lefebvre, Henri. The Production of Space (1974)
—. Rhythmanalysis: Space, Time and Everyday Life (1992)

Lecture notes
Semester Reader will be made available as a download for registered participants.
Extended bibliography and further references will be made available as a download for registered participants.

**Prerequisites / notice**

Introduction: SEPT. 19TH
Mid-Term Reviews: OCT. 17th
Final Reviews: DEC. 19th-20th

Group Work only
Main Teaching Language: EN
LV-No. 052-1145-23U
Reader CHF 30 + Prints 50 CHF

For more information, please contact: dedardel@arch.ethz.ch

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### Social Competencies

| Communication                   | assessed              |         |
| Cooperation and Teamwork        | assessed              |         |
| Self-presentation and Social Influence| fostered |         |
| Sensitivity to Diversity        | fostered              |         |
| Negotiation                     | fostered              |         |

### Personal Competencies

| Adaptability and Flexibility    | assessed              |         |
| Creative Thinking               | assessed              |         |
| Critical Thinking               | assessed              |         |
| Integrity and Work Ethics       | assessed              |         |
| Self-awareness and Self-reflection | assessed |         |
| Self-direction and Self-management | assessed |         |

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**052-1147-24L Architectural Design V-IX: (M.Topalovic)**

Does not take place this semester.<br>Please register ([www.mystudies.ethz.ch](http://www.mystudies.ethz.ch)) only after the internal enrolment for the design classes (see [http://www.einschreibung.arch.ethz.ch/design.php](http://www.einschreibung.arch.ethz.ch/design.php)).

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### Social Competencies

| Communication                   | fostered              |         |
| Cooperation and Teamwork        | fostered              |         |
| Self-presentation and Social Influence| fostered |         |
| Sensitivity to Diversity        | fostered              |         |
| Negotiation                     | fostered              |         |

### Personal Competencies

| Adaptability and Flexibility    | fostered              |         |
| Creative Thinking               | fostered              |         |
| Critical Thinking               | fostered              |         |
| Integrity and Work Ethics       | fostered              |         |
| Self-awareness and Self-reflection | fostered |         |
| Self-direction and Self-management | fostered |         |

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### Abstract

The semester will focus on space as the language of architecture. Real-life constraints, requirements and disciplines will found the basis for the research in the form of fast-pace design exercise

### Objective

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### Content

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### Prerequisites / notice

Individual and group work
### Competencies

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#### 052-1151-24L  
**Architectural Design V-IX: (Student-led Teaching F. Persyn)**

- **W** 14 credits 16U  
- F. Persyn

**Does not take place this semester.**

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrollments on 30.10.2024 (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

### Abstract
To follow

### Objective
To follow

### Content
To follow

### Prerequisites / notice
To follow

#### 052-1105-24L  
**Architectural Design V-IX: Topic (J. De Vylder)**

- **W** 14 credits 16U  
- J. De Vylder

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrollments on 30.10.2024 (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

### Abstract
This studio work on the idea of PRAC-TEACH. How PRACTICE and TEACHING relates.

A PRACTICE OF THE SCHOOL lends 3 projects available for CHANGE – OBSERVATION – REFLECTION – IMAGINATION.

This studio will be held 7 semesters, each HS.

For the PILOT SEMESTER the PRACTICE BEHIND will be ours.

### Objective
This studio will be a small studio and will work in groups of 3 students.

One of 3 built projects will be allocated to each group by lottery.

The studio is divided in 3+1 movement: 9 weeks of collective work + 3 weeks of individual imagination.

3 review MOMENTS will take place and we will invite guests to share their knowledge supporting each project.

A study trip to Belgium has been planned. We will visit the 3 venues chosen for our semester Saturday 30.09 and Sunday 01.10.

### Content
The case study ROT-ELLEN-BERG, CARITAS, CHAPEX give perspective to housing, care and culture; private, shared and public; urban, suburban and rural.

### Prerequisites / notice
Individual and group work, including 5 or more weeks of group work.

- **Introduction:**
- **Intermediate crits:**
- **Final crits:**

**CHF xx.-- per student (estimated costs, without possible seminar week costs)**

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#### 052-1111-24L  
**Architectural Design V-IX: Japan Studio (GD W. Doi/Y. Iwata/C. Konno)**

- **W** 14 credits 16U  
- C. Konno, W. Doi, Y. Koizumi

Data: 15.06.2024 12:39  
Autumn Semester 2024  
Page 97 of 2653
The Japan Studio assignment is to design a tearoom as an extension of the cafe on the Hönggerberg campus and to assemble the structure using construction waste. Students will be challenged to reinterpret Japanese wooden architecture, which established a sophisticated circular economy, in the context of contemporary Switzerland, and to create a new architectural philosophy and technology.

The studio is divided into three phases. The competencies to be acquired in each phase are as follows.

1st Phase: Building Elements Study (4 weeks)
- understanding of basic principles of building construction
- creation method by interpreting existing building elements
- craftsmanship skills in working with building elements

2nd Phase: Designing ‘Tearoom’ (4 weeks)
- ability to read the context of the surroundings
- planning ability to mediate conflicting demands
- conceptual ability to find an extraordinary space in an everyday space
- ability to design a distinctive form with an intimate space

3rd Phase: Building ‘Tearoom’ using Construction Waste (5 weeks)
- understanding of basic materials and processing methods with construction waste
- ability to select appropriate materials, details, and processing methods
- ingenuity in construction, such as jigs for processing and assembly
- teamwork ability

Objective
The studio is divided into three phases. The competencies to be acquired in each phase are as follows.

1. Understanding of basic principles of building construction
2. Creation method by interpreting existing building elements
3. Craftsmanship skills in working with building elements

2. Ability to read the context of the surroundings
3. Planning ability to mediate conflicting demands
4. Conceptual ability to find an extraordinary space in an everyday space
5. Ability to design a distinctive form with an intimate space

3. Understanding of basic materials and processing methods with construction waste
4. Ability to select appropriate materials, details, and processing methods
5. Ingenuity in construction, such as jigs for processing and assembly
6. Teamwork ability

Content
The Japan Studio was established to exchange architectural culture between Japan and Switzerland in a contemporary context to look for new architectural answers to the sustainability issues that have rapidly become common world problems. In the Fall 2023 semester, a practical design studio will be conducted spanning architectural design and construction.

The task is to design a tea room as an annex of the Alumni Lounge at the Hönggerberg campus, and to assemble the designed building (or parts of it) using construction waste materials, referring to the Japanese architecture in the early modern period.

Because Japan was under a national isolation system in the early modern period, a sophisticated circular economy was established. The architecture then had been developed as a technological system that allowed for the reuse of materials as a matter of course. In addition, the influence of Zen culture led to the development of design techniques, such as “borrowed scenery” that harmonized and sublimated the surrounding scenery with the architectural space.

Such architectural thinking unique to early modern Japan must be helpful for modern architecture, which faces significant challenges such as the finite nature of resources and the chaos of urban landscapes. Students will challenge themselves to reinterpret the ideas of Japanese architecture developmentally in the context of contemporary Switzerland, and to create the germ of a new architectural philosophy and technology that will be required in the coming age.

Site and Building to Be Designed:
The site is located around the Alumni Lounge of the Hönggerberg campus, where we will design a tea room / Lounge furniture as an extension to the cafe. We want it to be a special and intimate place to spend special time with friends or guests invited to the university. The design will consist of tea spaces of no more than 10 square meters deployed inside and outside of the cafe. The tea room will be realised, in cooperation with the operators of the Alumni Lounge.

Studio Configuration:
Japan Studio consists of three phases. Students will develop comprehensive architectural skills spanning history, design, and construction through these phases.

1st Phase: Building Elements Study (4 weeks)
In the first phase, students will learn about demolished buildings that provide waste materials to be reused, and will be trained to open up the characteristics of the waste materials to new architectural possibilities. Specifically, students will research the history and industrial background of the demolished building (Huber Pavilions), as well as create a full-scale portion of a building element using the waste materials.

2nd Phase: Designing ‘Tearoom’ (4 weeks)
In the second phase, students will learn about Japanese tearooms and spatial design, and design a "new tearoom" as an extension to a small café on the ETH premises.

While learning about the design concepts of "having a small but rich world", "feeling enclosed and connected", and "finding resources in a limited environment", all of which are common to tearoom architecture, students will observe the issues and potential attractions of the target site and how to find resources in a limited environment through the design of small architectural interventions. Final deliverables will include a presentation to the cafe operators.

3rd Phase: Building ‘Tearoom’ using Construction Waste (5 weeks)
In the third phase, students will produce the designed tearoom at 1/1 scale through group work and learn about the characteristics of basic materials such as wood, metal, and resin, as well as processing and joining methods. Students will be using dry construction methods that do not use adhesives, using details that will not wear off during assembly and dismantling. In order to realize the conceived space, technical invention from both form and material is required.

Lecture notes
Each student will receive a printed reader, containing the basic information about the course, such as schedule, syllabus and other important information, as well as examples and references for the design task, and readings to support the theoretical framework of the course.
Abstract
This studio works on the idea that a substantial understanding of today’s technology (internet of things, big data, machine intelligence ...) changes the perspective to architectural theory and will result in different architectural designs and building constructions.

Objective
1) Identification and understanding of the challenges of today’s technologies;  
2) techniques of working within the plenty of the internet; 
3) a methodology to design digital architectures; 
4) an understanding of the shift from hard building construction to soft building applications, and 
5) an understanding of the importance of becoming a literate digital persona in order to be an architect today.

Content
METEORA #09 will use artificial intelligence to write a text to explicate a precise position in today’s world, to create a spectrum of images to reflect this world and design an architectural artefact which brings things into adequate proportions

Prerequisites / notice
Individual work only

Introduction: Intermediate crits; Final crits:

052-1109-24L Architectural Design V-IX: Topic (L.Hovestadt)

W 14 credits 16U L. Hovestadt, J. Orozco Esquivel

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www. einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrolments on 30.10.2024 (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.


W 14 credits 16U F. Gramazio, M. Kohler

Autumn Semester 2024
This semester we will design an extension to the Swiss Institute in Rome. This consists of Villa Maraini, located in the middle of an elevated park, and an outbuilding integrated into the perimeter wall of the property. This outbuilding, the so-called “Dipendenza”, is to be extended in height and will consequently have its own presence in the park. The addition will house contemporary spaces for individual and collective work, workshops, and meeting places for interdisciplinary exchange among the Institute’s guests.

We do not presume any prior knowledge of Rhinoceros or Grasshopper. We will introduce the necessary methods and will rehearse them together.

- We learn to computationally design with the parametric tool Grasshopper in Rhino
- We learn how to develop and explore our projects with virtual reality
- We learn how to develop and explore our projects with virtual reality
- We produce orthogonal representations of the project. We will generate plans and sections using horizontal and vertical section planes on the 3D model. This allows us to efficiently and interactively present abstractions necessary for understanding the spatial relationships.

The possibility to present the designs in the Immersive Design Lab using a room-filling projection and to immerse with VR goggles requires new forms of presentation, which we will explore together.

- We learn how to develop and explore our projects with virtual reality
- We learn to computationally design with the parametric tool Grasshopper in Rhino
- We present our projects interactively in the Immersive Design Lab

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- We present our projects interactively in the Immersive Design Lab

The official language in our studio is German. Table critiques can also take place in English. Lectures and project meetings can also be held in English depending on our guests.

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- We present our projects interactively in the Immersive Design Lab
In Switzerland, official data shows that nowadays the burdens of child-rearing still predominantly fall upon women, with 70 percent expressing concerns that having a child will impact on their careers. There are a myriad of reasons for the country’s declining birth rates – for instance a stronger focus on women’s careers, challenging socio-economic conditions, and the availability of contraception – and architecture is one of them: urbanisation leading to smaller living spaces and the dispersion of support networks, the scarcity of nearby public care facilities, and the lack of adequate spaces for shared forms of care beyond the domestic sphere of the nuclear family. Public relief, despite being remarkably generous in comparison to other countries, is still insufficient: fertility treatments like IVF are not covered by insurance – while three percent of children born were conceived in vitro – child care costs are only partially subsidised, etc. Unsurprisingly, people who can become pregnant are having less and less children and, if so, much later in their life. In this context, what can the role of architecture be?

In this design course, we will imagine architectures that support alternative reproduction practices at different stages, from fertility treatments to upbringing. Speculating with new programmes and institutions, we will design collective spaces that promote and visualise shared forms of reproductive care. In the present context, the division between productive and reproductive labour, the spaces it takes place in, and the bodies that carry it out, are once again being reshaped. The limits of the domestic are blurring, the home is no longer necessarily a space for care; instead, it is a transient, productive, and networked space. On the other hand, public and collective spaces can shelter former domestic activities and become spaces for care through different bodies (human and non-human), technologies, and strategies at multiple scales.

Addressing architecture from the urban to the body, the course aims to develop a comprehensive understanding of the relationship between design and reproduction in Switzerland. We will understand dependency as a positive kin, and propose programmes and spaces that support sharing reproductive labour in transversal ways. This realignment can contribute to generating new forms of balance, ones in which we stop “caring for” and start “caring with” as a form of interdependence. We will look at the body – its spaces, contexts and rituals – as a starting point for an architectural and aesthetic proposal at multiple scales. The students will be asked to design avoiding former forms of spatial oppression and exploitation and, instead, explore the paths of otherness, wildness, diversity, complexity, and the impractical. The final objective is to propose institutions providing inclusive spaces for reproductive futures based on collective kinship.

This semester, the Design Studio (14KP) is offered in conjunction with an integrated design-build seminar week in Davos (2KP) on the Schatzalp and the elective 052-0911-24L Repair: Keep in Place (2KP) as a heritage-led teaching project. To take part in the required 052-0911-24L Repair: Keep in Place you must register separately. You will be automatically enrolled for the seminar week when you join the design studio.

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrolments on 30.10.2024 (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract
Building Construction (BUK) as an integrated discipline is included in this course.

Please register (www.mystudies.ethz.ch) only after the...
The course deals with spatial phenomena at the interface of film and architecture. The alternating influence of these two media will be fostered.

**Prerequisites / notice**
Building Construction (BUK) as an integrated discipline is included in this course.

Introduction:
Intermediate crits:
Final crits:
Extra costs: CHF xxx per student. (Approximation, excl. Material for Model Building, excl. Seminar Week)

**E lectives and Focus Works**

**E lectives**

**D esign and Architecture**

### Electives

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<td>CAAD Theory: Epic Encounters - Telling Stories from the Vectorial World</td>
<td>W</td>
<td>2 credits</td>
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<td>L. Hovestadt</td>
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**Abstract**
The ubiquity of neural nets calls on architects to explore the vectorial world they index. After introducing participants to basic concepts of coding and machine learning, this course invites them to inventively explore hidden connections among vectorized digital objects.

**Objective**
- Familiarizing participants with Wolfram Mathematica as an agile coding laboratory and theoretical ideas related to the digital/vectorial world.
- Inviting participants to work with pre-and self-trained machine learning models to play among millions of digital objects.
- Supporting participants in strengthening their storytelling and presentation skills across different media.

**Content**
The first phase of the course, CODING, offers entry points to coding literacy as well as related theoretical literature without attempting exhaustive coverage: using Wolfram Mathematica, participants will get familiar with functional programming, including importing and exporting data, organizing it into data structures, writing simple functions and encoding and decoding digital objects into and from vectors.

In the second phase, INVENTING, participants are given access to a multi-modal corpus, an inventory containing millions of digital objects pertaining to different media – scans, sounds, samples and sentences – and a series of bespoke functions in Wolfram Mathematica. Aided by machine-learning algorithms, participants will join characteristic collections of digital objects into a story a character might tell. These collections can be based on authors, inviting participants to further engage with theoretical ideas. In the third phase, STAGING, participants will focus on bringing these stories to life through a deliverable in their chosen format, accompanied by weekly tutorials.

**Method-specific Competencies**
- Support participants in strengthening their storytelling and presentation skills across different media.
- Inviting participants to work with pre-and self-trained machine learning models to play among millions of digital objects.

**Social Competencies**
- Analystical Competencies
- Decision-making
- Media and Digital Technologies

**Personal Competencies**
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection

**052-0513-24L** Spatial Concepts in Film and Architecture

**Abstract**
The course deals with spatial phenomena at the interface of film and architecture. The alternating influence of these two media will be analyzed, the dispositions of perception and effect will be compared and thus will sharpen the view for a architectural way of looking at space.

**Objective**
The examination of filmic space situations and performance discloses new perceptions of architecture which will be studied on behalf of film analyses and experimental topics. During the course space-effective creative means such as editing or framing will be introduced and discussed under perceptive aspects. Mediality within spatial perception can thus be integrated into a development of cultural history and leads towards a conception which goes beyond the limits of architecture and stimulates new processes of design.

**Content**
New perceptions of architecture are studied on behalf of film analyses and experimental topics. During the course space-effective creative means such as editing or framing will be introduced and discussed under perceptive aspects. Mediality within spatial perception can thus be integrated into a development of cultural history and leads towards a conception which goes beyond the limits of architecture and stimulates new processes of design.

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Analytical Competencies

Subject-specific Competencies

- Concepts and Theories
- Analytical Competencies
- Decision-making
- Specific Competencies
- Communication
- Sensitivity to Diversity
- Negotiation
- Personal Competencies
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

Lecture notes

The students will receive a reader at the beginning of the semester.

Archives of the Living

Abstract

This course intends to use different techniques of recording and research to capture a special and important time in the history of Zurich between the late 1970s and the early 1980s. The documents that each student produces will be test of how to communicate and archiving specific topics of this time.

Objective

- The students will engage with existing archives, but will ask new questions in order to extend the received meanings of the material
- The students will use photographic and video recordings to represent the sites that we are studying
- This material will be assembled into small documents that communicate specific topics from the main theme

Content

Zurich between the late 1970s and the early 1980s was a city where urban activism, punk and a nascent contemporary art scene came together in an explosive way. Inspired by other scenes, in say London and New York, what was special in Zurich was how intermingled the members of the different scenes were and how influential they would become for the future shape of the city. This must have something to do with the scale of the city and how intertwined its society is.

Independent of official policies and large capital investments, it was the ideas and the participants of these times that has given shape, for better and for worse, to contemporary Zurich. This course will begin to engage with the stories, the people, and the artefacts of that time. Drawing on the holdings of existing social archives in the city, but also engaging through photography and writing, we will begin to construct an archive of the living for Zurich.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking

BUK Re-Detailing

Abstract

Remodeling and reuse is the order of the day. This should be learned (again). In this elective course we construct with what we find. We examine what influence sustainability has on the development process and the perception of the buildings, what new architectural language they have in store for us and what processes are taking place in the background. All students write their own short text. Over the course of the semester, they continuously revise their text and reflect on what they have written with feedback from their teachers and fellow students. The focus does not lie on the finished text, but on sharpening and at the same time constantly questioning their own attitude and continuously reflecting on what they have written.

Objective

- Using text as a way of approaching questions on climate-relevant architecture.
- Reflection on one's own role as an architect in the architectural discourse, in relation to the climate crisis and in the changing professional field.

Content

How do we find a new architectural form and thus a new language in a time where everything is changing rapidly – and must change? The issues of ecological sustainability in particular are causing fundamental changes in the field of architecture and in our understanding of the profession. How does writing serve us as a means of approaching an architectural language that remains relevant in this environment? In the best sense, writing forces us to take a stance.

Over the course of the semester, all students explore several buildings. Through writing, they try to find out what it contributes to finding new forms for architecture in the climate crisis. We examine what influence sustainability has on the development process and the perception of the buildings, what new architectural language they have in store for us and what processes are taking place in the background. All students write their own short text. Over the course of the semester, they continuously revise their text and reflect on what they have written with feedback from their teachers and fellow students. The focus does not lie on the finished text, but on sharpening and at the same time constantly questioning their own attitude and continuously reflecting on what they have written.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
Practice-oriented seminar on the topic of analog & artistic photography

Objective: Instructed by Nicolas Rolle, the seminar serves as an introduction to analog experimentation in the creative process of artistic practice. By analyzing the motifs and ways of thinking of photographers, the aim is to develop a basic approach to the medium of photography and to expand practical work in the darkroom through theoretical questions about the medium.

Content: Theoretical and practical introductions form the core of the targeted exploration of the photographic apparatus. Students are encouraged to gather their own experiences in analog experiments and to explore the urban space and their surroundings with the camera. With an artistic work developed over the semester, the expanded concept of photography will be sharpened and brought to an individual expression.

Prerequisites / notice: Lecturer approval required for all students. Please send a letter of motivation (max. 300 words) to rolle@arch.ethz.ch by 05.09.2024. The number of participants is limited to 20. The course will be held in German in the Fall Semester 2024.

Participants pay CHF 25.00 for the materials required in the course.

Competencies

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052-0579-24L Understanding Light W 2 credits 2S R. Barba, P. Anantha Murthy

Abstract: The seminar explores light from the perspectives of Physics and Art, opening up new dimensions for collaboration across disciplines by tackling questions such as: What is the origin and nature of light? How does it travel through space and time? How can it be made productive in an artistic sense and what, in turn, can artistic methodologies contribute to experimenting and thinking about light?

Objective:
- Learn about the properties of light: intensities, phases, colors, and interactions with matter
- Exploring optical effects: reflection, refraction, dispersion
- Learn to plan and carry out an art project based on research inputs from other sciences
- Enhancing conceptual and interdisciplinary thinking in unusual set-ups
- Learn how to cope with unforeseen results and make random events productive for the successful implementation of a project
- Fostering communication and presentation skills

Content: In this course, we will set a performative frame for experimentation and exploration.

At the end of the semester, the artistic experiments will be presented.

Prerequisites / notice: Max. number of participants: 15

Competencies

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<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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052-0585-24L Unveiling Habitats W 2 credits 2S F. Gradin, M. Conen

Abstract: How can architects integrate the topic of cohabitation and biodiversity into the design process? As an interdisciplinary discipline, architecture plays a key role in promoting biodiversity in urban areas. In this seminar, promising leverages and fields of action will be explored and discussed in order to create ecologically rich and networked living spaces of high-quality.

Objective:
- Knowledge of relevant topics and discourses in the growing transdisciplinary field of architecture and biodiversity
- Definition of personal leverages and fields of action to promote cohabitation and biodiversity as an architect
- Critical and reflective analysis of various existing examples
- Analysing and developing relevant parameters based on a case study

Content: Biodiversity forms the indispensable basis of our lives. However, in Switzerland, its quality, quantity and connectivity are rapidly declining. The country is particularly hard hit by climate change. Almost half of all habitats and more than a third of all species are threatened (Biodiversity in Switzerland analysis report, FOEN 2023). Urban areas play a central role in this context. The built environment in Switzerland has almost doubled since the 1970s, putting enormous pressure on ecosystems.

In this context: how can integrative construction projects of the future be designed with a high ecological quality and a high quality of life - both for humans and other living beings? In this seminar, we will look at the notions, issues and actors involved in questions of biodiversity in the urban area of the city of Zurich from an architectural perspective. Theory and practice in the field of architecture and biodiversity will be linked through a variety of guest contributions from experts and on the basis of a case study and several field trips. The individual research and findings are summarized in the form of a visual project documentation and will be presented at a final event.
Fostered

Complex buildings such as health care buildings are subject to constant change. In a new hospital building 60% of the diagnostic and treatment areas are subject to building changes within the first 10 years of operation. Architecture has to develop concepts which accommodate this level of dynamics into the building structure in a better way. In the coming years this need for adaptability is going to be challenges even further by the even more reducing health care resources. The paper should discuss in this context a specific question in detail by analysing problems and developing and discussing potential planning solutions.

Prerequisites / notice

The number of places is limited. Interested students are requested to send a short motivation letter by e-mail by September 17.

Classroom teaching takes place on a total of seven dates, including 2x2 and 5x4 lessons each. Individual events are organised as excursions in the city of Zurich and will not take place at ETH. The costs incurred (public transport tickets) will not be covered.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Decision-making

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Creative Thinking
- Critical Thinking

Lecture notes

Presentations of the lecturer and guests will be made available.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Problem-solving

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management
- Customer Orientation

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Self-awareness and Self-reflection

Example of Health Facilities

Independent written scientific paper concerning a subject of planning of complex buildings - such as health facility planning and design - with special focus upon the dynamic changes in this context and the related planning and building reactions to them.

The objective is that the students engage in a debate of a differentiated functional planning as a basis for complex buildings which are to be successful functionally, operationally and in design.

On the basis of a given scope of themes the students carry out research aiming for possible improvements for example in health facility planning. The scope of subjects is announced at the beginning of each semester.

Content

Complex buildings such as health care buildings are subject to constant change. In a new hospital building 60% of the diagnostic and treatment areas are subject to building changes within the first 10 years of operation. Architecture has to develop concepts which accommodate this level of dynamics into the building structure in a better way.

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052-0511-24L

Planning Strategies for Complex Buildings Using the Example of Health Facilities

W: 2 credits
1V: T. Guthknecht

Abstract

Independent written scientific paper concerning a subject of planning of complex buildings - such as health facility planning and design - with special focus upon the dynamic changes in this context and the related planning and building reactions to them.

Objective

The objective is that the students engage in a debate of a differentiated functional planning as a basis for complex buildings which are to be successful functionally, operationally and in design.

On the basis of a given scope of themes the students carry out research aiming for possible improvements for example in health facility planning. The scope of subjects is announced at the beginning of each semester.

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Complex buildings such as health care buildings are subject to constant change. In a new hospital building 60% of the diagnostic and treatment areas are subject to building changes within the first 10 years of operation. Architecture has to develop concepts which accommodate this level of dynamics into the building structure in a better way.

In the coming years this need for adaptability is going to be challenges even further by the even more reducing health care resources. The paper should discuss in this context a specific question in detail by analysing problems and developing and discussing potential planning solutions.

052-0587-24L

Re-Imagine: architectures of transformation

W: 1 credit
1V: T. Rapelli, L. Crignola

Abstract

The shift from ‘Ersatzneubau’ as the status quo to an intelligent approach to our existing building stock has just begun. This transition demands new roles, new knowledge, and new ways of action. The course examines, through lectures and discussions with guests, the fields of action that open up for architects to actively shape a changing building culture.

Objective

- Develop an awareness of the field of action of one’s own profession to help shape a sustainable building culture
- Understand and analyze complex and multifaceted mechanisms in the construction process, especially in the transformation processes of existing buildings
- Investigate and discuss relevant case studies, practices, and processes
- Question common practices and formulate alternative approaches

Content

There is a sense of new beginnings in architecture. Over the past two decades, efforts in sustainable construction have primarily focused on (replacement) new buildings that consume as little energy as possible in operation. Recently, the issue of embodied energy has gained more attention: in Switzerland, there is an increasing willingness to preserve not only monuments but also “everyday” buildings from demolition and to redesign them for continued use and a new life cycle. Although the practice of replacement construction still constitutes a large part of overall construction activity, a path is slowly opening towards a building culture that seeks the ongoing redesign of existing buildings instead of the tabula rasa and “clean solutions” of past decades.

This shift from a demolition culture to a transformation culture requires a new set of skills from architects. The times of standard solutions and pre-drawn construction detail catalogs are over. Transformation projects require imagination, technical skill, and a profound understanding of our building stock. We will explore the changing role of architects in this new building culture through discussions with local experts and pioneers who have demonstrated exemplary approaches in their practice and made significant contributions to the transformation. Each week, we will examine a specific step in the transformation process of a building, from strategic planning to construction. This will provide a detailed understanding of the tools and competencies that practicing architects need to learn, the contributions we can make as individuals to the transformation, and the opportunities a changing building culture can offer us.

Each session will include an introduction to the topic with practical examples, followed by guest presentations sharing their experiences, expertise, and case studies. The inputs will be discussed in plenary at the end of each lesson.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Problem-solving

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Self-awareness and Self-reflection
The elective class Model and Design addresses architectural model-making through systematic experimentation. By examining and adapting digital-analog relationships, students are introduced to the concept of Hybrid Reality, which represents the coexistence of physical and digital spaces. This course introduces the term "Hybrid Reality," which interprets the rapid growth of digital technologies on our life necessitates constant adaptation. The course explores the influence of various digital tools and techniques on the design process, including 3D scanning, freeform modeling, and virtual reality (VR) technologies. Students will learn to use VR tools and VR techniques for creating hybrid reality environments and design interactive exhibitions.

Aims:
- The students will design models as tools for understanding complex questions by investigating an existing architectural project.
- The students will test materials, techniques, and construction principles for model-building by completing hands-on activities.
- The students will review their work by creating annotated images and writing texts as part of their course documentation.
- The students will research questions and allow the students to check the validity of their assumptions to inform their studies.
- The students will further develop the research question.

Competencies:
- Method-specific Competencies: Media and Digital Technologies, Creative Thinking
- Personal Competencies: Problem-solving

Prerequisites / notice:
- The course is interconnected with "3D Scanning and Freeform Modeling" and "3D Modeling" (2x2 ETCS). Classroom teaching as 4h block + self-teaching and research at home. Max. number of participants 15 students.
- The students will review their work by creating annotated images and writing texts as part of their course documentation.
- Students formulate a precise research question for the course that they investigate through tests and a model of a built architectural project during the semester.
- The students must register for both courses: "360 – Reality to Virtuality" and "3D-Modeling" (2x 2 ETCS).

Classroom teaching as 4h block + self-teaching and research at home.

Max. number of participants 15 students.

Please send a short application email (max 150 words) to Adam Kiryk: kiryk@arch.ethz.ch

For students who already have an Oculus Quest 2, you do not need to pay any deposit and can work on your own device.

Please note:
- A 200 CHF deposit will be charged for the VR Headset. It will be refunded upon the return of the headset on the last day of the course.
The HYTAC Elective Course offers the opportunity to explore alternative ways to approach Point Cloud and 3D Printing in a simple way. The students will learn the basic principles and workflows behind photogrammetry, 3D-modeling and 3D-printing, to produce digital and physical (3d-printed) models.

By the end of this course, the students will be capable of:

a) creating and processing point-cloud-generated models in Blender
b) producing 3D-printed models in architectural scale
c) using the above digital tools to advance their personal design workflows.

The course includes:
- Introduction to photogrammetry and 3D printing through lectures and tutorials.
- Generation of a digital twin of the selected site through photogrammetry and production of a physical model (3D printed)
- Use of Blender. Basic skills can be acquired during the course.

In case of questions regarding the course, please visit our website: https://hytac.arch.ethz.ch/courses/elective-2/ or contact us directly via email (hytac@arch.ethz.ch).

The course includes:
- Use of Blender. Basic skills can be acquired during the course.
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### BUK Construction Lab

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<tr>
<td><strong>Integrated Discipline HS24 in the Field of Design and Architecture (IEA)</strong></td>
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<tr>
<td><strong>Enrolling in this course is only possible on agreement with the lecturer and if you attend a design course (V-IX) at the same time.</strong></td>
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<tr>
<td><strong>Abstract</strong></td>
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<td>The formal framework needs to be discussed with a chair within the institute IEA.</td>
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<td><strong>Objective</strong></td>
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<td>The aim is a well-founded examination of a clearly formulated question.</td>
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<td>Spoilsport will expand Voluptas' research on Play and Architecture. It will test Playfulness as critical design tool for deconstructing rule-making mechanisms and surpassing them. Students will play a typological design game based on collaborative competition: together defining criteria for success, competing towards answers to these criteria, and again collaborating in choosing the best answers.</td>
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<tr>
<td><strong>Excerpt of Johann Huizinga’s “Homo Ludens – A Study of The Play Element in Culture”, 1955</strong></td>
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<tr>
<td>This course will invite students to take the stance of a spoilsport in relation to established typological norms and rules. By doing so, the edges of knowledge on typological definition should be expanded in unforeseen ways, allowing new interpretations of existing architectural stapples and the formulation of new design approaches to long-standing norms and rules. Withdraw from the current, play a different game.</td>
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<tr>
<td>F. Neto Moura Veiga</td>
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<td>A. Kiryk</td>
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<td>M. Pschorn, C. Aires Teixeira</td>
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### 3D Scanning and Freeform Modeling

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<td>This course explores the concept of “Hybrid Reality,” blending digital and physical spaces using VR technologies. Students will learn to digitize spaces, create immersive environments, and design interactive exhibitions.</td>
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<td>The goal is to digitize an existing space and use it in virtual reality as a context for further design. During the course, AI tools will be utilized to enhance the photogrammetry 3D scanning process. In the first part of the course, we learn the tools; then we work on architectural VR projects, either in groups or individually. Throughout the course, we will examine VR workflows to create immersive and interactive architectural spaces. At the end of the course, we will present the works in a VR exhibition. Each student receives an Oculus Quest VR headset to work with at home throughout the semester.</td>
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<td><strong>Supervisors</strong></td>
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<td>A. Kiryk</td>
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### 3D Scanning and Freeform Modeling

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<tr>
<td><strong>3D Scanning and Freeform Modeling</strong></td>
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<tr>
<td><strong>Enrolment in agreement with the lecturer only <a href="mailto:kiryk@arch.ethz">kiryk@arch.ethz</a>.</strong></td>
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<tr>
<td><strong>Abstract</strong></td>
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<tr>
<td>This course explores the concept of “Hybrid Reality,” blending digital and physical spaces using VR technologies. Students will learn to digitize spaces, create immersive environments, and design interactive exhibitions.</td>
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<td><strong>Objective</strong></td>
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<tr>
<td>The goal is to digitize an existing space and use it in virtual reality as a context for further design. During the course, AI tools will be utilized to enhance the photogrammetry 3D scanning process. In the first part of the course, we learn the tools; then we work on architectural VR projects, either in groups or individually. Throughout the course, we will examine VR workflows to create immersive and interactive architectural spaces. At the end of the course, we will present the works in a VR exhibition. Each student receives an Oculus Quest VR headset to work with at home throughout the semester.</td>
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<td><strong>Content</strong></td>
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<td>Fusions of digital-analog relationships have accompanied us since the very beginning of the digitalization era. The rapidly growing impact of digital technologies on our life necessitates constant adaptation. The course introduces the term “Hybrid Reality,” which represents the coexistence of physical and digital spaces. Using state-of-the-art VR technologies, the methodology focuses on immersive, real-time, 1:1 scale space creation, exploring corporeal design, and reinventing conventional methods. Students will learn to digitize physical spaces, create hybrid reality environments, and design interactive exhibitions.</td>
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<td><strong>Places are limited. Before registering you need the acceptance of the lecturers!</strong></td>
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<td><strong>Supervisors</strong></td>
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<td>A. Kiryk</td>
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</table>
The course "360 – Reality to Virtuality" is interconnected with "3D Scanning and Freeform Modeling". You must register for both courses: "360 – Reality to Virtuality" and "3D-Modeling" (2x 2 ETCS). Classroom teaching as 4h block + self-teaching and research at home.

A 200 CHF deposit will be charged for the VR Headset. It will be refunded upon the return of the headset on the last day of the course. If you already have an Oculus Quest 2, you do not need to pay any deposit and can work on your own device.

Please send a short letter of motivation (max 150 words) to Adam Kiryk: kiryk@arch.ethz.ch

### History and Theory of Architecture

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<td>052-0827-24L</td>
<td>Seminar History and Theory of Urban Design: 'Sites- and-Services'</td>
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#### Abstract
'Sites-and-services' was an important housing paradigm that was mobilized in the context of development aid to provide cost-efficient housing for the global poor. As these were essentially unfinished projects that relied on their future inhabitants to complete their dwellings, in this seminar we discuss what we can learn from the histories of such atypical housing projects.

#### Objective
By focusing on the history of sites-and-services projects, this seminar course aims to foster, on the one hand, a historical understanding of urban design in the postcolonial context of development aid, and, on the other, a theoretical understanding of the centrality of the act of inhabitation to architecture and its history.

Upon completion of the course, students will have:

1. acquired a general knowledge of the role of architecture and urban planning in the historical context of development aid, the main actors involved, and strategies adopted
2. acquired an in-depth knowledge on the specific housing paradigm of 'sites-and-services'
3. developed a critical attitude in engaging with the history of postcolonial urban design
4. developed a theoretical understanding of the act of inhabitation as central to architecture and its history
5. developed a reflective attitude on the modes of writing architectural history and the role of inhabitation in it
6. strengthened their analytical skills by engaging in text- and project-based discussions, their collaborative skills through team-based project analyses, and their communication skills through presenting the outcomes of their work to their peers.

#### Content
The City Lived: 'Sites-and-Services'

In our seminar series 'The City Lived' we focus on the history of urban design, with a particular emphasis on the lived experiences in the city. This semester’s seminar will focus on 'sites-and-services’, an important housing paradigm that was mobilized in the context of development aid to provide cost-efficient housing for the global poor.

This housing strategy consisted of providing ‘sites’ – plots of land to construct dwellings on – in combination with a set of ‘services’, ranging from infrastructural features, such as sewerage and waste disposal, to market-based interventions that aimed to make cheap building material more easily accessible, or financial loan schemes that offered inhabitants the means to invest in their homes. It often operated on a large scale, and targeted thousands of households in a single project. For several decades from the 1970s, it was heavily endorsed by major actors such as the World Bank and the United Nations as a cost-efficient way to meet the most basic housing needs of a high number of people, whilst simultaneously offering authorities the means to direct the enormous growth of spontaneous settlements in the urban peripheries as part of their broader urban development plans. As such, these sites-and-services schemes have left a major imprint on many cities in the Global South. Despite this impact, however, their histories are not well documented.

Whereas sites-and-services were promoted as a cost-efficient solution to 'the housing problem' of the global urban poor, the housing paradigm attracted severe criticism from its inception. One line of critique considered such programs as formalizing the state’s disinvestment in its poorest citizens, symptomatic of neoliberal policies that erode structures of state support, while another line of critique considered them as instruments of a globalizing debt economy, incorporating the global poor in an expanding, profit-oriented capitalist market.

Beyond its praise and criticism, in this seminar course we study sites-and-services projects in the first place as material artefacts: as man- and woman-made built environments that have shaped the lives of thousands of people, whose history for that very reason deserves to be studied.

In doing so, we will discuss two broader themes. On the one hand, sites-and-services projects allow us to problematize the notion of housing expertise and how it was mobilized in the Global South. Therefore, we will discuss them against the background of housing policy in the Global South more generally. Which housing paradigms were relied upon in the context of the Global South? And what were the logics underlying them? On the other hand, since these were essentially unfinished projects that relied on their future inhabitants to complete their dwellings, in this seminar we not only intend to dig up the histories of such projects, but also to discuss what we can learn from the histories of such atypical housing projects. Inhabitants have drastically expanded and transformed the initial minimal design to often unrecognizable degrees according to their needs and resources, and many sites are now integrated into wider urban patterns. How do we write the history of ‘unfinished’ projects? How do we acknowledge the act of appropriation and inhabitation as an integral part of such projects?

This course is based on weekly two-hour seminars, in combination with a case study analysis in small groups. After introducing the main context, the seminars are structured around the themes of ‘housing expertise’ and ‘lived architecture’, and gradually shift from tutor-led input sessions to student-led text discussions and project presentations. After the first class, students will be asked to form balanced groups of 3 students to work on one sites-and-services project (from a pre-selected list) over the course of the semester. The semester-long case study analysis will culminate in a final presentation and an exhibition entry that will be included in a collaborative online exhibition. Three main feedback opportunities are provided within the contact hours: short ‘Flash Presentations’ during Seminar 3, ‘Mid-Term Presentations’ during Seminar 6, and a final in-class workshop focused on students’ writing and exhibition entry during Seminar 9.

Students are expected to actively attend and participate in each session. During the input phase, each week students are required to read 1–3 texts (‘Compulsory Reading’) and actively engage with other students and tutors on a pre-assigned digital canvas sheet (via Padlet).

An online exhibition based on earlier student work can be consulted here: https://repository.avermaete.ethz.ch/exhibitions/sites-and-services/
**052-0813-24L History, Criticism and Theory in Architecture: Communication**

**Abstract**
In this seminar we will, on the one hand, deal with the central strategies in the context of the climate crisis and get to know them by reading theoretical key texts. On the other hand, we will analyze concrete architectural case studies from Europe and Japan on this basis and thus examine these as well as the theoretical strategies for their potentials.

**Objective**
By combining theoretical foundations and practice-based approaches, the course aims to develop a deeper understanding of theoretically grounded ecological architecture while capturing and questioning the methods of current practice from a variety of perspectives.

**Content**
Climate change confronts architecture with a series of new and complex challenges that are reflected in a specific vocabulary. Terms like sufficiency, circularity or cohabitation are shaping the debates around this crisis or are standing for possible ways out of it. At the same time, the immediate nature of the situation forces us to critically question or revise common standards in the built practice - without having established new reliabilities in advance. Instead, a wide variety of isolated, sometimes contradictory strategies are being pursued simultaneously: Replacing fossil building materials with ecological ones, striving for "less" or a "different" way of building, low-tech and high-tech approaches, simple or multi-layered constructions. Theoretical and practical perspectives seem to be little connected so far.

In this seminar we will, on the one hand, deal with the central concepts and strategies of the current debates and get to know and question them by reading key theoretical texts. On the other hand, we will analyze relevant case studies from Europe and Japan on this basis and thus examine both the theoretical strategies and the concrete projects for their potentials.

By combining theoretical foundations and practice-based approaches, we thus aim to develop a deeper understanding of an academically informed, ecological architecture, while at the same time capturing and questioning the methods of our current practice from a variety of perspectives.

**Prerequisites / notice**
As we want to ensure a constructive discussion during the Seminar, we need to limit the amount of students participating.

To this end, we kindly ask you to send us a short letter of motivation. This does not need to be long (3-5 sentences should be enough), but make sure to state concisely why you would like to join us for this course.

Please send your statement to kersting@arch.ethz.ch by Monday the 18th of September (23:59). We will notify the accepted candidates by Wednesday the 20th.

**Competencies**

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<th>Competencies</th>
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**052-0817-24L Architectural Ecology II: A History**

**Abstract**
Worlds' major deserts—both hot and cold—have often served to search, extract, and transport the deserts' various natural resources, such as oil and gas, as well as to design and build new cities, infrastructures, residential architecture, tourist complexes, farming systems, solar power plants, climate and aerospace research centers, chemical weapons testing complexes, nuclear weapon research centers

**Objective**
In this seminar we will, on the one hand, deal with the central strategies in the context of the climate crisis and get to know them by reading theoretical key texts. On the other hand, we will analyze concrete architectural case studies from Europe and Japan on this basis and thus examine these as well as the theoretical strategies for their potentials.

By combining theoretical foundations and practice-based approaches, we thus aim to develop a deeper understanding of theoretically grounded ecological architecture while capturing and questioning the methods of current practice from a variety of perspectives.

**Content**
Climate change confronts architecture with a series of new and complex challenges that are reflected in a specific vocabulary. Terms like sufficiency, circularity or cohabitation are shaping the debates around this crisis or are standing for possible ways out of it. At the same time, the immediate nature of the situation forces us to critically question or revise common standards in the built practice - without having established new reliabilities in advance. Instead, a wide variety of isolated, sometimes contradictory strategies are being pursued simultaneously: Replacing fossil building materials with ecological ones, striving for "less" or a "different" way of building, low-tech and high-tech approaches, simple or multi-layered constructions. Theoretical and practical perspectives seem to be little connected so far.

In this seminar we will, on the one hand, deal with the central concepts and strategies of the current debates and get to know and question them by reading key theoretical texts. On the other hand, we will analyze relevant case studies from Europe and Japan on this basis and thus examine both the theoretical strategies and the concrete projects for their potentials.

By combining theoretical foundations and practice-based approaches, we thus aim to develop a deeper understanding of an academically informed, ecological architecture, while at the same time capturing and questioning the methods of our current practice from a variety of perspectives.

**Prerequisites / notice**
As we want to ensure a constructive discussion during the Seminar, we need to limit the amount of students participating.

To this end, we kindly ask you to send us a short letter of motivation. This does not need to be long (3-5 sentences should be enough), but make sure to state concisely why you would like to join us for this course.

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**052-0817-24L Theory of Architecture: Desert Modernism(s)**

**Abstract**
Worlds' major deserts—both hot and cold—have often served to search, extract, and transport the deserts' various natural resources, such as oil and gas, as well as to design and build new cities, infrastructures, residential architecture, tourist complexes, farming systems, solar power plants, climate and aerospace research centers, chemical weapons testing complexes, nuclear weapon research centers

**Objective**
Knowledge of architectural photography

**Content**
History, theory and practice of photography in relation to architecture

**Prerequisites / notice**
This course runs on a bi-weekly schedule in two separate groups limited to 15 students each and is taught in English.

Students will be selected on the basis of a motivation letter.

Course dates and place: see room reservation.
Special Questions in History of Art and Architecture: Architecture in the Expanded Field

**Abstract**
This seminar will explore contemporary architecture through the lens of its ever expanding field, taking as a starting point the view that we “both do and do not know” what architecture is. Together we will discuss texts, visit workspaces and have conversations with practitioners who work at the interfaces of architecture, art and other disciplines.

**Objective**
This course aims to sharpen critical reading and thinking skills. Students should come away clearer about their position on the contemporary contours and potentials of architecture.

**Content**
Adapting our course title from Rosalind Krauss’s prominent essay on sculpture (1979) but not strictly following its argument, we will pay special attention to ways that architecture intersects with art (and other disciplines), whether through direct collaboration, cross-referencing, role-swapping, or the engagement of parallel topics or methods.

A series of conversations with internationally known practitioners who work at the interfaces of architecture, art and other disciplines will form the basis of our discussions.

In addition, we will visit relevant locations and read and discuss texts from the fields of history and theory.

In probing architecture along its peripheries, or even from an outside perspective looking in, this seminar seeks to expand insights into what architecture is, or might be, today.

**Literature**
Literature will be provided at the start of the semester.

**Prerequisites / notice**
Due to the guest talks and visits planned, individual sessions might take place at times or locations different from the regular time-table. The adapted schedule will be communicated during the first meeting.

Texts and conversations will be in german and/or english.

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PhD Teaching: Drawing Things Together: Drawings Beyond Disegno

**Abstract**
This seminar will study the material, cultural, and social parameters that conditioned drawing practices in Europe from the 15th through 19th centuries. We will examine drawings firsthand, and compile critical perspectives to grasp the varied roles drawings performed in artistic and architectural practices as well as the production of knowledge, and the constitution of power structures.

**Objective**
The course aims to sharpen the historical awareness of the media conditions of architectural design. It does so by highlighting the practice of hand drawing in the face of today’s digital imaging devices and through a critical engagement with the material, cultural, and social conditions and implications of the allegedly neutral blank page. This exploration also involves a methodological reflection of historical research. We will delve into in-depth reading of texts from various scientific fields and disciplinary perspectives. This will require the preparation of one text per session, which will be moderated alternately by one or two assigned students. This reading component will be complemented by visits to drawing collections and study rooms, to familiarize ourselves with the historical materials.

Texts and discussions will be held in German and English, requiring a sufficient command of both languages.
How can we think of utopias in the dystopian times we live in? Are all utopian visions devoid of reformist agency, as historians have pointedly warned us? What is the role of architectural history in navigating these questions? This course critically interrogates the concept of utopia in its historical and spatial dimensions, through a combination of lectures, readings, and in-class discussion.

Architecture’s historical failure to breathe life into reformist, utopian dreams can feel disempowering, especially in light of current escalating ecological, political, and cultural challenges. If, however, the clean slate worlds envisioned by architectural avant-gardes have traditionally failed to materialize into a more equitable future, there is still a lot to learn from practitioners, theorists, and communities who devoted their efforts to resist disenfranchisement, and to reclaim and restore the equity of their present.

Such “utopias of the rear-guard” will be the focus of our course. Bringing together archival material and secondary sources, we will explore the spatial articulation of feminist, decolonial, spiritual, and other collectivist sites of resistance. Although the gravity of this theme is heightened by the exigencies of our present, the emphasis of the class will be on pre- and early modern examples, with particular attention paid to the socio-political structures of the Enlightenment.

Students will learn how to approach primary / archival and secondary sources and will be given a curated selection of readings to support their understanding of key concepts, such as utopia, identity, colonialism, etc. They will be given the opportunity to research their own case studies, curate material, and present on it at the end of the semester in a symposium format. Most importantly, they will learn methodologies to engage with the architectural form and the built environment critically, as well as to approach early modern episodes through contemporary lenses, in a historically responsible way.

Attendance, participation, and collaboration are key, as most of the work will take place in the classroom, which too, will be approached as a form of a radicalized, “concrete utopia” of our present.
Subject-specific Competencies

The goal of this seminar is to develop an understanding of how international organisations such as UNESCO work internally and how they try to act in the world. In addition to academic argumentation and writing, the seminar will provide basic skills in working with archival material and analysing printed material from the 1970s and 1980s. The final assignment will be a short academic paper on one of the three case studies.

Competencies

- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies, Decision-making, Problem-solving, Project Management
- Social Competencies: Communication, Cooperation and Teamwork, Sensitivity to Diversity
- Personal Competencies: Creative Thinking, Critical Thinking, Integrity and Work Ethics

Literature

The compulsory texts will be available at the beginning of the seminar.

Prerequisites / notice

The seminar is limited to 20 people. There will be a waiting list.

Please note:

Several meetings will take place at Graphische Sammlung ETH Zürich in the main building or in museums in Zurich. Time for travel before and after the meetings is therefore necessary.

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 113 of 2653
This is not a seminar on how to get a job at UNESCO. Rather, we will explore who works for UNESCO, what they do in the field of architecture, and the role of bureaucracy and international relations in their work.

The United Nations Educational, Scientific and Cultural Organisation (UNESCO) is an international organisation that coordinates a wide range of activities related to architecture. These include the preservation of historical monuments and the establishment of a universal cultural heritage, initiatives for school construction projects, the commissioning of manuals and the implementation of training programmes. In this seminar, we will focus on three case studies to disentangle the UNESCO apparatus.

The first section will look at the UNESCO project on “Traditional Forms of Architecture” in the 1970s, led by Wolf Tochtermann, Acting Director of UNESCO’s Human Settlements and Socio-Cultural Environment Division. Through contacts with a variety of architects and academics around the world, he collected and commissioned studies on what he called “architecture without architects”, particularly in countries where development projects threatened to transform the existing built environment. We will look at published articles, audio-visual material and documents from the UNESCO archives to understand how these studies were produced (negotiations, contracts, payment) and used (publications, exhibitions, etc.) by UNESCO.

The second part will focus on the cooperation between UNESCO and the International Union of Architects (UIA), exemplified by the joint project ARKISYST, “an international information network in architecture”. Sponsored by the Spanish government and coordinated by the architect Donald Conway, the possibility of establishing a global exchange of information on architecture and urban planning was intensively studied but never implemented. This case study allows us to question notions of international standardisation, global participation and open access.

The third section of the seminar will examine the UNESCO Workshop on “Training of Barefoot Architects” in Bangkok, 30 May–June 1983, which was organised by the UNESCO Regional Office for Education in Asia and the Pacific. The aim of this analysis is to explore the different perspectives of the various actors involved in this workshop, including the architect Yona Friedman. The UNESCO archives provide a valuable source of information on the criticism of the approach and attitude of the “foreign expert” by local architects.

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Abstract
Works in the integrated discipline art and architectural history evolve in close connection with projects in design. Textual and creative works are possible. The length of the text or the extent of the creative project will be decided upon individually. Interested students are asked to develop a (textual or diagrammatic) concept sketch explaining the content and the form.

Objective
We expect that students pursue their examination of the design process independently and in an original manner or that they develop a related theme from the perspective of the history of art and architecture. The work should be part of the design process and interact with it formally and in regard to content.

Content
Works in the integrated discipline art and architectural history evolve in close connection with projects in design. Textual and creative works are possible. The length of the text or the extent of the creative project will be decided upon individually. Interested students are asked to develop a (textual or diagrammatic) concept sketch explaining the content and the form.

Abstract
The School of (Sub)Curating asks, discusses, plays with and ventures into the question of how to visualise art and knowledge in space. Experiment at Kunsthalle Zürich; guest artists, curators and researchers will present and discuss their projects with you. Then over to you: you take on one project, visualise it, install it and present it during an opening. It will be part of the exhibition AAA stage children's books? To show a magazine stored on a USB stick? To translate travel books into space? Or films about exhibitions?

Objective
The School of (Sub)Curating teaches you about curating both historically and practically. It increases the knowledge of and sensitivity towards space in relation to presentation and exhibition and their underlying histories. The work should be part of the design process and interact with it formally and in regard to content.

Content
The School of (Sub)Curating asks how to translate art and artifacts into space. How to install documents about an exhibition? Or a book? Or a digital magazine? How to contextualise an early platform for digital arts? How to introduce historic design for therapeutic toys? To stage children’s books? To show a magazine stored on a USB stick? To translate travel books into space? Or films about exhibitions? What about presenting sound? Or a radio station? The collaborative seminar starts with introducing ways of curating, formats and projects. Then over to you: you take on one project, visualise it, install it and present it during an opening. It will be part of the exhibition AAA.

Literature
https://ursprung.arch.ethz.ch/lehrveranstaltungen

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 114 of 2653
The seminar is a close cooperation with the Chair of Prof. Dr. Tom Avermaete.

"Why look at animals?" is the title of an article from 1980 by British writer and art critic John Berger. In this fundamental text Berger looks at the cohabitation of humans and animals in historic perspective. Selected examples of historic architecture, urban planning and architectural theory will be analyzed with help of groundbreaking texts from various fields like biology, sociology, art history, literary studies — and apply this knowledge on architecture. Thereby buildings and cities are not seen as a mere stage for interactions between humans and animals but as active contributors to the spiritual and cultural relation of humans towards animals. In this course, this text and some more recent texts form the starting point.

I Building for animals

The first module will focus on buildings (or environments) designed to accommodate animals (and often to accommodate the proximity of "non human animals" and "human animals". Examples include structures which have been built with often high architectonic ambitions for certain species of animals, like stables, riding houses, pigeon towers, zoos and different typologies of agricultural buildings from different regions and epochs.

II Animal city

The second module focusses on the city as a shared space for humans and animals. Until the beginning of the 20th century, masses of animals were kept within the confines of big cities. It came with its own challenges, so called "cultural followers" and "pests", which made a strong impact on building, zoning, and developing the city. Zoonoses were and still are a serious thread today, influencing urban planning.

III Architectural and animal theories

The final module focusses on recent discourses of human-animal-relations in philosophy, biology and literary studies, leading to the new field of more or less radical "animal studies" or "human-non human animal studies" emerging within the last two decades. In this part of the course the renewed focus on questions of cohabitation in a global perspective is studied through contemporary texts and art/architectural projects with a strong political message. These objects and projects are taken as a starting point for a discussion on the future role of architecture and urban planning in fostering biodiversity.

The seminar is organized in three modules:

- short students presentations 15-20 minutes
- several mini lectures by the lecturer
- impulse lectures by guest
- joint close reading of key texts
- joint analysis of projects
- excursion Hönggerberg
- final discussion
- submission of power point presentation (The lecturer will comment individually on the submission of the power point presentation.)

The program comprises following elements:

* submission of power point presentation (The lecturer will comment individually on the submission of the power point presentation.)

The seminar is a close cooperation with the Chair of Prof. Dr. Tom Avermaete. Throughout the course, students will develop a high degree of independent thinking, the ability to read texts critically and apply the results on historic and contemporary examples, be it the built environment, a text or an art project. Via individual presentations students learn to process complex content verbally and visually and answer questions. This schools several important skills like abstraction of content, conveyance of content, visualization, reaction to unforeseen questions et. al. With the joint close reading students will further exercise the analytical skills whereas the final discussion will train the discursive skills and show how to synthesize differing positions.

I Building for animals

The first module will focus on buildings (or environments) designed to accommodate animals (and often to accommodate the proximity of "non human animals" and "human animals"). Examples include structures which have been built with often high architectonic ambitions for certain species of animals, like stables, riding houses, pigeon towers, zoos and different typologies of agricultural buildings from different regions and epochs.

(Examples: Riding house of William Cavendish in Bolsover Castle 1660ies, Hameau de la Reine, toy farm for Marie Antoinette, Versailles, 1785-1788; Pigeon towers in Iran; Hugo Häring, Gut Garkau, 1922; next phase for the expansion of Zoo Zürich, Tessiner Houses, etc.)

II Animal city

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(Examples: Johann Bernhard Fischer von Erlach, Imperial riding school and stables in Vienna; Animals in „Georgian“ London; Union Stock Yards, Chicago, ab 1865; Pest and rats, Urban Foxes, Raccoons in Berlin et. al.)

III Architectural and animal theories

The final module focusses on recent discourses of human-animal-relations in philosophy, biology and literary studies, leading to the new field of more or less radical "animal studies" or "human-non human animal studies" emerging within the last two decades. In this part of the course the renewed focus on questions of cohabitation in a global perspective is studied through contemporary texts and art/architectural projects with a strong political message. These objects and projects are taken as a starting point for a discussion on the future role of architecture and urban planning in fostering biodiversity.

Communication

Subject-specific Competencies

How do we comply, condone, distort, or resist gender roles in our manners and social conduct? And how does this performance inform our fostered

Creative Thinking

There are two types of bodies which will be discussed in the course, the body(s) of the person who contributed to build the archive by means

I can safely say that the taken-for-grantedness of the emotionally contained subject is a residue of Euro-centerism in critical thinking. The

Concepts and Theories

For centuries, advice literature has extensively examined the codes of propriety, or decorum, and ordered both the plot and the stage of

What happens if we think about the archive through our bodies? Can we see archives as fragments of personal encounters instead of an

Prerequisites / notice

Recommended reading:

non

Competencies

Subject-specific Competencies

fostered

Concepts and Theories

fostered

Method-specific Competencies

fostered

Analytical Competencies

fostered

Media and Digital Technologies

fostered

Problem-solving

fostered

Social Competencies

fostered

Communication

fostered

Cooperation and Teamwork

fostered

Sensitivity to Diversity

fostered

Personal Competencies

fostered

Creative Thinking

fostered

Critical Thinking

fostered

Integrity and Work Ethics

fostered

Self-awareness and Self-reflection

fostered

052-0921-24L

PhD Teaching II: Miss Manners: Gender, Etiquette, and Architecture

W 2 credits 2S

D. Göre, M. Delbeke, C. Rachele

Abstract

This seminar draws architectural history’s attention to textual sources from advice literature that formulate the normative and gendered standards of interior design, decoration and homemaking. Through a critical examination of advice ranging from Ottoman adab books to Western etiquette manuals, we will examine the various regimes and expressions of gender embedded in the skin of architecture.

Objective

How do we comply, condone, distort, or resist gender roles in our manners and social conduct? And how does this performance inform our spatial imagination? This seminar broadens the scope of what can be considered as source material for architectural history and theory by reading a set of historical and contemporary texts against the grain. Over the course of the semester, students will become familiar with vocabularies pertaining to gender, sex, and sexuality that are referenced in the narrative strategies of advice manuals and examine how these influence aspects of architectural discourse. In addition to this historical inquiry, they will independently explore texts, cases, or designs from the intersection of race, class, and gender, and discuss the materiality of sex within imaginary and/or real space configurations.

Content

For centuries, advice literature has extensively examined the codes of propriety, or decorum, and ordered both the plot and the stage of domestic living provided by its rules about hosting, dining, decorating, or designing the private sphere. Although these manuals stood somewhere between fact and fiction, they always conveyed to their readers the performative nature of a home. From Italian books of courtiers (Alberti, 1434; Castiglione, 1528) to Ottoman adab manuals (Mustafa Ali, 1599; Mithat, 1894) to modern experts of etiquette publishing in newspapers and the read-write pages of the web (Gentlewoman, 2021; Judith Martin, 2023), this pervasive literature reflected norms and normative behaviors and still continues to feed into the exclusive designs of residential architecture. This seminar will draw the attention of architects to this extensive but also thorny collection of writings, which is replete with arguments about class, race, and gender. The seminar is composed of three modules that arrange the main sources in a chronological and thematic manner. Subsequently, there is a workshop dedicated to the final assignment, during which students reflect on a selected text, case, or design of their choice.

Competencies

Subject-specific Competencies

fostered

Concepts and Theories

fostered

Techniques and Technologies

fostered

Method-specific Competencies

fostered

Analytical Competencies

fostered

Social Competencies

fostered

Communication

fostered

Cooperation and Teamwork

fostered

Personal Competencies

fostered

Creative Thinking

fostered

Critical Thinking

fostered

Integrity and Work Ethics

fostered

Self-awareness and Self-reflection

fostered

Self-direction and Self-management

fostered

052-0835-24L

Phd Teaching III: Archival Laziness at the Ethnographic Museum Zurich

W 2 credits 2S

D. B. Borah, C. Rachele, P. Ursprung

Abstract

What happens if we think about the archive through our bodies? Can we see archives as fragments of personal encounters instead of an impersonal all-encompassing institutional authority? The course critically approaches museum institutions, archives and the politics of value in the postcolonial and centres the body and its contingencies to think towards the museum and archive of the future.

Objective

I can safely say that the taken-for-grantedness of the emotionally contained subject is a residue of Euro-centerism in critical thinking. The separation of our body and mind, the distinction between material and emotional being is a style of thought; and Dipesh Chakrabarty in “Provincializing Europe” has showed us that this style of thought was born in a certain place (Europe) and in a certain time (Modernity). In an attempt to blur such binaries and offer personal ambiguities instead of modern precision, the course attempts to look at the politics of the archive and its relationship to bodies. The course introduces decolonial, postcolonial, queer, and feminist theories, and attempts to reduce the archival premise from its modern totality and suspend in a state of partiality.

Content

There are two type of bodies which will be discussed in the course, the body(s) of the person who contributed to build the archive by means of collection by travel, research, and scientific enquiries. The other body is our own body(s) as architecture students, artists, researchers who access these archives to make sense of the historical and contemporary. We will think about the body and its aspects of hunger, thirst, desire, ego, fear etc and look at the museum collection and archive through these fundamental bodily aspects. The course departs from laziness of the body as a vector upon which museum collections and archives are built. The notion of laziness comes from the colonial myth of the lazy native. We will look at certain case studies of objects from the archives from the Ethnographic Museum of Zurich in order to understand our own position. We are exposed to the notion of social lives of objects.
Analytical Competencies
Communication fostered
Participants will be expected to engage actively in:
- fostering

Social Competencies
Communication fostered

Personal Competencies
Adaptability and Flexibility fostered

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<tr>
<th>Number</th>
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<td>052-0723-24L</td>
<td>Sociology: Henri Lefebvre and the Theory of the Production of Space - Theory Seminar</td>
<td>W</td>
<td>2 credits</td>
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<td>C. Schmid</td>
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Abstract
This theory seminar discusses the new book on Henri Lefebvre by Christian Schmid. We will read and discuss a chapter of this book every week.

Objective
Participants will be expected to engage actively in:
- reading, debating and discussing a scholarly text

The goals of this course include:
- acquiring new skills in reading and applying a theoretical text
- strengthening ability to read, present and debate academic texts
- getting familiar with one of the most important theories on space and the urban in social sciences

Content
On the occasion of the publication of the forthcoming book ‘Henri Lefebvre and the Theory of the Production of Space’ by Christian Schmid, we are organising a special seminar in the autumn semester 2022 in which we will read and discuss the book together.

The book will be published by Verso in November 2022, and offers an encompassing, systematic, and accessible introduction to Lefebvre’s theory of space and the urban. We will provide pre-print copies of the individual chapters to the seminar participants.

Lecture notes
On the book:

Henri Lefebvre developed an extraordinarily and far-reaching spatio-temporal theory of society that is today widely applied in humanities and social sciences, particularly in urban studies, human geography, sociology, cultural anthropology, political sciences, philosophy, literature, cultural studies and the arts, and also in architecture, urban design and planning. This book provides the first systematic reconstruction of Lefebvre’s theory of the production of space. While many receptions represent Lefebvre’s work as a collection of inspiring but disparate thoughts and reflections, this book starts from the thesis of coherence, assuming that this work is distinguished by a continuity of concepts and categories that are connected in a consistent way. It reveals the epistemological context of this theory in French philosophy and in the German dialectic (Hegel, Marx, and Nietzsche), and explores the historical development of the core concepts. It illuminates Lefebvre’s understanding of everyday life, the right to the city, the thesis of the complete urbanization of society, and the intrinsic relationship between space and the state. It explains the famous double triad of the production of space: perceived, conceived and lived space – and spatial practice, representation of space and spaces of representation. And it develops a dialectical matrix of a theory of society, which is based on the core categories of spatio-temporal dimensions, levels, and configurations of social reality. It also gives an overview on the different Lefebvre receptions and discusses a wide range of applications of his concepts in various research fields.

For further information see: https://www.versobooks.com/books/4089-henri-lefebvre-and-the-theory-of-the-production-of-space

Prerequisites / notice
The course will be held in English. Participants must be able to read and speak English.

In order to make the seminar open to a wider audience, we are organising it hybrid – over Zoom and in-person.

Places are limited. Please send a short application expressing your interest in the seminar to bathla@arch.ethz.ch

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<td>W</td>
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Abstract
The elective deals with current transformation processes of metropolitan landscapes in Europe and introduces landscape architecture design on a territorial scale. On the basis of cartographic analysis and field trips, students will develop concrete strategies for the urban landscape of the Città Metropolitana di Torino.

Objective
The elective introduces to the subject and complexity of the urbanized landscape and teaches the critical engagement with the challenges and potentials of current tendencies in Landscape Architecture. On the basis of a concrete study area, students examine the large-scale processes of reuse, reform and reinterpretation of metropolitan landscapes in Europe and develop new approaches and strategies on various scales. They become familiar with GIS as an analytical tool, model building as a design methodology and the representation of landscape through plans. They develop a project based on the perception of place, knowledge of landscape-architectonic typologies and conception of public space. The design process is accompanied by workshops, lectures, excursions, critiques and a workbook.

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Autumn Semester 2024
Content


Prerequisites / notice

A workbook with texts and background information is available for purchase (CHF 20.-). A digital version is also available for free.

052-0725-24L

ACTIONS! On the Filmed City: Video Games

W 2 credits

H. Klumpner, C. E. Papanicolaou

Abstract

In the 1970’s and 80’s, video games began as forms of entertainment for the middle classes. 40 years later, they have grown into an industry larger than the film and music industry, creating an ever-growing format for experiencing reality.

How can we tap into the power of video ‘gaming’ as a spatial research tool, making use of filmmaking and digital animation as forms of audiovisual literacy?

Objective

Through a combination of practical exercises in video and audio techniques in parallel with the study of seminal observation-driven texts, this course aims to equip students with the basic tools and core principles to create short but complex experiments reflecting on urban space. This semester, the focus falls on the topic of video games, asking students to think about how filmmaking and digital animation skills may be used to tap into the multi-faceted possibilities presented by contemporary video gaming.

Using widely available recording tools and editing software, students will turn their fieldwork into short video or audio works of about 3-5 minutes.

NOTE: Students of this course will be given preference to the Semester Studio of the Chair of Architecture and Urban Design

Content

The course will consist of lectures, practical crash courses in media use and storytelling, and fieldwork sessions. The course will be a laboratory in the creation of short media works that aim to inform the architectural design process, working between the city and the studio in ONA. Students will be expected to complete all required work within the hours that the elective meets, with few requirements outside of the class hours.

Literature

Seminal texts include:

- 'Mirror Images: Cinematic and Sensory Ethnography for Landscape and Urban Studies (Papanicolaou)
- 'Cross-Cultural Filmmaking’ (Barbash, Castaing-Taylor)
- 'Acoustic Territories (LaBelle)
- 'Space Time Play: Computer Games, Architecture and Urbanism: The Next Level’ (Davidson)
- 'The Semiotics of Architecture in Video Games’ (Aroni)
- 'Documentary’s Expanded Fields: New Media and the Twenty-first-century Documentary’ (Kim)

063-0761-24L

Integrated Discipline HS4 in the Field of Landscape and Urban Studies (LUS)

W 3 credits

Supervisors

Abstract

Enrolling in this course is only possible on agreement with the lecturer and if you attend a design course (V-IX) at the same time.

Content

Design concepts ranging from architectural objects to urban planning are developed together with the discipline of landscape architecture. Dependent on the task at hand different themes are investigated. The goal of the integrated discipline is to develop design solutions of a specific topic in landscape architecture, which have to be incorporated into the overall design submission.

Objective

Students gain an insight into the integrated disciplins of design in architecture together with landscape architecture.

052-0713-24L

Serendipity: Zurich Section

W 2 credits

Abstract

Does not take place this semester.

The course Serendipity: Züriberg Section will combine two research approaches at the D-Arch and teaches current methods for recording, analysing and documenting the existing urban environment in 3D models and processing it into CAD drawings.

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Students will reflect on the perception of the urban environment and the methods used to map and model the existing context – discussing, how different methodologies shape the way we perceive our environment. Therefore 3D tools such as laser scanning and photogrammetry will be tested in the field. Their application in the urban context and the workflow from scan to drawing will become known to the students.

This is the question that the teaching and research project Schnitt durch Zürich (Section through Zurich) has been investigating by the Chair of Laurent Staldner. As an Addition to the existing work, this course will create a section of the Uetliberg. In the course of methodical refinement 3D laser scanning and point cloud modeling methods, developed at the Chair of Christophe Girot and are used to digitally model the topography and vegetation as well as pathways and buildings. Following the data collection the materials will be transferred to common CAD Software and reproduced in a section. Students will use scanners to scan the slopes and forests of the Uetliberg in fieldwork and get introduced to the workflow from scan to CAD drawing. This should give a tool for a better understanding of the existing context in future projects and thus broaden the students’ methodological scope.

- Learning Materials and Software Tutorials will be provided during the classes.
- Students will generally work in groups of 2

The lectures will be held in English, assistance in English and German

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**Objective**

Can architecture, urban design and planning contribute to housing reconstruction after conflicts and natural disasters? Answers to this question will be provided by researchers and socially engaged architects from Europe, Asia and Latin America through the presentation of concrete case studies and projects.

**Content**

- General introduction: reconstruction approaches after conflicts and natural disasters
- Housing culture and post-tsunami reconstruction in Tamil Nadu, India
- Patterns of adaptation to culturally inadequate post-disaster housing
- Reconstruction challenges in rural and urban settings
- Housing reconstruction in rural and urban Nepal after the 2015 earthquake
- Rebuilding communities and schools in Haiti
- Learnings from postwar reconstruction in Kosovo
- Bottom-up housing initiatives in ongoing conflicts: the case of Ukraine
- Humanitarian planning: tackling emergency shelter needs.
- Housing initiatives in temporary camps

**Literature**

A bibliography will be made available to inscribed students prior to the start of the semester.

**Competencies**

- Analytical Competencies
- Problem-solving
- Communication
- Sensitivity to Diversity
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics

**Prerequisites / notice**

- Students will generally work in groups of 2
- The lectures will be provided during the course.

**Objective**

This elective course gives architecture students the opportunity to further develop their perception of space through a site-specific approach in the field of landscape architecture. The students will learn to use 3D point cloud technology and other spatial sensing technologies in order to analyze complex urban landscape and develop new ways of editing and representing these intertwined spaces.

**Abstract**

The elective course “Topology” in the Autumn Semester 2023 builds on a long standing specialization in the spatial exploration of the landscape. We will embark the participants on a terrain that we shape through our own thoughts and actions, adopting different perceptual perspectives, supported by examples from art, literature, technology and history.

**Content**

- Students will generally work in groups of 2
- The lectures will be held in English, assistance in English and German

**Competencies**

- Analytical Competencies
- Problem-solving
- Communication
- Sensitivity to Diversity
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics

**Prerequisites / notice**

- The lectures will be provided during the course.
Students will document and analyze a case-study site to reveal its topological potentials and sensory qualities. This understanding will be gained through point cloud modeling and audiovisual composition. In particular, we will develop a new, comprehensive sectional model of a topologically interesting site situation. Students will become acquainted with working with point cloud models produced with laser scanning. Through a series of steps, they will learn how a laser-scanning survey is conducted, how the raw data is processed, how point cloud models are assembled, and what qualities these models can provide for analyzing, exploring, and representing space as an audiovisual experience.

Collected samples from the field will be assembled and built into an interactive application in the «Landscape Visualization and Modelling Lab». All software required is open source and can also be installed on private laptops, facilitating work from home if necessary.

Lecture notes
- Literature will be provided during the course.

Prerequisites / notice
- The course is limited to 20 students (based on available computer stations)
- Students will work in groups of 2
- The lectures will be held in English, assistance in English and German
- The enrolment will be prioritized by the time of inscription and balanced between departments

Competencies

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052-0737-24L My Garden’s Boundaries are the Horizon: A Case Study of Queer Gardens

W 2 credits 2S C. Baumann

Abstract
This course aims to raise awareness about the necessity to look at architectural history through a non-normative lens. The participants will be invited to explore the topic of queer gardens via the review of exemplary case studies. We will discuss how the shape of those gardens have been influenced by their owner’s personality and argue if such spaces share a common denominator.

Objective
Participants will conduct an analysis of case studies through the means of archival and iconographical research. They will also redraw the gardens in plans and sections in order to understand the specificity of those spaces. They will be invited to sharpen their critical thinking and debate the topic of queer gardens: Can one define the spatial criteria of such a typology? Does such a genre even exist? The outcome of this weekly elective course will be a presentation of the selected garden along with pictures, plans, section, a brief descriptive text and a bibliography list.

Content
"My garden’s boundaries are the horizon" (1) is one of the first sentences used by Derek Jarman, the late English artist, filmmaker and gay rights activist in the book Modern Nature to describe his small garden located in Dungeness, south Kent. The diary depicts Jarman’s artist life, his ordeal dealing with AIDS as well as his love for gardening. The word garden comes from the etymology “to guard” and is by definition an enclosed outdoor space. What a contradiction then to describe a garden, as Jarman’s does, by the absence of its limits! Dungeness has emerged over time as an exemplary reference of queer garden, but does such a typology even exist? And if it does, what are its characteristics?

“Growing up queer means experiencing the destabilising absence of broad and accessible queer history”.(2) Architecture as well as landscape architecture are far from exempt from this reality and there are little stories about queer landscapes to be found in the textbooks. In order to bridge this knowledge gap, we will study the gardens of openly queer personalities of the 20th and 21st century. The case studies will include, but not limited to, the followings:
- Casa Azul, Frida Kahlo, Mexico
- Dungeness, Derek Jarman, United Kingdom
- Majorelle Garden, Yves Saint-Laurent and Pierre Bergé, Morocco
- Sissinghurst, Vita Sackville-West, United Kingdom
- Temple de l’Amitié, Natalie Clifford Barney, Paris
- Villa Gamberaia, Florence Blood and Princess Ghyka, Italy

(1) Modern Nature, The Journals of Derek Jarman, Derek Jarman, Paperback, 2018
(2) Queer spaces, an Atlas of LGBTQ+ Places and Stories, Adam Nathaniel Furman and Joshua Mardell (Eds), Routledge, 2022

Literature
A bibliography specifically focused on queer spaces will be given at the beginning of the semester.

Prerequisites / notice
The assessment will be based on the following criteria: quality of the research, critical thinking, participation in the group discussions, and quality of the final presentation.

The number of participants is limited to 20. A short letter of motivation via mail is expected for application.
### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: fostered
- Project Management: fostered

#### Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

#### Technology in Architecture

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>151-8015-00L</td>
<td>Moisture Transport in Porous Media</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>J. Carmeliet, A. Kubilay, A. Rubin, D. A. Strebel</td>
</tr>
</tbody>
</table>

#### Abstract

#### Objective
- Basic knowledge of moisture transport and related degradation processes in porous materials
- Knowledge of experimental determination of moisture transport properties
- Application of knowledge to moisture transport in cracked materials, drying of porous materials and microclimate in urban street canyons

#### Content
1. Introduction
   - Moisture damage: problem statement, durability
   - Applications: building materials, soil science, geoscience
2. Moisture transport: theory and application
   - Description of moisture transport
   - Determination of moisture transport properties
   - Exercises on moisture transport properties
3. Special topics
   - Liquid transport in cracked materials, Drying of porous materials, Microclimate in urban street canyons

#### Literature
Handouts, supporting material and exercises are provided online via Moodle.

#### Competencies
- Subject-specific Competencies: Concepts and Theories: assessed, Techniques and Technologies: assessed
- Method-specific Competencies: Analytical Competencies: assessed, Decision-making: assessed, Problem-solving: assessed
- Social Competencies: Communication: fostered, Cooperation and Teamwork: fostered

---

### An Introduction to Sustainable Development in the Built Environment

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>101-0577-00L</td>
<td>An Introduction to Sustainable Development in the Built Environment</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>G. Habert, E. Zea Escamilla</td>
</tr>
</tbody>
</table>

#### Abstract
In 2015, the UN Conference in Paris shaped future world objectives to tackle climate change. This decarbonization strategy is additional to Sustainable Development goals formulated the same year by the UN general assembly.

What does that mean for the built environment? This course provides an introduction to the notion of sustainable development when applied to our built environment.
At the end of the semester, the students have an understanding of the term of sustainable development, its history, the current political and scientific discourses and its relevance for our built environment.

In order to address current challenges of climate change mitigation and resource depletion, students will learn a holistic approach of sustainable development. Ecological, economical and social constraints will be presented and students will learn about methods for argumentation and tools for assessment (i.e. life cycle assessment).

For this purpose an overview of sustainable development is presented with an introduction to the history of sustainability and its today definition as well as the role of cities, urbanisation and material resources (i.e. energy, construction material) in social economic and environmental aspects.

The course aims to promote an integral view and understanding of sustainability and describing different spheres (social/cultural, ecological, economical, and institutional) that influence our built environment.

Students will acquire critical knowledge and understand the role of involved stakeholders, their motivations and constraints, learn how to evaluate challenges, identify deficits and define strategies to promote a more sustainable construction.

After the course students should be able to define the relevance of specific local, regional or territorial aspects to achieve coherent and applicable solutions toward sustainable development.

The course offers an environmental, socio-economic and socio-technical perspective focussing on buildings, cities and their transition to resilience with sustainable development. Students will learn on theory and application of current scientific pathways towards sustainable development.

The following topics give an overview of the themes that are to be worked on during the lecture.

- Overview on the history and emergence of sustainable development
- Overview on the current understanding and definition of sustainable development and beyond

Methods
- Method 1: Life cycle assessment (planning, construction, operation/use, deconstruction)
- Method 2: Life Cycle Costing
- Method 3: Labels and certification
- Method 4: Material Flow Analysis

Main issues:
- Operation energy at building, urban and national scale
- Mobility and density questions
- Embodied energy for developing and developed world
- Synthesis: Transition to sustainable development

052-0615-24L Building Process: Realization

Enrolment is only possible in agreement with the lecturer (eglin@arch.ethz.ch).

Abstract
Visits to construction sites and interdisciplinary lectures on the topics of communication, complexity, landscape and investment are the main focus of the workshop. In addition, the term process is to be depicted by means of visits to manufacturers of construction components.

Objective
The main focus of the diploma elective subject is in showing the building process by means of current examples of urban design with architectural relevance. The Chair views itself as the facilitator between those involved in construction and students. Active participation is a prerequisite.

Content
The main focus of the diploma elective subject is in showing the building process by means of current examples of urban design with architectural relevance. Visits to construction sites and interdisciplinary lectures on the topics of communication, complexity, landscape and investment are the main focus of the workshop. In addition, the term process is to be depicted by means of visits to manufacturers of construction components. The Chair views itself as the facilitator between those involved in construction and students. Active participation is a prerequisite.

Lecture notes
The recordings of the lectures are available on the MAP under the link https://map.arch.ethz.ch (book symbol at the top right).

Prerequisites / notice
The number of participants is limited and enrolment is only possible in agreement with the chair!

Introductory event: Participation in the introductory event is a prerequisite for this course!
Structure (Lectures, field work, final presentation) will be communicated in time.

052-0629-24L CAAD Practice: Favela is City

Favelas – the Brazilian version of informal cities – are no longer exceptions but the massive mode of urban production in the XXI Century. They are informal by nature - if you call it 'informality', the ambiguity between instant stability and constant change.
This Online course provides an introduction to climate-responsive design using the Hive tool and how to apply it in early building design. It will foster a background of historical knowledge and architectural culture. Develop a critical reflexion on tools and methods of digital design.

**Objective**
1. To gain insight into informal urbanism and the prominent urban phenomenon of favelas, their inherent informality, dynamic nature, and the interplay between stability and change.
2. To develop the ability to decode the intricate fabric of favelas, to read the interrelationships between various elements, resources, and the nuanced rhythms of signals, noises, and uncertainties that define their urban landscapes.
3. To gain familiarity with AI algorithms as tools for exploring and interpreting favelas, employ images and textual analysis to uncover urban themes and issues these informal settlements embody.
4. To develop critical thinking skills, encouraging a deeper exploration of the underlying social, economic, and cultural factors at play.
5. To gain broader insights and generalizations from the study of favelas, to identify overarching principles that can contribute to the discourse on urbanism and informal settlements.
6. To enhance design fluency, effectively communicating complex ideas and interpretations through images and words, refining the ability to conceptualise and share favela ideas.
7. To develop the ethical dimensions of studying and representing informal urban environments.

**Content**
Students will learn and engage with various modes of engagement with favelas using visual and written forms, becoming familiar with AI techniques and strategies to tackle both. By the end of the semester, students should have broadened their understanding of impoverished urban areas of the South and a clearer perspective on urban trends and opportunities in those areas. Using texts and images will develop competencies to be more effective visual communicators, understanding how to generate and manipulate images and text to express their ideas confidently, clearly, and precisely. Throughout the semester, students will write around 1000 to 2000 words and create self-organising maps using internet-sourced images guided by provided algorithms. Self-organising maps (SOMs) are an artificial neural network that helps visualise and group complex data by finding patterns and similarities, making it easier to understand and analyse large sets of information. Thus, a significant portion is dedicated to the data's curation, editing, and publishing of the final assignment: a speculative exhibition that includes a poster and catalogue with a curator's readings of favelas.

**Prerequisites / notice**
No previous knowledge is required for joining this course.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
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<tr>
<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Media and Digital Technologies</td>
<td>Sensitivity to Diversity</td>
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**052-0639-24L Climate Responsive Architecture with Hive**

**Abstract**
This Online course provides an introduction to climate-responsive design using the Hive tool and how to apply it in early building design stages. Hive allows architecture and building science students to understand the relation between architectural design, climate, comfort and energy. Hive is a plugin for the 3D modeling environment Rhino and its visual programming interface Grasshopper.

**Objective**
- Recall general principles of climate responsive design and examples of it.
- Utilize 3D building geometries to conduct simplified energy demand and supply simulations.
- Observe relevant physical principles and interactions between climate, energy and geometry.
- Implement passive and active concepts for Climate Responsive Design.
- Apply Hive for building design analysis and integrate it into own designs or in design courses.
- Identify and harness synergies and trade-offs between climate, energy and architectural design aspects.

**Content**
The course can be frequented individually, or as a prerequisite for other courses such as the master course Climate and Energy Systems 3 or architectural design studios. Modules:
1. Course overview.
2. Introduction to climate responsive design.
3. Introduction to Rhino, Grasshopper and Hive.
4. Early solar analyses.
5. Passive Solar Design (e.g. Fixed and movable shading).
6. Active Solar Design (e.g. Using Photovoltaics).
7. Real-world Applications and Examples.

**Prerequisites / notice**
A working Rhino 6 or 7 license is necessary.

**052-0641-24L Digital Lexicon**

**Abstract**
The seminar focuses on the etymology and use of terms. It engages students to interrogate words and notions in order to understand the historical and theoretical implications related to the digital. The seminar aims to be a collective and shared work through the edition of a common lexicon.

**Objective**
Enlarge a background of historical knowledge and architectural culture. Develop a critical reflexion on tools and methods of digital design. Foster writing and synthesis skills and organize a collective publication.

**Content**
- Is digital design a tool, a language, a content, a style, a dogma? In the last four decades the digital turn had a radical impact in the field of architecture from the conception to the fabrication stage, through different ways of representing and simulating space. Despite its recent history and a substantial rapid evolution, digital design is also naturally in continuity with previous techniques of craftsmanship and traditional design.
- Digital, computer, analog, virtual, artificial intelligence, smart technology, virtual reality, parametric design, rendering, modelization, auralization: to only name some of the most widely employed terms. The proposed seminar focuses on the theoretical definition of a recent although already dense and evolving vocabulary related to digital design. Building on the etymology of chosen terms and borrowing from a selected bibliography, we will edit a collective lexicon tackling the historical roots and theoretical implications of our everyday language employed in relation to the digital.
The course is organised based on the Future Cities Laboratory (FCL) publication Indicia 03. Indicia 03 conveys the main research results of FCL and provides a platform for interdisciplinary knowledge exchange and critical thinking crossing domains.

The course consists of 12 colloquiums with specific themes that correspond to the chapters of Indicia 03. Each colloquium is joined by two to four external experts and FCL Global researchers from different disciplines to present their work. Moderated dialogues (debates and discussions) encourage students to explore the interrelationship between actions and guidelines as described in Indicia 03.

These include but are not limited to:
- Dialogue 1: Design Liveable Density
- Dialogue 2: Plan Variable Flows
- Dialogue 3: Partner with Nature
- Dialogue 4: Adopt Open Processes
- Dialogue 5: Harness Cyber-Physical Interactions
- Dialogue 6: Stimulate Diverse Economies
- Dialogue 7: Build Well
- Dialogue 8: Foster Settlement Systems
- Dialogue 9: Waterfront Tanjong Pagar: An Exploration in Transformative Design Research
- Dialogue 10: Cooling Singapore: Towards Urban Climate Design and Management
- Dialogue 11: Bioregion Java
- Dialogue 12: The Pandemic City

At the end of the course, students write an essay of 2,000 to 3,000 words based on one of the dialogues. The essays reflect the specific research content and actions described in Indicia 03 and address students' insights into sustainable urban development.

This elective course is organised with a focus on FCL Global research contents. We provide digital copies of the Indicia 03 for the students attending the course. The format of the course is physical (at ETH Hönggerberg) and virtual. It will be open to all researchers and students in FCL Global, D-Arch, and D-Baug.

The course examines how headphones and loudspeaker systems make electroacoustics and their application in room acoustics simulation and auralisation, a tool for acoustic design in architecture. It provides the software and hardware tools to measure and analyse the acoustics of existing spaces and how to design and predict the acoustics of modelled spaces. The course provides a comprehensive understanding of acoustics and its practical applications in architecture, enabling students to apply their knowledge of acoustics in real-world scenarios.

Lectures by guest speakers round up the content and broaden the focus outside the box. Finally, the course concludes with a short semester thesis, allowing students to apply their acquired knowledge to a small design project.

The course format is a 1-hour lecture and a 2-hour hands-on exercise session.

Lecture notes are provided every week through the course's website.

The course takes place in the Immersive Design Laboratory (IDL) at HIT F22.
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### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: fostered

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

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**063-0661-24L Integrated Discipline HS24 in the Field of Technology in Architecture (ITA)**

*Enrolling in this course is only possible on agreement with the lecturer and if you attend a design course (V-IX) at the same time.*

**Abstract**

This part of the curriculum addresses design work in different areas of architecture and urbanism and integrates the knowledge acquired in previous years. It involves the active participation of specialists from the chairs of the institute ITA.

**Objective**

Understanding of the importance of the ITA disciplines for architectural design and integration of structural thinking into the design process.

**Content**

This part of the curriculum addresses design work in different areas of architecture and urbanism and integrates the knowledge acquired in previous years. It involves the active participation of specialists from the chairs of the institute ITA.

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**Table: Integrated Discipline HS24 in the Field of Historic Building Research and Conservation (IDB)**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<td>063-0961-24L</td>
<td>Integrated Discipline HS24 in the Field Historic Building Research and Conservation (IDB)</td>
<td>W</td>
<td>3</td>
<td>2A</td>
<td>Supervisors</td>
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</table>

*Enrolling in this course is only possible on agreement with the lecturer and if you attend a design course (V-IX) at the same time.*

**Abstract**

The formal framework needs to be discussed with the staff members.

**Objective**

A study in building research and preservation of building heritage with a clear topic.

---

**052-0913-24L Preservation: Exhibiting and Communicating**

*W 2 credits 2S S. Langenberg, A. Koller, A. Ruby, Y. Shinozaka*

**Abstract**

In addition to theory, heritage conservation also plays an important practical role in the current building revolution. In order to make the diverse possibilities in architecture visible, this course develops new strategies for communicating the discipline of monument preservation for an exhibition on this topic at S AM in 2025.

**Objective**

The aim of the seminar is to develop concepts for communicating and exhibiting heritage-related content and debates that go beyond specialist discourse and address a broader public. As part of the course, participants will acquire in-depth knowledge of various exhibition strategies in the field of architecture and will have the opportunity to develop exhibits for an exhibition organised by the S AM Swiss Architecture Museum (Basel) in collaboration with the Chair of Construction Heritage and Monument Preservation at ETH Zurich and ICOMOS Suisse in spring 2025.

**Content**

At a time when the maintenance of existing buildings is seen as an essential element of the building revolution, the theory and practice of heritage conservation is taking on an integral role. Nevertheless, heritage conservation still has to contend with image problems: people often misunderstand exactly what its aim is and, unaware of its mission, principles and (still highly topical) theories, the discipline is often assumed to have a purely conservative attitude. 50 years after the European Year of Monument Conservation in 1975, when the whole of Europe was dominated by the question of how to preserve the built heritage, there is no need for a fundamental repositioning, but there is certainly a need for an “update” on issues of monument conservation and its attitude in the face of current challenges. The joint exhibition at the S AM Swiss Architecture Museum in spring 2025 is dedicated to this topic. The course offers the opportunity to deal with architectural exhibition strategies and to participate in the development of various concepts for communicating the theory and practice of heritage conservation. New guiding principles for the future practice of heritage conservation will be jointly derived on the basis of best practice examples. In group work, current examples of successful cooperation between heritage conservation and architecture will be analyzed and documented for presentation in the exhibition in the form of drawings, texts and models. Depending on the number of participants, other parts of the exhibition can also be the subject of the work.

**Prerequisites / notice**

The course addresses primarily students of the MAS ETH in Denkmalpflege und Konstruktionsgeschichte and the CAS ETH in Future Heritage.
### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: fostered
- Project Management: fostered

#### Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### Abstract

Complex constructions that are difficult to maintain and industrial manufacturing processes decrease the lifespan of objects not only in product design but also in architecture. Repairability is becoming less of a concern – replacement seems to be the norm. We need to rethink the way we build, starting already with the planning phase.

### Objective

In this course, we combine traditional topics of preservation with concepts of repair and FAB initiatives to raise awareness for sustainable thinking and action. Students will learn both traditional and digital methods as well as the basic building and material criteria for repair. The objective is not only the hands-on repair of a building part but especially to learn about the concepts of heritage preservation.

### Content

The elective course will discuss and examine the reparability of constructions and building systems. Students will identify building parts in need of maintenance and subsequently develop a repair concept. In groups, they will carry out the repair under expert guidance or possibly with the aid of digital fabrication processes. The objective is to recognize and analyze mechanisms of deterioration and to propose adequate repair measures.

### Literature

- Baier, Andrea u. a. (Hg.), Die Welt reparieren, Bielefeld 2016.
- Krebs, Stefan u. a., Kulturen des Reparierens, Bielefeld 2018.
- Langenberg, Silke (Hg.), Repair. Encouragement to Think and Make. Berlin 2018.

### 052-0915-24L Building Surveying and Building Archaeology

**W 2 credits 2G**

**S. Langenberg**

*Does not take place this semester.*

- Abstract
  Surveying and measuring technologies in historical building archaeology. Case studies on building archaeology.

- Objective
  Basic understanding of different surveying methods and first practical contacts with technical surveys instruments. Understanding of the procedures and aims of building archaeology.

- Content
  From folding rule to laser scanner: surveying techniques and their possible applications.

  The elective subject "Building Surveying and Building Archaeology" covers surveying and measurement methods ranging from simple hand measurements and tachymetry to laser scanning, terrestrial and drone-based photogrammetry (structure from motion) and other non-invasive assessment methods such as thermal imaging. The different methods and technologies will be presented on the basis of current or completed research projects and their practical applications will be discussed. Internal and external guest speakers will report on their latest research projects in the field of building research and construction history. In the course of the elective, students will also have the opportunity to try out the methods themselves and integrate them into a small concluding project of their own.

  The course is composed of theoretical and practical parts in and outside the classroom.

- Literature
  Will be announced in the course for the individual lectures.
### Competencies

**Subject-specific Competencies**
- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Social Competencies**
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Media and Digital Technologies
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Personal Competencies**
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

### Focus Works

*see Architecture MSc “Focus Work”*

### Seminar Weeks

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>052-1205-24L</td>
<td>Seminar Week Autumn Semester 2024</td>
<td>W</td>
<td>2</td>
<td>3A</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

**Abstract**
The seminar week is obligatory for students of all semesters. There are many and varied study contents. The students will be enabled to discuss narrowly formulated factual questions in small groups and in direct contact with the professors.

### Science in Perspective

*see Science in Perspective: Type A: Enhancement of Reflection Capability*

**Recommended Science in Perspective (Type B) for D-ARCH**

### Language Courses

*see Science in Perspective: Language Courses ETH/UZH*

### Architecture Bachelor - Key for Type

| O   | Compulsory                           | E-   | Recommended, not eligible for credits |
| W+  | Eligible for credits and recommended | Z    | Courses outside the curriculum       |
| W   | Eligible for credits                 | Dr   | Suitable for doctorate               |

#### Key for Hours

| V   | lecture                           | P    | practical/laboratory course        |
| G   | lecture with exercise             | A    | independent project                |
| U   | exercise                          | D    | diploma thesis                     |
| S   | seminar                           | R    | revision course / private study    |
| K   | colloquium                        |      |                                    |

**ECTS**
European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
### History of Art and Architecture V: Caractère

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<thead>
<tr>
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<th>Hours</th>
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**Abstract**
This course is a reading class in which the architectural category of 'caractère' or character - a key concept in the 18th century but of great relevance until today - will be examined by a close reading of several key texts, from the late 1700s up until today. Independent reading and vivid discussion in class make up this course’s character.

**Objective**
Deepen basic knowledge, improve ability to critically read and analyze texts of architectural theory, and understand shifts in architectural thinking.

**Content**
'Caractère' or character is not only a quality applied to human beings. It is also a category of architectural discourse, developed in the 18th century when architects and theorists were seeking new ways to talk about and judge buildings, pushing architectural discourse beyond Vitruvian categories to which it had been tied for centuries before.

This reading class will closely examine key texts that discuss the phenomenon of a building's 'character' from the 1700s up until today. The weekly assigned texts (in the original French, English or German) will be read at home and then discussed in class. Independent reading and vivid participation in class are a fundamental prerequisite. In addition, there will be weekly written assignments, which will all be graded. A final written assignment at the end of the semester will be graded as well. To pass the course, students will have to read each assigned text, and hand in all written assignments on time.

**Competencies**

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Assessments</th>
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<td>Subject-specific Competencies</td>
<td>assessed</td>
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<tr>
<td>Method-specific Competencies</td>
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### History of Art and Architecture VII: Burning Down the House: Architecture and Political Dissent

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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**Abstract**
Through the close reading of specific case studies, this lecture course will examine how architecture’s capacity to embody meaning is perhaps most explicit when it is violently destroyed through political dissent.

**Objective**
Deepen an understanding of political meaning in architecture including the methods and materials by which one can precisely research such meaning.

**Content**
When we talk about meaning in architecture we often begin with the architect, the patron or any number of contingencies which shaped a particular building's construction. But it is perhaps when architecture is violently destroyed that its capacity to embody meaning is most explicit. During acute periods of political dissent certain buildings have such a palpable entanglement with oppression that for certain groups their elimination almost becomes a necessity. In such moments architecture is suddenly transformed from an apparatus of control to an instrument of rebellion.

Whether it is the burning of the 3rd precinct headquarters of the Minneapolis police after the murder of George Floyd or the storming of the Bastille, there is no ambiguity here. Stones, concrete and plaster become so loaded that all involved know precisely why they are raising them to the ground. When Black Jamaicans burnt down Morant Bay courthouse in 1865, they were very consciously attacking an object of imperial control. And when suffragette women bombed baroque churches in Britain they were bringing the fight to a religious-political structure which refused to give them the vote. In many of these cases, recourse to violence came only after it was clear that polite pleading was all too inadequate.

Each week we will look in detail at the violent destruction of a specific building through political dissent. Where available we will turn to textual sources which record the voices of those who were committed to violent dissent against architecture but we will also recognise certain cases as acts of direct political speech through architecture by those to whom printed representation was not available.

This course is a combined lecture and discussion class. There will be short set texts to read each week. Active in-class participation in the discussion is required. The final assignment is a short written research assignment which will be due during the exam period.

**Literature**
Scans of the readings relevant to each week’s case study will be available on the course Moodle page.
This lecture series aims to introduce students to specific contemporary urban (design) conditions. The lecture series examines historical, political, and environmental challenges of our time become prominent and urgent, and that most often shape the condition wherein architects, landscape architects, and urban designers have to operate. From climate change to segregation, and from the housing crisis to pandemics, all these become visible and tangible within cities, challenging its inhabitants.

It is, nevertheless, valuable to examine the ‘urban’ condition today, as it is in the urban territory – in all its diversity – that the societal, political, and environmental challenges of our time become prominent and urgent, and that most often shape the condition wherein architects, landscape architects, and urban designers have to operate. From climate change to segregation, and from the housing crisis to pandemics, all these become visible and tangible within cities, challenging its inhabitants.

In this course, which is offered by the Chair of the History and Theory of Urban Design (Avermaete) as part of the History and Theory of Architecture IX lecture series, students will be introduced to a variety of themes that are at stake in today's urban condition. Getting to understand these circumstances is a prerequisite for any architectural engagement with the city. The starting point of this lecture series is the claim that the built environment conditions its use, and thus forms the condition of human, societal, and political life.

Throughout this course, the lectures will explore perspectives upon the urban condition from a historical, political and social perspective, as well as reflections from philosophy, and urban geography. It urges how design and design research can contribute to the understanding of and intervening in the urban territory, to establish a more just urban condition.

This course offers a survey of several theories of urban design through a series of thematic lectures. The aim of the lectures is to address conceptual and methodological aspects of urban design, and to explore the role of theories in the development of urban design practices.

Throughout this course, the lectures will explore perspectives upon the urban condition from a historical, political and social perspective, as well as reflections from philosophy, and urban geography. It urges how design and design research can contribute to the understanding of and intervening in the urban territory, to establish a more just urban condition.

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### History and Theory of Architecture IX: Prehistory in Architecture. The Past Today

**W 1 credit 1V M. Gnehm**

**Abstract**

Is our Age of Algorithms the new Stone Age? The lecture course discusses such parallelization in architectural theory and practice from the nineteenth century to the present day.

**Objective**

The course conveys tools for the critical assessment of references to history in their theoretical and practical application in architecture.

**Content**

The "invention" of the term "prehistoric" and its corollaries such as "primal history" in the early nineteenth century shaped an image of science that architecture still reflects today. Architectural historicism was confronted with new depths of time, modernism was inspired by new conceptions of origin. The "return to origins", whether as a means of reflecting on historical truth or primal creativity, gave rise to a panoply of architectural manifestations and theoretical approaches. Architectural prehistory is often associated with a "prearchitectonic" world that articulated itself for instance in caves. However, when literary scholar Ann Bergren or philosopher Elizabeth Grosz speak of "prearchitectural" conditions, they are referring to a kind of mythical time in the sense of an eternal truth rather than to a long gone historical period. These positions seem to run parallel to the presence of archaisms in modern and contemporary architecture.

Topics of the lecture course include Gottfried Semper's reflections on "antediluvian" societies and "prearchitectonic" cultural techniques; Walter Benjamin's "primal history of the nineteenth century"; nineteenth-century Egyptomania and twentieth-century reappraisals of Mayan architecture; the new Swiss sense of deep time that was awakened by the mid-nineteenth-century discovery of lacustrine dwellings on Switzerland's lakeshores and echoed in Le Corbusier's self-fashioning as a noble savage; Sigfried Giedion's pondering on today's loss of an environment which resembles the catastrophes that once buried prehistoric life.

**Literature**

For syllabus and readings, see [https://www.gta.arch.ethz.ch](https://www.gta.arch.ethz.ch)

### Intersectional Histories: How Architectures Were Also Made

**W 2 credits 2G A. Hultzsch**

**Abstract**

From a ‘cottage’ in Chile, a ‘tea equipage’ in London, a ‘veranda’ in Mumbai, to a ‘cathedral’ in Strasbourg, this course presents global entanglements of built spaces while asking who we listen to when forming our understanding of architectural histories. By combining intersectional history with reception history, we ask: how and by whom were architectures also made?

**Objective**

This course encourages students to critically reflect on the relevance and critical importance of historical research for the present and the future. By completing this course, students will:

- develop an understanding of history as a living practice that shapes our present and future,
- deepen knowledge about local and global entanglements of buildings and objects,
- learn about concepts such as intersectional feminism, coloniality and decolonization,
- become familiar with historiographic methods such as the global microhistory or collaborative reading,
- improve both analytical and speculative writing skills.
Content

This course introduces students to intersectional history – how accounts of the past are shaped by intersecting privileges and marginalizations – as well as reception history – how the meaning of architecture is and has been shaped also by those who dwell in it and use it. It draws heavily on the research of the ERC-funded group WoWA – Women Writing Architecture. It will focus, as the project, on the 18th and 19th centuries, complicating European histories within colonial contexts, especially linking to Latin America and the Indian subcontinent. However, it will also reach beyond this time frame to bring in a wider context – up to the Renaissance and into the 20th century.

Through a set of lectures which are interspersed with exercises over the semester, students will engage with a diverse set of primary sources – texts, objects, sites – to actively re-think and re-read the past of the built environment. Lectures will present both theories and concepts such as intersectional feminism, critical race theory, (de- and post-) colonialism and coloniality, as well as showcase global microhistories of texts, objects, and sites that materialise the approach of intersectional histories. We reflect on what constitutes architecture – or architectures – from the point of view of the user, critic, and dweller. In several structured exercises, students will analyse an object, site, or text on both a micro and global scale, producing their own global microhistories over the semester. They will receive feedback and their work process and outcome will be graded.

Lecture notes

All readings will be available on Moodle.

Prerequisites / notice

This course is intended for students from the 5th semester onwards. Attendance is a key requirement.

Competencies

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<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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<td>Techniques and Theories</td>
<td>Decision-making</td>
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Field of Historic Building Research and Conservation

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<th>Lecturers</th>
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<tr>
<td>063-0901-00L</td>
<td>Construction History: The Construction Site and Its Technology</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>S. Holzer</td>
</tr>
</tbody>
</table>

Abstract

History of the construction site and its technology.

Objective

Introduction to Construction History and the so-called "building archeology": ability to perform a "close reading" of historic built fabric, based on an in-depth knowledge on historic production techniques, both in the workshop and on the construction site itself. The focus is on constructions in stone.

Content

- History of building production
- The autumn semester is primarily dedicated to building with stone: from quarrying to dressing and lifting. We consider tools, construction site technology such as scaffolding, centring and other temporary works, cranes. We study all types of stone constructions, from foundations to walls to vaults, from concrete-like rubble stone through small dressed stone to huge monoliths.
- The spring term lecture, conversely, is mostly dedicated to timber construction and to the evolution of structural concepts over time.

Lecture notes

PDFs of the lecture slides will be provided before the lecture. Furthermore, the audience will be granted access to recent journal articles and book chapters providing in-depth insight into the topics covered by the lecture.

Prerequisites / notice

This lecture will NOT be given by Prof. Holzer in the fall term 2024 (sabbatical). Rather, students are asked to listen to the recordings from fall 2023 (video.ethz.ch) and to have a look at the slides from 2023. Both will provide all information necessary to pass the exam.

However, there will be biweekly lecture-hall events during which topics from last year's lecture will be considered, questions answered, and some additional illustrative examples presented. This will include presentations by PhD students reporting from their ongoing research projects.
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Competencies

Subject-specific Competencies
Concepts and Theories  assessed
Techniques and Technologies  assessed

Method-specific Competencies
Analytical Competencies  assessed
Decision-making  fostered
Media and Digital Technologies  fostered
Problem-solving  assessed
Project Management  assessed

Social Competencies
Communication  fostered
Cooperation and Teamwork  fostered
Customer Orientation  fostered
Leadership and Responsibility  fostered
Self-presentation and Social Influence  fostered
Sensitivity to Diversity  assessed
Negotiation  fostered

Personal Competencies
Adaptability and Flexibility  assessed
Creative Thinking  assessed
Critical Thinking  assessed
Integrity and Work Ethics  fostered
Self-awareness and Self-reflection  assessed
Self-direction and Self-management  fostered

Case Studies Construction History and Building Preservation

063-0903-24L  W  4 credits  2G  S. Holzer

Abstract
Acquiring in-depth knowledge of construction history and building archeology by means of detailed study of selected historic monuments.

Objective
The participants will gain in-depth knowledge on the methodology of building archeology by means of the documentation and interpretation of real historic structures in on-site studies.

Content
We study historic constructions in German-speaking Switzerland (individual small groups, objects within 2 hrs public transport reach from ETH Hoenggberg). Each group will be assigned an individual tutor (PhD student) who will be present on-site, on individual appointment.

We will survey, document and analyze a historic construction, with particular attention to production traces, constructive detail and load-carrying system.

We will start with introductory classroom lectures and on-site teaching during the first third of the semester. This will be followed by individual investigations on site. The progress will be pinpointed in three critiques:
1) on site, with individual tutor
2) at institute, with professor and institute members
3) final delivery, at institute, with professor and all institute members

The detailed schedule of the case studies can be found here:

Lecture notes
Detailed instructions on on-site investigations, as well as manuscripts on the background, will be provided. It is mandatory to read them in due time!

Literature
Will be announced during the introductory lectures

Prerequisites / notice
This class will NOT take place in fall term 2024, due to prof. Holzer's sabbatical.

The class will start again in spring term 2025, with a new concept and topic (roof trusses instead of bridges).

Future Monuments

063-0911-24L  W  2 credits  2V  S. Langenberg

Abstract
Heritage conservation is dedicated to the preservation and protection of historical buildings. In this lecture, students will learn about the theoretical positions on historic monuments and the basics of preservation in practice.
Objective

In addition to active participation in the discussions, students will be asked to engage with a topic or object of their own choice in order to be able to develop and comprehensibly justify their own positions within the context of preservation. Our goal here is to foster students' communication skills and the culture of discussion.

Content

The responsible reconstruction and further development of the existing building stock requires knowledge and an understanding of the theoretical positions conservation and the basics of preservation in practice. The core course of spring semester 2024 conveys this knowledge to students with the help of selected writings and discusses them in the context of various guest lectures.

Literature

READING LIST

Monographs and edited volumes:

- Dehio, Georg, Kunsthistorische Aufsätze. München 1914
- ICOMOS Deutschland/ Österreich/ Luxemburg/ Schweiz (Hg.), Monumenta I: Internationale Grundsätze und Richtlinien der Denkmalpflege, Stuttgart 2012.
- Petzet, Michael und Gert Mader (Hg.), Praktische Denkmalpflege, Stuttgart/ Berlin/ Köln 1993.
- Schmidt, Leo (Hg.), Einführung in die Denkmalpflege, Darmstadt 2008.
- Wohlleben, Marion und Georg Mörsch, Georg Dehio und Alois Riegl - Konservie-ren, nicht restaurieren. Streitschriften zur Denkmalpflege um 1900, Basel 1988 (Bauwelt Fundamente 80)
- Hassler, Uta, Langfriststabilität. Beiträge zur langfristigen Dynamik der gebauten Umwelt, Zürich 2011
- Fundamentals and legal texts:
- Stadt Zürich Hochbaudepartement, Amt für Städtebau, Denkmalpflege und Archäologie (Hg.), Schulhäuser der Stadt Zürich. Spezialinventar Archäologie und Denkmalpflege, September 2008
- Stadt Zürich Hochbaudepartement, Amt für Städtebau (Hg.), Bauten, Gärten und Anlagen 1960 bis 1980. Inventarerergänzung, August 2013
- Denkmalpflegegesetzgebung in den Heimatkantonen der Kursteilnehmenden.
- Die Kunstdenkmäler der Schweiz
- INSA – Inventare der Heimatkantone der Teilnehmenden
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: fostered
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: assessed

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Field of Landscape Architecture and Urban Studies

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<tr>
<th>Number</th>
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<tr>
<td>063-0703-24L</td>
<td>Architecture of Territory: Territorial Design in Histories, Theories and Projects</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>M. Topalovic</td>
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</table>

Abstract

This lecture series sets up an agenda for widening the disciplinary field of architecture and urbanism from their focus on the city, or the urban in the narrow sense, to wider territorial scales, which correspond to the increasing scales of contemporary urbanisation. It discusses the concepts of territory and urbanisation, and their implications for the work of architects and urbanists.

Objective

The course will enable students to critically discuss concepts of territory and urbanisation. It will invite students to revisit the history of architects' work engaging with the problematic of urbanising territories and territorial organisation. The goal is to motivate and equip students to engage with territory in the present day and age, by setting out our contemporary urban agenda.

The lectures are animated by a series of visual and conceptual exercises, usually on A4 sheets of paper. All original student contributions will be collected and bound together, creating a unique book-object.

Content

The lecture series consists of 7 core lectures delivered by professor Milica Topalović, and 4 curated guest lectures highlighting a selected theme.

This fall, within the theme MY WEATHER, we will trace the uneven impacts of the environmental crises on the ground, and reflect on the entanglements of weather, atmosphere, and climate with the constructed environments and ecologies.

21. 09. 2023
On Territory
MILICA TOPALOVIĆ

28. 09. 2023
Architecture and Urbanisation
MILICA TOPALOVIĆ

05. 10. 2023
Methods in Territorial Research and Design
MILICA TOPALOVIĆ

19. 10. 2023
Title TBC
Guest lecture by MARCO FERRARI and ELISA PASQUAL – STUDIO FOLDER

02. 11. 2023
Planetary Urbanisation: Hinterland
MILICA TOPALOVIĆ

09. 11. 2023
Critical Walking
Curated walk by NAZLI TÜMERDEM

16. 11. 2023
Disappearance of the Countryside
MILICA TOPALOVIĆ

23. 11. 2023
Metropolitan Repair
MILICA TOPALOVIĆ

30. 11. 2023
Architecture is Climate
Guest lecture by ANTHONY POWIS and CHRISTINA SERIFI – MOULD

07. 12. 2023
Profiles of the Alps: Landschaft, Landscape, Paysage – Talschaft
Guest lecture by THOMAS KISSLING – STUDIO VOGT

14. 12. 2023
Our Common Territories: An Outlook
MILICA TOPALOVIĆ
The lecture series "Methods of Urban Research: Extended Urbanisation" presents the methodology of sociological analysis of territories of extended urbanisation. These territories, which have traditionally been beyond the sensorium of architecture and urban design professions provide important terrains for urban practice. The lecture series will bring together researchers that have been part of a long-standing research project on territories of extended urbanisation. They will present methods, experiences and findings from a great variety of territories of extended urbanisation.

The grading will be based on the attendance record and the three graded exercises.

The lectures will take place on Thursdays, 10.00-12.00, at ONA Fokushalle E7.

80% attendance is required (9 sessions out of 11). The A4 exercises created during the lectures will count toward the attendance record.

The A4 exercises created during the lectures will count toward the attendance record.

The grading will be based on the attendance record and the three graded exercises.

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The grading will be based on the attendance record and the three graded exercises.
Content

Introduction: Christian Schmid
Contesting the dispossession of Land and Nature. The Peripheralisation of Arcadia - Metaxia Markaki
The Horizontal Factory. The Operationalisation of the US Corn and Soy Belt - Nikos Kastikis
Loosing Sea. Abstraction and the End of the Commons in the North Sea - Nancy Couling
The Mine, the City and the Encampment. Contesting Extractivism in Eastern Amazonia - Rodrigo Castriota
Palm Oil and Extended Urbanisation in the Malaysian Hinterland - Hans Hörtig
Urbanisation en Route. The Lagos-Abidjan Corridor - Alice Herzog
Extended Urbanisation in Guateng, South Africa - Lindsay Howe
The Extended Urbanisation of Beijing - Yiqi Liu
The Highway Revolution. Enclosure and State Space in India - Nitin Bathia

Concluding Discussion

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Problem-solving assessed

Social Competencies
- Sensitivity to Diversity assessed

Personal Competencies
- Creative Thinking assessed
- Critical Thinking assessed
- Self-awareness and Self-reflection assessed

103-0569-00L European Aspects of Spatial Development

Abstract

Following the insight into historical perspective and contemporary models of governance and planning, the course focuses on the international dimension of spatial planning in Europe. This includes a discussion of how European spatial policy is made and by whom, how planners can participate in such process and how they can address transnational challenges of spatial development cooperatively.

Objective

Keeping the general aim of exploring the European dimension of spatial planning in mind, the specific course learning objectives are as follows:

- to interpret the history of spatial planning at the transnational scale
- to understand and explain the content of the European spatial policy agenda
- to describe and analyse the role of territorial cooperation in making European spatial development patterns and planning procedures
- to discuss the changing role of planners and evaluate the ways of their engagement in European spatial policy-making

Content

- European spatial policy agenda: introduction and basic directives
- governance models
- planning models; collaborative planning model (main concepts & critics)
- post-positivist approach to spatial planning
- transnational spatial planning in Europe; questioning the European spatial planning; spatial development trends in Europe
- EU as a political system: EU institutions & non-EU actors
- planning families in Europe; the European spatial planning agenda
- spatial planning strategies and programmes on territorial cooperation
- the notion of planning culture and planning system; planning cultures in Europe
- basic characteristics of planning systems in Europe
- the relevance of European transnational cooperation for spatial planning
- European transnational initiatives

Lecture notes

The documents for the lecture will be provided at the moodle.

Literature

Obligatory literature:

Recommended literature:
- Governance models:
- Planning models:
- EU as a political context:
- Territorial cooperation in Europe:
- Planning families and cultures:
- Planning systems in Europe:
Prerequisites / notice

Only for master students, otherwise a special permission by the lecturer is required.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making

Social Competencies
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-presentation and Self-reflection
- Self-direction and Self-management

Field of Technology in Architecture

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<tr>
<td>151-8007-00L</td>
<td>Urban Physics</td>
<td>W</td>
<td>3</td>
<td>3G</td>
<td>D. W. Brunner, H. Wernli</td>
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</tbody>
</table>

Abstract
Urban physics: wind, wind comfort, pollutant dispersion, natural ventilation, driving rain, heat islands, climate change and weather conditions, urban acoustics and energy use in the urban context.

Objective
1. Basic knowledge of the global climate and the local microclimate around buildings
2. Impact of urban environment on wind, ventilation, rain, pollutants, acoustics and energy, and their relation to comfort, durability, air quality and energy demand
3. Application of urban physics concepts in urban design

Content
- Climate Change. The Global Picture: global energy balance, global climate models, the IPCC process. Towards regional climate scenarios: role of spatial resolution, overview of approaches, hydrostatic RCMs, cloud-resolving RCMs
- Urban micro climate and comfort: urban heat island effect, wind flow and radiation in the built environment, convective heat transport modelling, heat balance and ventilation of urban spaces - impact of morphology, outdoor wind comfort, outdoor thermal comfort
- Urban energy and urban design. Energy performance of building quarters and cities, decentralized urban energy production and storage technologies, district heating networks, optimization of energy consumption at district level, effect of the micro climate, urban heat islands, and climate change on the energy performance of buildings and building blocks.
- Wind driving rain (WDR): WDR phenomena, WDR experimental and modeling, wind blocking effect, applications and moisture durability
- Pollutant dispersion. pollutant cycle : emission, transport and deposition, air quality
- Urban acoustics. noise propagation through the urban environment, meteorological effects, urban acoustic modeling, noise reduction measures, urban vegetation

Lecture notes
The course lectures and material are provided online via Moodle.

Prerequisites / notice
For MIBS Master students 151-8011-ooL Building Physics Theory & Application is a pre-requisit for this course or instructor permission. For others no prior knowledge is required.

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<td>063-0669-00L</td>
<td>Coding Architecture I</td>
<td>W</td>
<td>3</td>
<td>3G</td>
<td>G. Casas, F. Gramazio, H. Hassan, L. Wiedemeier</td>
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Abstract
"Coding Architecture I-II" is a programming class for architects with particular focus on demystifying technology - both software and hardware - and exploring the programmability of our world through powerful methods of digital, computational, and algorithmic design. This course welcomes students from all backgrounds, as no prior coding experience is required.

Objective
1. Understand essential concepts in programming and algorithmic thinking.
2. Understand and apply powerful methods of digital, computational and algorithmic design.
3. Apply digital technologies to design processes.
4. Ability to understand a problem and create a solution in algorithmic terms.
5. Ability to produce and implement novel and useful ideas.
6. Materialize ideas into the physical world.

Content
Lectures, tutorials and exercises will focus on:
* Advanced Grasshopper usage as a continuation of Computational Design III-IV course.
* Build up basic proficiency in programming using Python.
* Programming using Python within the design environment.
* Applications in architecture and digital fabrication.
* Familiarity with Grasshopper visual programming is expected.

Autumn Semester 2024
The course "Architektur und Tragwerk" represents an opportunity for architecture students to develop a design project in which load-bearing structures and architectural space support and enhance each other as inherent parts of the same design process.

**Abstract**

The demonstration of economic considerations within the design and construction process of buildings is the main focus of the diploma elective subject. The economic factors of building construction are examined and the specific decision process is simulated.

**Objective**

To grasp the coherences of costs, income and income return.

**Content**

To participate in this course it is recommended that the student has previously taken the courses Tragwerksentwurf I-IV.

**Literature**


Further information: http://www.bauprozess.arch.ethz.ch/education/MSc/BauprozessOekonomie.html

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

- **Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management

- **Social Competencies**
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Sensitivity to Diversity
  - Negotiation

- **Personal Competencies**
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

**Prerequisites / notice**

ITA Pool - information event on the courses offered at the institute ITA: Wednesday 7th September 2022, 10-11 h:

Room: HB Open Space 2 (HIB E52) or online. Zoom link: https://ethz.zoom.us/j/6684810727

Your presence on the first course day is obligatory!
This course presents the potentials of combining graphic statics with computational tools.

- Use statics graphic for the form finding and analysis of structures.
- Understand the goal and structure of an algorithm.
- Create algorithms based on graphic statics to explore equilibrium systems.
- Explain the potential of studying graphic statics models using computational tools.
- Use Interactive Graphic Statics (IGS2) for the analysis, form finding and design of 2D structures.
- Apply computational graphic statics in design contexts.
- Basic use of Rhinoceros and Grasshopper.
- Demonstrate elementary skills in Python scripting.

This course presents new structural design opportunities that emerge when graphic statics, an intuitive equilibrium-based method for the form-finding, analysis and design of structures, is combined with computational tools. After a review of graphic statics fundamentals and an introduction to basic parametric tools, the course focuses on studying different computational approaches to program graphic statics algorithms for the form-finding and analysis of structures, from linear (procedural) algorithms to programs with more complex data structures. More specifically, the students will create graphic statics interactive drawings using Grasshopper, read and code basic graphic statics algorithms using Python, and explore the design space offered by Interactive Graphic Statics (IGS2), a tool developed by the Block Research Group for the analysis, form-finding and design of 2D equilibrium structural systems. The practical potential and relevance of these methods will be demonstrated through various design-oriented tutorials and exercises.

"Skript Tragwerksentwurf I & II"

http://www.block.arch.ethz.ch/eg/course/4?lang=en

"Faустформel Tragwerksentwurf"
(Philippe Block, Christoph Gengangel, Stefan Peters, DVA Deutsche Verlags-Anstalt 2013, ISBN: 978-3-421-03904-0)

"The art of structures. Introduction to the functioning of structures in architecture"

"Form and Forces: Designing Efficient, Expressive Structures"

Prerequisites
ITA Pool - information event on the courses offered at the institute ITA: Wednesday 7th September 2022, 10-11 h:
Room: HIB Open Space 2 (HIB E52) or online. Zoom link: https://ethz.zoom.us/j/6684810727

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed
Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed

Personal Competencies
- Creative Thinking assessed
- Critical Thinking assessed

Architectural Design

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>063-0655-24L</td>
<td>Subject Semester HS24 (Fachsemester) in the Field of W Technology in Architecture (Schlüter)</td>
<td>W</td>
<td>14</td>
<td>29A</td>
<td>A. Schlüter</td>
</tr>
</tbody>
</table>

A student can only register once for a "Fachsemester" during the Master studies!

The application deadline for this "Fachsemester" is 4.9.2024, 8 p.m. You will receive a message about acceptance or rejection for the subject semester by 5.9.2024, 2 p.m. at the latest. Students who have been rejected have the opportunity to choose a design class (enrollment ends on 5.9.2024, at 6 p.m.).

In this subject semester, we explore the topic of zero-emission building design, which integrates aspects of energy, materials, technology, human behavior, and comfort into architectural design and seeks synergetic design solutions.

Upon successful completion of the subject semester, students will be able to identify concepts and relevant design parameters for zero-emission building design and develop integrated architectural design strategies. They will know how to select and use appropriate simulation and analysis tools to quantify and design solutions and will be able to visualize their concepts with both technical schematics and architectural drawings and visualizations.

The goal of the semester is to demonstrate the relationships between building systems and architecture and to find ways to manifest building systems in design.

Students begin with a research and mapping phase in which they first investigate various building systems for zero-emission building design. They then map the building systems with architectural parameters for successful interaction between the two and create a catalog of their findings.

After the research and mapping phase, students design a small building in which they explore how to maximize the interactions between the building systems and the architectural parameters. Finally, students attempt to quantify their design solutions using low-threshold modeling, simulation, and optimization tools such as Rhino/Grasshopper or Hive. To assess and discuss their concepts not only numerically but also architecturally and aesthetically, students also find appropriate forms of visualization.

Students document the process and results both numerically and architecturally, which are then discussed with a final jury.

All materials (lectures, tools, examples) are available on the **A/S Knowledge Platform**: https://moodle-app2.let.ethz.ch/course/view.php?id=11917

All materials (lectures, tools, examples) are available on the **A/S Knowledge Platform**: https://moodle-app2.let.ethz.ch/course/view.php?id=11917
Preparatory Semester Free Master Thesis HS24

Objective
Self-dependent development of a program, according to which one intends to realize a free master thesis in the following semester.

052-1201-24L
Preparation Semester for a self-determined Master thesis within the Department of Architecture of ETH Zurich.

063-0859-24L
Subject Semester HS24 (Fachsemester) in the Field of History and Theory of Urban Design (Avermaete)

Objective
The Research Studio has two main objectives:

1. Archaeology of Swiss Coloniality.

First, students will develop an ‘archaeology’ of the historical entanglements of Swiss industry with global colonialism. In this part, the studio work is understood as an archaeological venture, digging up traces of the past. Students will systematically probe the built environment of Switzerland for traces and influences of global colonialism and its aftermath. The result will be a catalogue of colonial entanglements, illustrating how they are inscribed into architectural and urban figures and how they continue to impact the urban fabric of Switzerland and its industry.

2. Processing Swiss Coloniality.

In a second step, students will attempt to ‘process’ the enduring impact of Swiss Coloniality. Based on the ‘Archaeology,’ students will explore the inherent logics of global colonialism in relation to Swiss industry as it impacts the present. The central idea is to avoid considering the past as a closed chapter, but as an ongoing process and condition of coloniality that still structures our present and future, which needs acknowledgement and dialogue. Students will be asked, using the tools of the architect, to explore strategies to represent these entanglements and suggest openings for repair where needed.

Based on these main objectives, this course will:
- offer students an overview of the most important historical and contemporary contributions to debates on postcolonial and decolonial theory and the entanglement of Switzerland’s industry with global colonialism;
- equip students to reflect critically upon the manifestations of Swiss Coloniality in the built environment with the help of both theoretical and historical perspectives;
- make students aware that the production of the city is not a neutral given but is always shaped by cultural values, assumptions, and expectations, which impact the everyday environment and, as such, condition inhabitants and users;
- help students to position themselves within current debates on cities, urban development, and urban life in relation to broader challenges such as sustainability and social inequality.

Content
Swiss Coloniality

Cities have never been isolated entities and have always existed by grace of the myriad connections with their hinterland. Throughout the past centuries, and especially since the 15th century onwards, these connections have become increasingly far-reaching across the globe, and the history of urban development in areas such as Europe has been intricately entwined with conditions and realities elsewhere. As such, urban history cannot be seen as entirely separate from global colonialism and its aftermath. While designing and constructing the architecture of the city, architects, urban designers, builders, and inhabitants also inevitably take part in the wider ecologies of material and immaterial flows that are shaped by and contribute to a global system of inequality. Not uncoincidentally, the metropole – a key term of colonial history – finds its roots in the political urban figure of the polis and identifies the center-periphery relationship between the ‘motherland’ and its hinterland. The metropole is the place from where power is exercised over foreign territories and the place that reaps the fruits of this exercising of power.

While Switzerland never had colonies of its own, it was nevertheless in many ways involved in and contributed to the history of global colonialism: by taking part in the economy sustained by colonialism, by financing and securing slave trade, by contributing to race-based science practices, etc. So, despite being a country without colonies, what if we consider Switzerland and its position in the world from the perspective of the colonial metropole? What would be the specific architectural and urban dimension of this figure of Metropole Switzerland? In raising such questions, in this Research Studio, we aim to focus on the entanglements of the architectural and urban histories of Switzerland and the history of global colonialism.

Starting to answer such questions requires a widened understanding of colonialism and its impact, which has been grasped with the notion of coloniality in recent debates. While colonialism refers to the historically specific phenomenon of one area of the world colonizing another, settling on foreign land, extracting its resources, and violently disciplining its inhabitants, the term coloniality refers to the more long-lasting processes and indirect effects that are the result of centuries of colonialism, and that mark a landscape of global inequality, even after the ‘official’ reign of colonialism has ended. In this sense, the disparity between the so-called ‘Global North’ and ‘Global South’, and the way in which a country such as Switzerland is still profiting from an advantageous position in this globally unequal world, can be considered the result of centuries of colonialism, and to be still part of a condition of coloniality. As this condition is a two-sided and mutually inductive phenomenon, to unravel the knot of Swiss coloniality, we not only aim to investigate how Switzerland was implicated in activities abroad but also, conversely, how these activities have impacted Switzerland. While in the fields of political, social and economic history, a revisionist effort is underway to reconsider/correct the image of Switzerland as a neutral country without colonies, in the field of architecture and urban history, however, we are yet to unravel the impact of this entanglement on the built environment, and, more widely, on the aesthetic, material and craft cultures of Swiss cities.

Apply with a brief letter of motivation by 8 p.m. on September 7, 2022 to: illias.hischier@arch.ethz.ch. Your participation in the subject semester will be confirmed by September 9, 2022.

Prerequisites / notice
The working mode is an individual design research studio with weekly group meetings and reviews. We expect good basic knowledge of sustainable construction and energy and climate systems. Prior experience in parametric design tools (e.g. Rhino) and/or simulation tools is a plus.

Please note that a student can only register once for a subject semester during the master's program!
The overarching hypothesis of this Research Studio is that historical and theoretical research can profit profoundly from the use of the tools and knowledge of architects. On the one hand, the spatial, formal, material, and constructive knowledge gained throughout architectural studies will guide the historical research in the archives, in the library, and/or in the city itself and will allow students to articulate specifically architectural interpretations of the materials they find. On the other hand, the Studio explicitly asks students to employ specific architectural tools such as drawing, writing and model-making to explore the historical and theoretical realities that are being investigated. By actively reflecting on the composition of a varied set of analytical and interpretative drawings, texts, and models, students will probe the capacity of these media to act as tools for historical and theoretical research.

Within the general theme of Swiss Coloniality, students will be guided to identify their own subtheme, which will require exploring their own specific research methodologies. These architecture-specific methodologies will be strategically chosen to discuss specific aspects of society: political, economic, social, cultural, or otherwise. Thus, conjoining these ‘autonomous’ and ‘heteronomous’ dimensions of architecture, a new understanding of the city and our built environment is developed that allows us to answer (some of) the research questions mentioned previously.

Research process

Students will be guided through three phases with different emphases: Definitions, Logics and Reinterpretations of Swiss Coloniality. The first phase, Definitions, is focused on developing an understanding of what the notion of Swiss Coloniality can entail and how it relates specifically to industry and the production of the city. This phase will allow students to become familiar with the historical and current entanglements of Switzerland with global colonialism and, by closely examining its main actors, practices, and materials, will set the stage for students to develop their own, individual research project.

The second phase, Logics, is about understanding and demonstrating the inner workings and mechanisms of Swiss Coloniality. Each of the students will focus on one specific case – a material, a site, an actor, a practice, etc. – and will examine it closely through targeted archival and library research, as well as through drawing, writing, and model-making.

In the third phase, Reinterpretations, students will formulate and investigate a hypothesis regarding the entanglements of Swiss industry with global colonialism. Based on this hypothesis, students will position themselves in relation to Swiss Coloniality, its history and its enduring impact. The position statement can take the form of a written text, architectural drawings and/or models and will be presented in the form of a student-curated studio exhibition and an online adaptation of it.

Course syllabus and reader will be made available during the course’s first week.

Further course information on https://avermaete.arch.ethz.ch/researchstudio

Students can register only once for a "Fachsemester" during the Master studies.

Enrollment will not take place through the D-ARCH website. To enroll for this Fachsemester please send an e-mail to sebastiaan.loosen@tga.arch.ethz.ch by Wednesday 6 September 2023, 8PM. If necessary, available places will be allocated firstly conform the A-B-C-studio priority system, and secondly, randomly. You will receive a confirmation by Thursday 7 September 2023, 12AM (noon). In case of over-applications, students who are not selected have the opportunity to choose a regular design studio through the D-ARCH website (enrollment ends on September 7, at 6 p.m.).

The Research Studio is self-dependent work and tutoring takes place on Tuesdays and Wednesdays.

Further course information on https://avermaete.arch.ethz.ch/researchstudio

Abstract

In slang, “peace out” means “goodbye”. It also relates to the word “peace” which is, today, rarely used and hard to focus on. This double-meaning is the entry point for our Fachsemester. Can peace, in our present time, only be imagined as something that is over or yet to come? Are art or architecture peaceful as such? Does something like violent art or architecture exist?

Objective

Our aim is to increase the knowledge and sensitivity of architecture students toward the history of art and architecture, to make their voices heard and to develop new teaching formats for the history and theory of architecture. Students will learn to take position in a field, they will practice argumentation and increase their skills in writing and presenting.
In slang, “peace out” means “goodbye”. It also relates to the word “peace” which is, today, rarely used and hard to focus on. This double-meaning is the entry point for our Fachsemester. Can peace, in our present time, only be imagined as something that is over or yet to come? Are art or architecture peaceful as such? Does something like violent art or architecture exist? Starting with a visit to the almost forgotten Paxmal, a monument for peace initiated exactly 100 years ago by Karl Bickel high over Walensee, we will dive into the history of pacifism and look backwards, forward and to the present.

The Fachsemester in HS 2024 will deal with issues of ethics and esthetics in the largest sense. The syllabus will contain articles and book chapters on philosophy, performance, political science, poetry and history. Students are invited to develop their own texts in relation to the overall topic.

Our aim is to increase the facility of students for understanding spatial, political and historical interrelations. We support students to develop their skills in writing and reading, to make their voices heard, and to experiment, together with the teaching group, with new educational forms for the history and theory of art and architecture.

The group will meet on Wednesdays 10-13 at Kunsthalle Zürich and Thursdays 10-13 in our office.

### Lecture notes

A Syllabus with source material for the lecture session will be provided.

### Competencies

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<tr>
<th>Subject-specific Competencies</th>
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<th>Personal Competencies</th>
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<td>Adaptability and Flexibility</td>
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<td>Techniques and Technologies</td>
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<td>Sensitivity to Diversity</td>
<td>Self-direction and Self-management</td>
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</table>

### Abstract

A History Research Studio fostering in-depth research where each student will propose and then develop their own individual project.

### Objective

The course will be organised in weekly meetings. We will begin with talks by researchers at Chair Delbeke, but we will mostly focus on discussing your findings and work, sharpening your tools of analysis and fostering the development of each project. Rather than individual ‘desk crits’, we will discuss each project collectively, in a round table, to enable mutual feedback and a more collective exchange of ideas. As each project develops, there will also be individual feedback sessions.

This Research Studio will teach you to be both historically and critically competent. By combining different historiographical approaches, you will develop the skills to articulate research questions, carry out appropriate primary and secondary study and you will be trained in academic research and writing.

### Content

Meaning in architecture is often a more fraught question than in painting or literature. Architecture’s non-figurative nature may not appear as easy to read as the iconography of a painting or the narrative of a novel, but buildings do mean things and this meaning is inflected through audience and time. At its creation, occupation, or even violent destruction, architecture can embody all sorts of specific identifiable meanings, for definable even antagonistic groups.

We are interested in meaning in architecture in the widest possible sense. This Fachsemester is a place where you can pursue your own research interests. You come to us with a topic and we will help you develop it from initial idea, through focused research, ending with a carefully edited essay which you will deliver as a lecture at the end of the course. Weekly discussions will be focused on your research and how you can most quickly develop your own expertise. Complimentary talks will be given by members of Chair Delbeke where they will explain how they have conducted their own research from initial idea to published paper.
A student can only register once for a "Fachsemester" during the Master studies!

Places for this "Fachsemester" are limited. If you are interested in taking part, please send us an email with a 300-word motivation letter including an initial topic proposal to: professur.delbeke@gta.arch.ethz.ch

If you already have a specific case study in mind, please describe what this is. If not, you can describe a general idea or area of interest and we will help you find a more specific object of study during the course.

Proposals are open but might include: decoding the iconography of a particular building, historically and ideologically placing the ideas of a particular architect, studying a performance and its architectural setting, explaining the significance of a building during a specific political event, or reconstructing how the ideas of a particular group or class shaped a particular building or architectural type.

Our sole stipulation is that most or at least part of your work will focus on the period before 1900.

Deadline for applications is Wednesday September 6, 8 p.m. You will receive a message about acceptance or rejection for the subject semester by Thursday, September 7, 2 p.m. at the latest. Students who have been rejected have the opportunity to choose a design class (enrollment ends on September 7, at 6 p.m.).

Feel free to get in touch with us over summer if you would like to discuss your proposal in advance.

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

**Social Competencies**
- Communication: assessed
- Cooperation and Teamwork: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

**Personal Competencies**
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

**Focus Work**

Realization in the respective fields of the institutes. Definition of topics by professors, in consultation with the students. The content may also refer to an elective course.

**Field of Historic Building Research and Conservation**

Definition of topics by professors, in consultation with the students (student’s proposal / content of an elective course).

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<td>063-0951-24L</td>
<td>Focus Work HS24 in the Field of Historic Building Research and Conservation (IDB)</td>
<td>W</td>
<td>6 credits</td>
<td>13A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

**Abstract**
Analysis of a single monument or a small group of interrelated monuments with the methods of archeological building research. Embedding of the objects studied into a context of construction history by means of archival and literature studies.

**Objective**
In-depth knowledge of the methods of archeological building research and construction history. Case-oriented in-depth knowledge of a selected historic building or construction type in its technical, social and economic setting and its architectural relevance.

**Content**
This study will require the in-depth analysis of a historic structure or a small group of structures. This includes an object documentation (survey drawings, photographic record, textual description). Contextual information to be researched by the methods of construction history (archival, literature).

**Prerequisites / notice**
The subjects can be proposed by the students. In consultation with the professors of architecture, the fixed topics are binding (see Art. 29 Reg. 201 MSc Architecture).

**Field of Design and Architecture**

Definition of topics by professors, in consultation with the students (student’s proposal / content of an elective course).

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>063-0551-24L</td>
<td>Focus Work HS24 in the Field of Design and Architecture (IEA)</td>
<td>W</td>
<td>6 credits</td>
<td>13A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

**Abstract**
IEA focus work, of which the content may also refer to an elective subject.

**Objective**
Development of skills and competences in a special area / sub-area of architectural theory or practice.
Content

In-depth work is carried out in the respective subject areas of the institute. The professors determine the topics in consultation with the students. The content of the in-depth work can also relate to the content of an elective course.

The performance assessment comprises either a purely written work with a subsequent oral examination or a creative, technical or graphic work, including a description, with a subsequent oral examination. At least in the case of one in-depth thesis, the performance assessment must take the form of a purely written work with a subsequent oral examination (Regulations Paragraph 2 Letter a). In formal terms, the written work must meet the criteria of an academic paper. In addition to the creative, manual or drawing part, it includes a written description of the question, the methodology and the possible gain in knowledge of the work.

The students take the oral examination with the professor with whom they have discussed the topic of the in-depth thesis.

The written or creative, manual or drawing work and the oral examination are each assessed individually. These two assessments are offset against each other and result in the overall grade for the in-depth work. Paragraph 7 remains reserved.

The oral examination can only be taken if the written work or the creative, technical or graphic work is sufficient.

A thesis is passed if the overall grade is at least 4.

It is considered not passed if the overall grade is below 4; if the written or creative, technical or graphic work is unsatisfactory and therefore the oral examination cannot be taken; in such a case, the failure will be noted with the term "dropout".

An in-depth thesis that has not been passed cannot be repeated. In order to acquire the required CP, a further in-depth work must be carried out and the performance must be assessed with an overall grade of at least 4. The number of attempts is limited (see regulations).

If more than one "in-depth study" course unit is not passed, the course is considered to have been definitively failed, which leads to exclusion from the course.

The creative, craft or drawing in-depth work is publicly exhibited. Purely written in-depth theses are made publicly available.

The topic is determined in consultation with the chosen professor.

Prerequisites / notice

The subject can be proposed by the students. In consultation with the professors of architecture, the fixed topics are binding (see Art. 29 Reg. 201 MSc Architecture).

### Field of History and Theory of Architecture

**Definition of topics by professors, in consultation with the students (student's proposal / content of an elective course).**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tr>
<td>063-0851-24L</td>
<td>Focus Work HS24 in the Field of History and Theory in W Architecture (gta)</td>
<td>W</td>
<td>6 credits</td>
<td>13A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

**Abstract**

Indentation work of the Institute gta, of which the content can also refer to an elective subject.

The topic is determined in consultation with the chosen professor.

**Objective**

Development of skills and competences in a special area / sub-area of architectural theory or practice.

In-depth work is carried out in the respective subject areas of the institute. The professors determine the topics in consultation with the students. The content of the in-depth work can also relate to the content of an elective course.

The performance assessment comprises either a purely written work with a subsequent oral examination or a creative, technical or graphic work, including a description, with a subsequent oral examination. At least in the case of one in-depth thesis, the performance assessment must take the form of a purely written work with a subsequent oral examination (Regulations Paragraph 2 Letter a). In formal terms, the written work must meet the criteria of an academic paper. In addition to the creative, manual or drawing part, it includes a written description of the question, the methodology and the possible gain in knowledge of the work.

The students take the oral examination with the professor with whom they have discussed the topic of the in-depth thesis.

The written or creative, manual or drawing work and the oral examination are each assessed individually. These two assessments are offset against each other and result in the overall grade for the in-depth work. Paragraph 7 remains reserved.

The oral examination can only be taken if the written work or the creative, technical or graphic work is sufficient.

A thesis is passed if the overall grade is at least 4.

It is considered not passed if the overall grade is below 4; if the written or creative, technical or graphic work is unsatisfactory and therefore the oral examination cannot be taken; in such a case, the failure will be noted with the term "dropout".

An in-depth thesis that has not been passed cannot be repeated. In order to acquire the required CP, a further in-depth work must be carried out and the performance must be assessed with an overall grade of at least 4. The number of attempts is limited (see regulations).

If more than one "in-depth study" course unit is not passed, the course is considered to have been definitively failed, which leads to exclusion from the course.

The creative, craft or drawing in-depth work is publicly exhibited. Purely written in-depth theses are made publicly available.

The topic is determined in consultation with the chosen professor.

### Field of Landscape Architecture and Urban Studies

**Definition of topics by professors, in consultation with the students (student's proposal / content of an elective course).**

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>063-0751-24L</td>
<td>Focus Work HS24 in the Field Landscape and Urban Studies (LUS)</td>
<td>W</td>
<td>6 credits</td>
<td>13A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

**Abstract**

Indentation work of the Institute LUS, of which the content can also refer to an elective subject.

The topic is determined in consultation with the chosen professor.

**Objective**

Development of skills and competences in a special area / sub-area of architectural theory or practice.

In-depth work is carried out in the respective subject areas of the institute. The professors determine the topics in consultation with the students. The content of the in-depth work can also relate to the content of an elective course.

The performance assessment comprises either a purely written work with a subsequent oral examination or a creative, technical or graphic work, including a description, with a subsequent oral examination. At least in the case of one in-depth thesis, the performance assessment must take the form of a purely written work with a subsequent oral examination (Regulations Paragraph 2 Letter a). In formal terms, the written work must meet the criteria of an academic paper. In addition to the creative, manual or drawing part, it includes a written description of the question, the methodology and the possible gain in knowledge of the work.

The students take the oral examination with the professor with whom they have discussed the topic of the in-depth thesis.

The written or creative, manual or drawing work and the oral examination are each assessed individually. These two assessments are offset against each other and result in the overall grade for the in-depth work. Paragraph 7 remains reserved.

The oral examination can only be taken if the written work or the creative, technical or graphic work is sufficient.

A thesis is passed if the overall grade is at least 4.

It is considered not passed if the overall grade is below 4; if the written or creative, technical or graphic work is unsatisfactory and therefore the oral examination cannot be taken; in such a case, the failure will be noted with the term "dropout".

An in-depth thesis that has not been passed cannot be repeated. In order to acquire the required CP, a further in-depth work must be carried out and the performance must be assessed with an overall grade of at least 4. The number of attempts is limited (see regulations).

If more than one "in-depth study" course unit is not passed, the course is considered to have been definitively failed, which leads to exclusion from the course.

The creative, craft or drawing in-depth work is publicly exhibited. Purely written in-depth theses are made publicly available.

The topic is determined in consultation with the chosen professor.
In-depth work is carried out in the respective subject areas of the institute. The professors determine the topics in consultation with the students. The content of the in-depth work can also relate to the content of an elective course. The performance assessment comprises either a purely written work with a subsequent oral examination or a creative, technical or graphic work, including a description, with a subsequent oral examination. At least in the case of one in-depth thesis, the performance assessment must take the form of a purely written work with a subsequent oral examination (Regulations Paragraph 2 Letter a). In formal terms, the written work must meet the criteria of an academic paper. In addition to the creative, manual or drawing part, it includes a written description of the question, the methodology and the possible gain in knowledge of the work.

The students take the oral examination with the professor with whom they have discussed the topic of the in-depth thesis. The written or creative, manual or drawing work and the oral examination are each assessed individually. These two assessments are offset against each other and result in the overall grade for the in-depth work. Paragraph 7 remains reserved.

If more than one “in-depth study” course unit is not passed, the course is considered to have been definitively failed, which leads to exclusion from the course.

The creative, craft or drawing in-depth work is publicly exhibited. Purely written in-depth theses are made publicly available. Exclusion from the course is only possible if more than one “in-depth study” course unit is not passed. The subjects can be proposed by the students. In consultation with the professors of architecture, the fixed topics are binding (see Art. 29 Reg. 201 MSc Architecture).

Taking place from 10.--28.1.22 in ONA G25.

### Field of Technology in Architecture

**Definition of topics by professors, in consultation with the students (student's proposal / content of an elective course).**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>063-0651-24L</td>
<td>Focus Work HS24 in the Field of Technology in Architecture (ITA)</td>
<td>W</td>
<td>6 credits</td>
<td>13A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

**Abstract**

Indentation work of the Institute ITA of which the content can also refer to an elective subject. The topic is determined in consultation with the chosen professor.

**Objective**

Development of skills and competences in a special area / sub-area of architectural theory or practice.

**Content**

In-depth work is carried out in the respective subject areas of the institute. The professors determine the topics in consultation with the students. The content of the in-depth work can also relate to the content of an elective course.

The performance assessment comprises either a purely written work with a subsequent oral examination or a creative, technical or graphic work, including a description, with a subsequent oral examination. At least in the case of one in-depth thesis, the performance assessment must take the form of a purely written work with a subsequent oral examination (Regulations Paragraph 2 Letter a). In formal terms, the written work must meet the criteria of an academic paper. In addition to the creative, manual or drawing part, it includes a written description of the question, the methodology and the possible gain in knowledge of the work.

The students take the oral examination with the professor with whom they have discussed the topic of the in-depth thesis.

The written or creative, manual or drawing work and the oral examination are each assessed individually. These two assessments are offset against each other and result in the overall grade for the in-depth work. Paragraph 7 remains reserved.

A thesis is passed if the overall grade is at least 4.

It is considered not passed if the overall grade is below 4; if the written or creative, technical or graphic work is unsatisfactory and therefore the oral examination cannot be taken; in such a case, the failure will be noted with the term “dropout”.

An in-depth thesis that has not been passed cannot be repeated. In order to acquire the required CP, a further in-depth work must be carried out and the performance must be assessed with an overall grade of at least 4. The number of attempts is limited (see regulations).

If more than one “in-depth study” course unit is not passed, the course is considered to have been definitively failed, which leads to exclusion from the course.

The creative, craft or drawing in-depth work is publicly exhibited. Purely written in-depth theses are made publicly available.

At least in the case of one in-depth thesis, the performance assessment must take the form of a purely written work with a subsequent oral examination.

The students can be proposed by the students. In consultation with the professors of architecture, the fixed topics are binding (see Art. 29 Reg. 201 MSc Architecture).

### Master’s Thesis

**Definition of topics by professors, in consultation with the students.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>063-0141-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>40D</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

Only students who fulfill the following criteria are allowed to begin with their master thesis:

a. successful completion of the bachelor programme;

b. fulfilling of any additional requirements necessary to gain admission to the master programme.

Ultimate deadline to unsubscribe or enroll for the Master Thesis is 23.10.2024.

Deleting a reservation after this date is prohibited.
The master's thesis is the completion of the Master's degree. It shows the students' ability to work independently and is a proof of the successful completion of their studies. The Master's thesis is supervised by a design professor D-ARCH. The students can choose one of the topics presented by the D-ARCH or - after approval by the head of the work - a free, self-chosen topic. Further details are regulated in Articles 31-38.

### Electives

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---
052-0559-24L | Analog Photography | W | 2 credits | 2S | R. Barba

**Abstract**

Practice-oriented seminar on the topic of analog & artistic photography

**Objective**

Instructed by Nicolas Rolle, the seminar serves as an introduction to analog experimentation in the creative process of artistic practice. By analyzing the motifs and ways of thinking of photographers, the aim is to develop a basic approach to the medium of photography and to expand practical work in the darkroom through theoretical questions about the medium.

**Content**

Theoretical and practical introductions form the core of the targeted exploration of the photographic apparatus. Students are encouraged to gather their own experiences in analog experiments and to explore the urban space and their surroundings with the camera. With an artistic work developed over the semester, the expanded concept of photography will be sharpened and brought to an individual expression.

**Prerequisites / notice**

Lecturer approval required for all students. Please send a letter of motivation (max. 300 words) to rolle@arch.ethz.ch by 05.09.2024. The number of participants is limited to 20. The course will be held in German in the Fall Semester 2024.

Participants pay CHF 25.00 for the materials required in the course.

**Competencies**

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

052-0579-24L | Understanding Light | W | 2 credits | 2S | R. Barba, P. Anantha Murthy

**Abstract**

The seminar explores light from the perspectives of Physics and Art, opening up new dimensions for collaboration across disciplines by tackling questions such as: What is the origin and nature of light? How does it travel through space and time? How can it be made productive in an artistic sense and what, in turn, can artistic methodologies contribute to experimenting and thinking about light?

**Objective**

- Learn about the properties of light: intensities, phases, colors, and interactions with matter
- Exploring optical effects: reflection, refraction, dispersion
- Learn to plan and carry out an art project based on research inputs from other sciences
- Enhancing conceptual and interdisciplinary thinking in unusual set-ups
- Learn how to cope with unforeseen results and make random events productive for the successful implementation of a project
- Fostering communication and presentation skills

**Content**

In this course, we will set a performative frame for experimentation and exploration. Coupled with experiments in the Dep. of Physics, students will be introduced to concepts such as the origin of light and color, and the interpretation of the optical world that surrounds us to understand what actually gives rise to the effects we see everyday—from butterfly wings and autumn colors to the appearance of buildings and cities. In addition, we will perform practical experiments with basic optical components like lenses, mirrors, and prisms, in order to understand how they can be used to capture images. Inputs by guest lecturers (e.g. on light in photography, anthropology or urban landscapes) are planned. Students will be asked to present related topics.

At the end of the semester, the artistic experiments will be presented.

**Prerequisites / notice**

Max. number of participants: 15

Please send a short motivation letter (max. 300 words) to artinspaceandtime@arch.ethz.ch by 05 September 2024.

**Competencies**

- Concepts and Theories
- Techniques and Technologies
- Problem-solving
- Project Management
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

063-0649-24L | Architectural Design with Machine Learning | W | 2 credits | 2G | A. Apolinarska

**Abstract**

This elective course presents machine-learning methods for data-driven design exploration in architectural design, and how to leverage them in combination with the parametric modelling paradigm.

**Objective**

The students learn how to harness parametric models for data exploration and how to augment the design process with project-specific generative deep learning models. They acquire basic understanding of the underlying methods and can implement them in their design tasks in architecture, urban planning, engineering etc.
The course will cover the following topics: data exploration (analytics and visualisations), forward and inverse design problems (enhancing parametric modelling with machine learning), basics of machine learning (feed-forward networks, backpropagation), and generative models with special focus on autoencoders.

The course consists of lectures providing a theoretical background followed by hands-on practical sessions with coding exercises in Python and Grasshopper. In parallel, the students will work in small groups on a semester project, in which they apply the presented data-exploration and inverse design methods to a design task of their choice. Building upon the provided framework (in Grasshopper and Python), students will generate custom datasets and train project-specific models, and then use them for concept-phase design exploration.

**Lecture notes**
Slides and other materials will be provided during the course.

**Literature**
Literature will be provided during the course.

**Prerequisites / notice**
063-0669-00 Coding Architecture I, or 063-0670-00 Coding Architecture II, or equivalent programming fluency in Python and Grasshopper.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<td>Techniques and Technologies</td>
<td>Communication</td>
<td>Creative Thinking</td>
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<td>Cooperation and Teamwork</td>
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<td>Leadership and Responsibility</td>
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<th>Media and Digital Technologies</th>
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<td>fostered</td>
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**Digital Creativity for Circular Construction** 8 credits 7.5P C. De Wolf

**All students who register go on a waiting list until 11.09.2024. To register:**
1. Enroll before 05.09.2024
2. Send a short motivation letter (max. 300 words) and a 1-page CV to cea-course@ibi.baug.ethz.ch by 05.09.2024
3. MIBS students: This course is mandatory and there is no need to send your application documents

Please only register for the course if you really intend to participate on all course dates (see course catalog), otherwise, you will deprive someone else of a place.

**Abstract**
The course is about digital innovation towards a circular economy in the built environment. How can we bring together two worlds that are often too distinct: low-impact construction and digital innovation? Bringing digital tools already used in other sectors into the construction sector, students will learn about circular construction (e.g., reuse of materials) through hands-on learning practices.

**Objective**
In the fall semester 2024 we will focus on applying artificial intelligence (AI) and extended reality (XR) to the circular design workflow and.

By the end of this course, students will be able to use augmented computational design enabling circular construction, with a view to environmental implications. They will be able to assess the challenges and opportunities of low-carbon, circular construction and evaluate possible solutions using digital technologies to enable a circular built environment (more specifically, with reused building materials). To achieve this, they need to be able to do the following:

1. Apply circular principles using recovered building materials.
2. Compare different digital technologies applied in circular construction (e.g., LiDAR scanning, drone imagery, photogrammetry, computational design, AI, computer vision, XR, LCA tools etc.).
3. Understand the potential and limitations of AI for circular construction, e.g. use machine learning to detect and digitize materials (computer vision) or to support creativity in the early design phases of circular construction (generative AI).
4. Communicate the importance and urgency of circular construction.
5. Assess the environmental impact implications of their design and technology decisions through a preliminary Life Cycle Assessment (LCA).

**Content**
Students will receive an introduction to circular principles by experts from the building industry and visit of (de-)construction sites where circular construction is exemplified. They will explore how to use digital technologies such as LiDAR scanning, photogrammetry, scan-to-BIM, computer vision, computational design, digital fabrication, blockchain technology and learn about the design implications using reclaimed building materials. This course is meant as an overview/introduction of many digital technologies that could be useful for circularity and gives the tools to students to further study the technologies they are most interested in on their own. Creativity in writing, filmmaking, design, construction, etc. is expected from the students. This course will give the tools to students to learn more on LCA if they wish to deepen their knowledge further.

**Lecture notes**
Language: English
Courses are on Tuesday afternoons in Kunsthalle or a room at ETH, but also require out-of-the-semester work and significant homework and site visits outside of class hours.

**Literature**


Interest in Digitalisation and Construction. Flexibility: This is a hands-on course, where students explore digital technologies and opportunities/challenges of reuse. Flexibility (e.g. adapting to unforeseen circumstances), responsibility (e.g. arriving on time for safety briefing), and spontaneity (e.g. finding innovative solutions) is expected from the students to adapt to the contingencies from demolition and construction sites with reused materials. The course is mandatory for MIBS students. If you are a first year MIBS student, please do not apply, you are automatically accepted. All other students from other departments should apply. Please only register for the course if you really intend to participate on all course dates (see course catalog). Please only register for the course if you are willing to send us a letter of motivation and really intend to participate; otherwise, you will deprive someone else of a place. All non-MIBS students who register go onto a waiting list until 11.09.2024 and up to 25 of them will be selected by the lecturer.

To register:
1. Enroll before 05.09.2024.
2. Send a short letter of motivation (max. 300 words) and a 1-page CV to cea-course@ibi.baug.ethz.ch by 05.09.2024.

Collaborators: Kunsthalle Zürich, ETH AI Center, Design++

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management
Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation
Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Abstract
This seminar deals with writings by Walter Benjamin. On the one hand, his most famous and influential essays and fragments on critique, history and experience will be read and discussed, and on the other, a special focus will be placed on his thinking on architectural themes.

Objective
On the one hand, students learn to know Walter Benjamin's most influential ideas, such as his views on art criticism, history and culture, as well as to reflect on his philosophical methods, such as thinking in constellations and pictures. On the other hand, students learn to apply Benjamin's methods of interpretation (Deutung) to architectural works and the Benjaminian texts themselves.

Seminar Weeks

Science in Perspective
see Science in Perspective: Language Courses ETH/UZH
see Science in Perspective: Type A: Enhancement of Reflection Capability
Recommended Science in Perspective (Type B) for D-ARCH

Course Units for Additional Admission Requirements
The courses below are only available for MSc students with additional admission requirements.

Abstract
Session requirements.
Objective
Requirements.
Content
Session requirements.

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php)
Project grading at semester end is based on the list of enrolments on 30.10.2024, (valuation date) only.
This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract
Session requirements.
Objective
Requirements.
Content
Session requirements.

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php)

Project grading at semester end is based on the list of enrolments on 30.10.2024, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract
Session requirements.

Objective
Requirements.

Content
Session requirements.

Architecture Master - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Key for Hours

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Atmospheric and Climate Science Master

 Modules

► Weather Systems and Atmospheric Dynamics
See Module Weather Systems and Atmospheric Dynamics

► Climate Processes and Feedbacks
See Module Climate Processes and Feedbacks

► Atmospheric Composition and Cycles
See Module Atmospheric Composition and Cycles

► Climate History and Paleoclimatology
See Module Climate History and Paleoclimatology

► Hydrology and Water Cycle
See Module Hydrology and Water Cycle

► Electives
The students are free to choose individually from the entire course offer of ETH Zürich and the universities of Zürich and Bern.

► Weather Systems and Atmospheric Dynamics
Courses are only offered in Spring Semester.

► Climate Processes and Feedbacks
Two additional courses are offered in Autumn Semester by University of Berne.

► Atmospheric Composition and Cycles
Courses are only offered in Spring Semester.

► Climate History and Paleoclimatology
Two courses are offered in Autumn Semester at University of Berne.

► Hydrology and Water Cycle
see Elective courses Hydrology and Water Cycle (without Self-Learning Courses)

► Prerequisites
The definition of prerequisites is part of the admission procedure for the master studies. You are informed by the admission office as to what courses of the section «prerequisites» you have to catch up with. You are accredited for these courses in the electives block of the master studies.

### Number 701-0471-01L Atmospheric Chemistry

**Abstract**
This course covers the chemical and physical processes controlling the composition of the troposphere and stratosphere and introduces the relevant fundamentals for processes in the gas phase, in aerosols and clouds. These concepts are explored in the context of key environmental issues, such as urban air pollution, stratospheric ozone depletion, and air quality connections to climate change.

**Objective**
1. describe the structure of the atmosphere and list atmospheric components and their main properties
2. define and describe the chemical and physical processes in the stratosphere and troposphere, follow reaction mechanisms, and apply rate laws
3. describe the physical and chemical principles of air pollution and summarize the most important legislative measures
4. discuss the local, regional, and global aspects of interactions between air quality, ecosystem health, and climate

**Content**
- Origin and properties of the atmosphere: composition (gases and aerosols), atmospheric structure, UV radiation, transport timescales
- Kinetics of gas phase reactions: rate laws, mechanisms of bimolecular and termolecular reactions.
- Stratospheric chemistry: Chapman cycle, catalytic ozone destruction cycles, polar ozone hole, Montreal protocol
- Tropospheric chemistry: oxidizing capacity of the troposphere and the role of OH, oxidation and global budgets of CO and CH4, role of NOx, and the global tropospheric O3 budget
- Surface ozone chemistry: HOx-NOx cycle, role of VOCs, O3 isopleth, ozone production efficiency
- Aerosols: primary and secondary sources, composition, quantities and measures, connections to climate
- Multiphase chemistry: solubility of gases, Raoult's Law and hygroscopicity, kinetics of gas to particle transfer, N2O5 chemistry, aqueous phase sulfur chemistry, secondary organic aerosol formation
- Air quality: role of planetary boundary layer, deposition processes, summer- versus winter-smog, environmental problems, legislation, long-term trends
- Global aspects: air quality - climate interactions

**Lecture notes**
Lecture materials (slides) are provided continuously during the semester, at least 2 days before each lecture. Annotations and corrections are provided at the latest within the same week.

**Prerequisites / notice**
Attendance of the lecture "Atmosphäre" LV 701-0023-00L or equivalent knowledge is a pre-requisite, and basic courses in physics and chemistry are expected.
On Mondays (or upon agreement) a tutorial is offered. This allows the students to discuss unresolved issues from the lecture or to discuss the problems of the exercise series and their solution. Participation is recommended.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>Concepts and Theories</td>
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<tr>
<td>Problem-solving</td>
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<td>Creative Thinking</td>
<td>fostered</td>
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<tr>
<td>Critical Thinking</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 150 of 2653
Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; Potential Vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer; water isotopes

The students are able to
- explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- to explain the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
- to explain how mountains influence the atmospheric flow on different scales
- basic understanding of stable water isotopes as tracers for moist adiabatic processes in weather systems

Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; Potential Vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer; water vapour transport in the atmosphere; water isotopes

Lecture notes
Lecture notes and slides

Literature
Atmospheric Science, An Introductory Survey
John M. Wallace and Peter V. Hobbs, Academic Press

Prerequisites / notice
Basic physics

Competencies

<table>
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<tr>
<th>Competencies</th>
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<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
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</table>

Atmospheric Physics

W 3 credits 2G
U. Lohmann

Abstract
This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation, especially prediction of showers and severe convective storms, and optical phenomena

Objective
Students are able to
- to explain the mechanisms of convective storm formation using knowledge of thermodynamics and cloud microphysics.
- to interpret precipitation radar images.
- to evaluate the significance of clouds and aerosol particles for artificial weather modification.

In the course "Atmospheric Physics", the competencies of process understanding, system understanding and data analysis & interpretation are taught, applied and examined. Measurement methods are taught as well.

Content
The course starts with introducing selected concepts of thermodynamics for atmospheric processes: The students learn the concept of the thermodynamic equilibrium and derive the Clausius-Clayperon equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Students also learn to use thermodynamic charts (tephigrams) and to identify cloud base, cloud top, available convective energy in radiosonde ascents. Atmospheric mixing processes are introduced as a basis for fog formation. The concept of an air parcel is used to understand convection.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

With these basics, the different forms of precipitation (convective vs. stratiform) are discussed and how they can be identified in radar images. Students will also learn under which conditions severe convective storms (especially supercells with tornados) can form.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

Lecture notes
Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=20400

Literature

An electronic version of this book can be obtained via the ETH library.

pdf-files of the revised book will be provided on moodle on a chapter-by-chapter basis.

There is a additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.

Competencies

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<td>Self-direction and Self-management</td>
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Additional Electives ETH

See recommended additional elective courses

Minors

Minor in Physical Glaciology

see Major in Atmosphere and Climate, MSc
Environmental Sciences

Minor in Biogeochemistry

See Module Biogeochemical Processes MSc in
Minor in Global Change and Sustainability

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<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0015-00L</td>
<td>Transdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement</td>
<td>W</td>
<td>2 credits</td>
<td>1S</td>
<td>B. Vienni Baptista, C. E. Pohl, M. Stauffacher</td>
</tr>
</tbody>
</table>

Abstract
This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants’ research projects more societally relevant.

Objective
Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, or how to secure broader impact of research. They learn to critically reflect their own research project in its societal context and on their role as scientists.

Content
The seminar covers the following topics:
1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants’ research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.

Literature
Literature will be made available to the participants. The following open access article builds a core element of the course:

Further, this collection of tools will be used:
https://naturalsciences.ch/topics/co-producing_knowledge
https://www.shapeitoolkit.eu

Prerequisites / notice
Participation in the course requires participants to be working on their own research project.

Dates (Wednesdays, 8h15-12h00)

Minor in Sustainable Energy Use

See Major in Sustainable Energy Use MSc Environmental Sciences

Seminars and Colloquia

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<th>Number</th>
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Abstract
The colloquium is a series of scientific talks by prominent invited speakers assembling interested students and researchers from around Zürich. Students take part of the scientific discussions.

Objective
The students are exposed to different atmospheric science topics and learn how to take part in scientific discussions.

Competencies
Subject-specific Competencies: Concepts and Theories

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<tr>
<td>701-1211-01L</td>
<td>Master’s Seminar: Atmosphere and Climate 1</td>
<td>O</td>
<td>3 credits</td>
<td>2S</td>
<td>H. Joos, R. Knutti</td>
</tr>
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</table>

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 152 of 2653
In this seminar, the process of writing a scientific proposal will be introduced. The essential elements of a proposal, including the peer review process, will be outlined and class exercises will train scientific writing skills. Knowledge exchange between class participants is promoted through the preparation of a master thesis proposal and evaluation of each other's work.

**Objective**
Training scientific writing skills.

**Content**
In this seminar, the process of writing a scientific proposal will be introduced. The essential elements of a proposal, including the peer review process, will be outlined and class exercises will train scientific writing skills. Knowledge exchange between class participants is promoted through the preparation of a master thesis proposal and evaluation of each other's work.

**Prerequisites / notice**
Attendance is mandatory.

**Competencies**

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<td>Self-awareness and Self-reflection</td>
<td>Self-direction and Self-management</td>
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</table>

**ECTS**
3 credits

**Hours**
2S

**Title**
Master's Seminar: Atmosphere and Climate 2

**Number**
701-1211-02L

**Objective**
Apply scientific project management techniques to your master project, practice the presentation of scientific results and how to chair other students presentations and lead the discussion.

**Content**
In this seminar, scientific project management is introduced and applied to the master projects. The course concludes with a presentation of all projects including an overview of the scientific content and a discussion of project management techniques related to the master thesis.

**Prerequisites / notice**
Attendance is mandatory.

**Competencies**

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</table>

**ECTS**
2 credits

**Hours**
OG

**Title**
Introduction Course to Master Studies Atmosphere and Climate

**Number**
701-1213-00L

**Objective**
The aims of this course are i) to welcome all students to the master program and to ETH, ii) to acquaint students with the faculty teaching in the field of atmospheric and climate science at ETH and at the University of Bern, iii) that the students get to know each other and iv) to assess needs and discuss options for training and education of soft-skills during the Master program and to give an overview of the study options in general.

**Competencies**

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</table>

**ECTS**
2G

**Hours**
OG

**Title**
Master's Thesis

**Number**
651-4275-00L

**Objective**
Students are to prove their skills in working autonomously on a scientific project. They document their work in a scientific report.

**Abstract**

The master thesis is supervised by a professor of the D-ERDW or of the Institute for Atmosphere and Climate (IAC, D-USYS), a professor who teaches in the module subjects or a senior scientist who is on the list of "competent leaders of master theses" of the D-ERDW or of the D-USYS (associated with the IAC).


**Prerequisites / notice**

Only students who fulfill the following criteria are allowed to begin with their master thesis:

- a. successful completion of the bachelor programme;
- b. fulfilling of any additional requirements necessary to gain admission to the master programme.

- The master programme will be completed by a master thesis on a topic selected from the subject range of the chosen major programme. Students are to prove their skills in working autonomously on a scientific project.
Powerpoint slides and script from LV 701-0475-00L Atmosphärenphysik will be made available At the end of this course, students are able to:

This is a self-study course targeted at Master students who did not follow the bachelor course "atmospheric chemistry" or equivalent, assessed

Lohmann, U., Lüönd, F. and Mahrt, F., An Introduction to Clouds: Adaptability and Flexibility assessed

ECTS

M. Ammann

6R - Origin and properties of the atmosphere: composition (gases and aerosols), atmospheric structure, UV radiation, transport timescales

Copies of the slides are provided in electronic form.

Analytical Competencies

, C. Heald, C. Mohr

Introduction of the most important components of the climate systems and their interactions.

S. I. Seneviratne assessed

assessed

U. Lohmann

M. A. Sprenger

Subject-specific Competencies

fostered

Communication

fostered

Critical Thinking

Concepts and Theories

Basic courses in chemistry and physics are expected

fostered

Techniques and Technologies

assessed

Method-specific Competencies

Analytical Competencies

assessed

Problem-solving

assessed

Personal Competencies

Adaptability and Flexibility

assessed

Creative Thinking

integrity and Work Ethics

fostered

Basic courses in chemistry and physics are expected

Number Title Type ECTS Hours Lecturers

701-0412-AAL Climate Systems E- 3 credits 6R S. I. Seneviratne

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Introduction of the most important components of the climate systems and their interactions.

Objective

Students have a basic understanding of the global energy balance, radiation budget, boundary layer, atmosphere, ocean, biosphere, land-surface coupling, cryosphere, carbon cycle, climate variability, climate of the past and anthropogenic climate change, and they are able to apply this to solve simple quantitative problems and answer qualitative questions.

Lecture notes

Copies of the slides are provided in electronic form.

Literature

A comprehensive list of references is provided in the class. Two books are particularly recommended:


Prerequisites / notice

Teaching: Reto Knutti, several keynotes to special topics by other professors

Course taught in german, slides in English

701-0471-AAL Atmospheric Chemistry E- 3 credits 6R M. Ammann, C. Heald, C. Mohr

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

This is a self-study course targeted at Master students who did not follow the bachelor course "atmospheric chemistry" or equivalent, providing a general introduction into atmospheric chemistry. It introduces the relevant fundamental concepts, which are explored in the context of key environmental issues, such as air pollution, stratospheric ozone depletion, and connections to climate change.

Objective

At the end of this course, students are able to:

1. describe the structure of the atmosphere and list atmospheric components and their main properties
2. define and describe the chemical and physical processes in the stratosphere and troposphere, follow reaction mechanisms, and apply rate laws
3. describe the physical and chemical principles of air pollution and summarize the most important legislative measures
4. discuss the local, regional, and global aspects of interactions between air quality, ecosystem health, and climate

Content


Lecture notes

The slides, notes and exercises of the preceding edition of the bachelor course 701-0471-01L Atmospheric Chemistry will be provided.

Prerequisites / notice

Basic courses in chemistry and physics are expected

Competencies

Subject-specific Competencies

Concepts and Theories

assessed

Techniques and Technologies

assessed

Method-specific Competencies

Analytical Competencies

assessed

Problem-solving

assessed

Personal Competencies

Adaptability and Flexibility

assessed

Creative Thinking

Integrity and Work Ethics

fostered

701-0475-AAL Atmospheric Physics E- 3 credits 6R U. Lohmann

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

This course is a self-study course for MSc students, who like to learn something about Atmospheric Physics but for cannot follow the course Atmosphärenphysik, because that is taught in German. However, the slides and the textbook of the course Atmosphärenphysik, and they form the basis also for this course.

Objective

See entry under LV 701-0475-00L Atmosphärenphysik

Content

See entry under LV 701-0475-00L Atmosphärenphysik

Lecture notes

Powerpoint slides and script from LV 701-0475-00L Atmosphärenphysik will be made available


pdf-files of the revised book will be provided as well.

Competencies

Subject-specific Competencies

Concepts and Theories

assessed

Method-specific Competencies

Analytical Competencies

assessed

Social Competencies

assessed

Personal Competencies

assessed

Critical Thinking

fostered

701-0473-AAL Weather Systems E- 3 credits 6R M. A. Sprenger, I. Thurnherr

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students,
Abstract

The students learn about the dynamical features of the Earth's atmosphere. They interpret satellite imagery and learn about basic concepts in dynamical meteorology. The global circulation is briefly discussed, before introducing the Eulerian and the Lagrangian perspective, which are used to study air streams in extratropical cyclones and to investigate basic aspects in mountain meteorology.

Objective

The students are able to
- explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- to discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
- to explain how mountains influence the atmospheric flow on different scales
- basic understanding of the role of moist adiabatic processes for weather systems and why stable water isotopes are useful in this context

Content

Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situtations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

Lecture notes

Lecture notes and slides

Literature

Atmospheric Science, An Introductory Survey
John M. Wallace and Peter V. Hobbs, Academic Press

Competencies

Subject-specific Competencies
Concepts and Theories
assessed
Method-specific Competencies
Analytical Competencies
assessed
Social Competencies
Communication

701-0106-AAL
Mathematics V: Applied Deepening of Mathematics I - III
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Selected mathematical topics are presented for later use in more specialised lectures. Part of the topics were already discussed in the lectures Mathematics I-III. Here, they should be shortly recapitulated and most importantly applied to practical problems. If necessary, new mathematical concepts and methods will be introduced in order to solve challenging and inspiring problems from practice.

Objective

The aim of this lecture is to prepare the students for the more specialised lectures. They should become more familiar with the mathematical background, the mathematical concepts and most of all with their application and interpretation.

Content

Practical examples from the following areas will be discussed: ordinary differential equations; eigenvalue problems from linear algebra; systems of linear and nonlinear differential equations; partial differential equations (diffusion, transport, waves).

701-0071-AAL
Mathematics III: Systems Analysis
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

The objective of the systems analysis course is to deepen and illustrate the mathematical concepts on the basis of a series of very concrete examples. Topics covered include: linear box models with one or several variables, non-linear box models; models in space and time.

Objective

Learning and applying of concepts (models) and quantitative methods to address concrete problems of environmental relevance. Understanding and applying the systems-analytic approach, i.e., Recognizing the core of the problem - simplification - quantitative approach - prediction.

Content

Introduction to principles of models; one-dimensional linear box models; multi-dimensional linear box models; nonlinear box models; models in space and time

Lecture notes

Teaching material: book (see literature).

Literature


Atmospheric and Climate Science Master - Key for Type

<table>
<thead>
<tr>
<th>Z</th>
<th>Courses outside the curriculum</th>
<th>W</th>
<th>Eligible for credits</th>
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<tbody>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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</table>

Key for Hours

| P | practical/laboratory course |
| A | independent project |
| D | diploma thesis |
| R | revision course / private study |

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.

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Autumn Semester 2024
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Educational Science for Teaching Diploma and TC

These are the general course offerings of the programmes Teaching Diploma (TD) - categories Educational Science and Compulsory Elective Courses - and Teaching Certificate (TC) - category Educational Science.

★ Educational Science Teaching Certificate

<table>
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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>871-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern, M. Rau</td>
</tr>
</tbody>
</table>

Abstract
This course looks into scientific theories and also empirical studies on human learning and relates them to the school.

Objective
Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

Content
Thematic Schwerpunkte:
Lernen als Verhaltensänderung und als Informationsverarbeitung; Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzentwicklung unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen; Intelligenztheorien, Geschlechtsunterschiede beim Lernen

Lernformen:

Lecture notes
Folien werden zur Verfügung gestellt.

Literature

Prerequisites / notice
This lecture is only apt for students who intend to enrol in the programs “Lehrpldrom” or “Didaktisches Zertifikat”. It is about learning in childhood and adolescence.

871-0240-22L | Coping with Psychosocial Demands of Teaching (EW4 W 1 credit) 2 credits | 3S | S. Maurer, P. Caprez, I. Sargenti

Abstract
In this class, students will learn concepts and skills for coping with psychosocial demands of teaching.

Objective
 Students possess theoretical knowledge and practical competences to be able to cope with the psychosocial demands of teaching.

(1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks).
(2) They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. legal or psychological services).

871-0242-06L | Cognitively Activating Instructions in MINT Subjects W 2 credits | 2S | R. Schumacher

Abstract
This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.

Objective
- Get to know cognitively activating instructions in MINT subjects
- Get information about recent literature on learning and instruction

Prerequisites / notice
Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.

871-0242-07L | Human Intelligence W 1 credit | 1S | E. Stern

Abstract
The focus will be on the book “Intelligenz: Grosse Unterschiede und ihre Folgen” by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.

Objective
- Understanding of research methods used in the empirical human sciences
- Getting to know intelligence tests
- Understanding findings relevant for education

871-0227-00L | Foundations of the Theory of Science for Science Lessons W 1 credit | 2S | R. Schumacher

Abstract
When are experiments meaningful? How do we have to proceed to test hypotheses with experiments? By which criteria do we estimate the explanatory value of competing theories? This answers to these questions are the key to understanding scientific research. This seminar focuses on how these foundations can be taught in science lessons.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 156 of 2653
**871-0228-00L**  
**Formation of Knowledge in STEM Fields in Primary and Secondary School**  
**Adresses to students enrolled either in Teaching Diploma* (TD) or Teaching Certificate (TC) (excluding Teaching Diploma Sport).**  
This course unit can only be enrolled after successful participation in the course 871-0240-00L "Human Learning (EW 1)".

**Abstract**  
Course promotes exchange between student teachers and elementary school teachers in STEM teaching with 3 parts: 1) block seminar (ca. 16 h), 2) collaboration with elementary school teacher in a class (ca. 34 h, with approx. 50% spent in the elementary or middle school class and ca. 50% for preparation), and 3) final report (ca. 10 h). Registration implies participation in all 3 parts.  

**Objective**  
Deepening the understanding of knowledge formation and learning processes of primary and secondary students from a cognitive and developmental psychology perspective for students. The assistant ship provides didactic experience and exposure to a different school level (more heterogeneous groups such as for example low-performing to very high-performing Children, language problems etc.).  

**Content**  
Students learn more about the potential and challenges of pupils. They get to know the early stages of knowledge as well as the development of pre-concepts of students in their subject area. The seminar with a phase of cooperation consists of three phases: In the block seminar, pre-concepts are discussed in their own subject as well as theoretical inputs from developmental and cognitive psychology. During the cooperation phase, a teaching task defined by the primary and secondary school teachers is actively undertaken in a class. Finally, a final report is written, which contains a description of the students' level of knowledge. This seminar is only suitable for students who can adapt flexibly to the needs of pupils from lower class levels.  

**Prerequisites / notice**  
https://www.minterlink.ch/student

**Competencies**  
- Subject-specific Competencies: Concepts and Theories, assessed  
- Method-specific Competencies: Analytical Competencies, assessed  
- Social Competencies: Communication, assessed  
- Personal Competencies: Adaptability and Flexibility, assessed  

**376-1309-00L**  
**Disorders of Social Cognition**  
Enrolment possible with matriculation in "Master HST".  
- Teaching Diploma or Teaching Certificate --- This course unit can only be enrolled after successful participation in, or during enrolment in the course "Human Learning (EW 1)".  
- Teaching Diploma Sport: allocation of the ECTS only possible in the category "Educational Science" !!!!

**Abstract**  
In this seminar, we consider how the human brain processes social Information. The approach focuses on exploring the neural bases of social cognition in healthy individuals, as well as providing case studies from atypical populations, whose pathologies are typified by dysfunction in social information processing, such as autism spectrum disorder and schizophrenia.

**Objective**  
- To familiarise students with forms of social cognition in humans, as well as the neural systems that support social cognition.  
- To critically evaluate theories and data relating to Social Cognition and Social Neuroscience.  
- To relate how knowledge of typical brain function can inform our understanding of individuals who process social information differently, and vice versa.  
- To develop effective scientific communication skills in oral and written formats.

**Content**  
This seminar will consider how the human brain understands and organises social behaviour. The approach will focus on exploring the neural bases of social cognition in healthy individuals, as well as providing case studies from atypical populations, whose pathologies are typified by dysfunction in social information processing. Examples of such pathologies include autism spectrum disorder, schizophrenia and attention deficit hyperactivity disorder. By examining healthy and atypical populations, this module will highlight how disorders of social cognition can inform the understanding of healthy brain function, as well as how understanding healthy brain function can inform disorders of social cognition.

**871-0226-00L**  
**Effective Use of Visualisations for Learning**  
Successful completion of the lecture "871-0240-00L Human Learning (EW 1)"

**Abstract**  

**Objective**  
Seminar participants learn how to examine visualizations for their pedagogical impact. They will learn how to assess when it is worth using visualizations, how many visualizations should be offered, and how they can be embedded in teaching materials to avoid misconceptions and promote learning.

**Content**  
Visualizations are an integral part of STEM subjects. Visualizations can make learning content intuitively accessible. However, visualizations can also create misconceptions. For example, ball-and-stick models in chemistry can create the misconception that chemical bonds consist of static connections. In order to avoid such misconceptions, the seminar teaches effective instructional methods with visualizations. The seminar builds on theories from EW1. Practical exercises with various visualization methods (e.g. images, graphs, animations, simulations, interactive diagrams) will help seminar participants to create effective learning materials with visualizations for their own discipline.

**Educational Science Teaching Diploma**

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
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<tr>
<td>871-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern, M. Rau</td>
</tr>
</tbody>
</table>

This lecture is only apt for students who intend to enrol in the programs "Teaching Diploma" or "Teaching Certificate". It is about learning in childhood and adolescence.
This course looks into scientific theories and also empirical studies on human learning and relates them to the school. Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

Thematical Schwerpunkte:
Lernen als Verhaltensänderung und als Informationsverarbeitung; Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzentwicklung unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotionen und Erklärungen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen

Lernformen:

Support and Diagnosis of Knowledge Acquisition Processes (EW3) — Enrolment only possible with matriculation in Teaching Diploma, who complete the sport-specific course unit EW3 and for students who intend to enrol in the "Teaching Diploma".

Abstract
In this seminar students learn advanced techniques to support and to diagnose knowledge acquisition processes in school.

Objective
The main goals are:
(1) You have a deep understanding about the cognitive mechanisms of knowledge acquisition.
(2) You have a basic understanding about psychological test theory and can appropriately administer tests.
(3) You know various techniques of formative assessment and can apply these to uncover students' misconceptions.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniques and Technologies assessed</td>
<td></td>
</tr>
</tbody>
</table>

Method-specific Competencies

| Analytical Competencies assessed |
| Decision-making fostered |
| Media and Digital Technologies fostered |
| Problem-solving fostered |

Social Competencies

| Communication fostered |
| Cooperation and Teamwork fostered |
| Leadership and Responsibility fostered |
| Sensitivity to Diversity fostered |

Personal Competencies

| Creative Thinking fostered |
| Critical Thinking fostered |

Designing Educational Environments in Physical Education (EW2 Sport) — Compulsory course requirements for EW2 Sport

"Outdoor Education: Concepts and Practice" (871-

Abstract
Students learn and practice techniques and skills for coping with psychosocial demands of teaching.

Objective
Students possess theoretical knowledge and practical competences to be able to cope with the psychosocial demands of teaching.
(1) They know the basic rules of negotiation and conflict management (e.g., mediation) and can apply them in the school context (e.g., in conversations with parents).
(2) They can apply diverse techniques of classroom management (e.g., prevention of disciplinary problems in the classroom) and know relevant authorities for further information (e.g., legal conditions; crisis intervention).
(3) They know stress coping strategies to prevent burnout (e.g., psychosocial support) and are familiar with relevant institutions.

Content
Major themes:
- counseling and counseling techniques
- conflict management and mediation
- classroom management
- supporting students in a psychological crisis
- preventing stress and burnout

Forms of learning
Theoretical foundations will be taught in workshops which contain different means of activation and interaction such as group work, panel discussions, and individual work. Subsequently, this knowledge will be transferred and applied in different school-relevant situations by means of role plays, discussing of cases and video sequences, as well as reflections of practical experiences.

Lecture notes
Slides of the lectureres`presentations, supplementary materials, and materials for further reading are made available on Moodle.

Literature
Verschiedenen Grundlagen- und Anwendungstexte werden den Studierenden zur Verfügung gestellt.

Prerequisites / notice
Der erfolgreiche Abschluss von EW1 und EW2 stellt eine wünschenswerte, jedoch nicht obligatorische Voraussetzung dar.
### Effective Learning Environments (EW 5)  

**Abstract**  
The successful completion of ALL modules relevant for the teacher's diploma is required for participation in this course.

**Objective**  
The students have to read the book "Lernwirksam unterrichten" from Felten/Stern and they have to answer questions. In individual or small-group sessions will be discussed how insights from learning research can inform classroom practice.

**Literature**  
Buch "Lernwirksam unterrichten" (Felten/Stern)

**Prerequisites / notice**  
EW2 is compulsory requirement for EW4 Sport

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credit</th>
<th>Semester</th>
<th>Instructor</th>
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<tr>
<td>871-0240-19L</td>
<td>Effective Learning Environments (EW 5)</td>
<td>1</td>
<td></td>
<td>E. Stern</td>
</tr>
</tbody>
</table>

### Human Intelligence  

**Abstract**  
The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.

**Objective**  
- Understanding of research methods used in the empirical human sciences
- Getting to know intelligence tests
- Understanding findings relevant for education

**Prerequisites / notice**  
Detailed information: https://ifvll.ethz.ch/studium/ew-5.html

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credit</th>
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<th>Instructor</th>
</tr>
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<tbody>
<tr>
<td>871-0242-07L</td>
<td>Human Intelligence</td>
<td>1</td>
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<td>E. Stern</td>
</tr>
</tbody>
</table>

### Foundations of the Theory of Science for Science Lessons  

**Abstract**  
When are experiments meaningful? How do we have to proceed to test hypotheses with experiments? By which criteria do we estimate the explanatory value of competing theories? The answers to these questions are the key to understanding scientific research. This seminar focuses on how these foundations can be taught in school lessons.

**Objective**  
- an overview of the most important models in the theory of science
- expertise to implement and discuss these models in science lessons

<table>
<thead>
<tr>
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<th>Title</th>
<th>Credit</th>
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<th>Instructor</th>
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<tr>
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<td>Foundations of the Theory of Science for Science Lessons</td>
<td>1</td>
<td>2S</td>
<td>R. Schumacher</td>
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</tbody>
</table>

### Cognitively Activating Instructions in MINT Subjects  

**Abstract**  
The seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.

**Objective**  
- Get to know cognitively activating instructions in MINT subjects
- Get information about recent literature on teaching and learning
- Small group discussions on models in science lessons

<table>
<thead>
<tr>
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<th>Credit</th>
<th>Semester</th>
<th>Instructor</th>
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<tbody>
<tr>
<td>871-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects</td>
<td>2</td>
<td>2S</td>
<td>R. Schumacher</td>
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</tbody>
</table>

### Using Outdoor Education  

**Abstract**  
In this seminar, future teachers will be trained to prepare and conduct excursions to out-of-school learning venues. For this purpose, excursions are offered at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf.

**Objective**  
Future teachers will learn to prepare and conduct excursions to out-of-school learning venues.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credit</th>
<th>Semester</th>
<th>Instructor</th>
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</thead>
<tbody>
<tr>
<td>871-0229-00L</td>
<td>Using Outdoor Education</td>
<td>1</td>
<td>1S</td>
<td>R. Schumacher, P. Faller</td>
</tr>
</tbody>
</table>

### Supervising and Assessing Matura Theses  

**Abstract**  
This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)".

**Objective**  
- To assess curricula critically and to use them properly
- How to combine theoretical and practical issues in the ‘Ergänzungsfach’
- How to plan events and camps
- To assess curricula critically and to use them properly
- How to combine theoretical and practical issues in the ‘Ergänzungsfach’

<table>
<thead>
<tr>
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<th>Credit</th>
<th>Semester</th>
<th>Instructor</th>
</tr>
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<tbody>
<tr>
<td>871-0240-27L</td>
<td>Supervising and Assessing Matura Theses</td>
<td>1</td>
<td>1V</td>
<td>J. Maue</td>
</tr>
</tbody>
</table>

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**Data:** 15.06.2024 12:39  |  **Autumn Semester 2024**  |  **Page 159 of 2653**
Disorders of Social Cognition

This course prepares prospective teachers to supervising and assessing scientific projects at upper secondary school level, particularly Matura theses in STEM subjects at Gymnasium.

Objective
1. Assessing the adequacy of Matura thesis topics and defining the scope of a project.
2. Determining and promoting a successful work process.
3. Devising and applying criteria for assessing process, product and presentation of a Matura thesis.

Prerequisites / notice
Focus on STEM subjects (biology, chemistry, computer science, mathematics, and physics) with no explicit discussion of geography or physical education.

871-0228-00L
Formation of Knowledge in STEM Fields in Primary and Secondary School

Addressed to students enrolled either in Teaching Diploma* (TD) or Teaching Certificate (TC) (excluding Teaching Diploma Sport).

Prerequisites / notice
https://www.minterlink.ch/student

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed

Method-specific Competencies
- Analytical Competencies: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Leadership and Responsibility: assessed
- Sensitivity to Diversity: assessed

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Self-awareness and Self-reflection: assessed

376-1309-00L
Disorders of Social Cognition

Enrolment possible with matriculation in:
- Master HST
- Teaching Diploma or Teaching Certificate ---- This course unit can only be enrolled after successful participation in, or during enrolment in the course "Human Learning (EW 1)"

Prerequisites / notice
This course unit can only be enrolled after successful completion of the lecture "871-0240-00L Human Learning (EW 1)"

Content
In this seminar, we consider how the human brain processes social Information. The approach focuses on exploring the neural bases of social cognition in healthy individuals, as well as providing case studies from atypical populations, whose pathologies are typified by dysfunction in social information processing, such as autism spectrum disorder and schizophrenia.

Objective
- To familiarise students with forms of social cognition in humans, as well as the neural systems that support social cognition.
- To critically evaluate theories and data relating to Social Cognition and Social Neuroscience.
- To relate how knowledge of typical brain function can inform our understanding of individuals who process social information differently, and vice versa.
- To develop effective scientific communication skills in oral and written formats.

4. Devising and applying criteria for assessing process, product and presentation of a Matura thesis.

Ju: Compulsory Elective Courses Teaching Diploma

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>871-0226-00L</td>
<td>Effective Use of Visualisations for Learning</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
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<tr>
<td>M. Rau</td>
<td></td>
<td></td>
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</tbody>
</table>

Abstract

Objective
Seminar participants learn how to examine visualizations for their pedagogical impact. They will learn how to assess when it is worth using visualizations, how many visualizations should be offered, and how they can be embedded in teaching materials to avoid misconceptions and promote learning.

Content
Visualizations are an integral part of STEM subjects. Visualizations can make learning content intuitively accessible. However, visualizations can also create misconceptions. For example, ball-and-stick models in chemistry can create the misconception that chemical bonds consist of static connections. In order to avoid such misconceptions, the seminar teaches effective instructional methods with visualizations. The seminar builds on theories from EW1. Practical exercises with various visualization methods (e.g. images, graphs, animations, simulations, interactive diagrams) will help seminar participants to create effective learning materials with visualizations for their own discipline.
Using Outdoor Education

Enrolment only possible with matriculation in Teaching Diploma Biology and Geography.

Abstract
In this seminar, future teachers will be trained to prepare and conduct excursions to out-of-school learning venues. For this purpose, excursions are offered at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf.

Objective
Future teachers will learn to prepare and conduct excursions to out-of-school learning venues.

Content
- Excursions at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf:
  - Dendrochronology: What annual rings tell
  - Photosynthesis/Climate change: The tracks in the forest
  - Forest Soil: The soil in the focus of the climate
Disorders of Social Cognition

871-0240-27L

Supervising and Assessing Matura Theses

Objectives:
1. Assessing the adequacy of Matura thesis topics and defining the scope of a project.
2. Determining and promoting a successful work process.
3. Devising and applying criteria for assessing process, product and presentation of a Matura thesis.

Prerequisites / Notice:
Focus on STEM subjects (biology, chemistry, computer science, mathematics, and physics) with no explicit discussion of geography or physical education.

Abstract:
In this seminar, we consider how the human brain processes social information. The approach focuses on exploring the neural bases of social cognition in healthy individuals, as well as providing case studies from atypical populations, whose pathologies are typified by dysfunction in social information processing, such as autism spectrum disorder and schizophrenia.

Objective:
- To familiarise students with forms of social cognition in humans, as well as the neural systems that support social cognition.
- To critically evaluate theories and data relating to Social Cognition and Social Neuroscience.
- To relate how knowledge of typical brain function can inform our understanding of individuals who process social information differently, and vice versa.
- To develop effective scientific communication skills in oral and written formats.

Content:
This seminar will consider how the human brain understands and organises social behaviour. The approach will focus on exploring the neural bases of social cognition in healthy individuals, as well as providing case studies from atypical populations, whose pathologies are typified by dysfunction in social information processing. Examples of such pathologies include autism spectrum disorder, schizophrenia and attention deficit hyperactivity disorder. By examining healthy and atypical populations, this module will highlight how disorders of social cognition can inform the understanding of healthy brain function, as well as how understanding healthy brain function can inform disorders of social cognition.

Effective Use of Visualisations for Learning

871-0226-00L

Abstract:

Objective:
Seminar participants learn how to examine visualizations for their pedagogical impact. They will learn how to assess when it is worth using visualizations, how many visualizations should be offered, and how they can be embedded in teaching materials to avoid misconceptions and promote learning.

Content:
Visualizations are an integral part of STEM subjects. Visualizations can make learning content intuitively accessible. However, visualizations can also create misconceptions. For example, ball-and-stick models in chemistry can create the misconception that chemical bonds consist of static connections. In order to avoid such misconceptions, the seminar teaches effective instructional methods with visualizations. The seminar builds on theories from EW1. Practical exercises with various visualization methods (e.g., images, graphs, animations, simulations, interactive diagrams) will help seminar participants to create effective learning materials with visualizations for their own discipline.

Educational Science for Teaching Diploma and TC - Key for Type

| O | Compulsory | E- | Recommended, not eligible for credits |
| W+ | Eligible for credits and recommended | Z | Courses outside the curriculum |
| W | Eligible for credits | Dr | Suitable for doctorate |

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 162 of 2653
## Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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</tr>
<tr>
<td>S</td>
<td>seminar</td>
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</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Colloquium in Structural Engineering (Autumn Semester)

- **Number**: 101-1187-00L
- **Title**: Colloquium in Structural Engineering (Autumn Semester)
- **Type**: W
- **ECTS**: 1 credit
- **Hours**: 2K
- **Lecturers**: A. Taras, E. Chatzi, A. Frangi, W. Kaufmann, B. Stojadinovic, B. Sudret, M. Vassiliou

#### Abstract
Professors from national and international universities, technical experts from the industry as well as research associates of the institute of structural engineering (IBK) are invited to present recent research results and specific projects from the practice. This colloquium is addressed to members of universities, practicing engineers and interested persons in general.

#### Objective
Learn about recent research results in structural engineering.

#### Content
Learn about recent research results and novel practical applications & methods in structural engineering.

#### Competencies
- **Subject-specific Competencies**: Concepts and Theories assessed
- **Method-specific Competencies**: Problem-solving fostered
- **Social Competencies**: Communication fostered

### Colloquia in Geotechnics

- **Number**: 101-1387-00L
- **Title**: Colloquia in Geotechnics
- **Type**: E-
- **ECTS**: 0 credits
- **Hours**: 1K
- **Lecturers**: A. Puzrin, G. Anagnostou, I. Anastasopoulos

#### Abstract
The Institute for Geotechnical Engineering invites distinguished speakers from research and practice, nationally and internationally. The colloquia are directed towards staff and students from Universities as well as engineers and scientists working in industry. Details can be obtained from www.igt.ethz.ch by following Events & Public Events. Some colloquia are available via webcast.

#### Objective
Learn about recent research results in geotechnics.
**Civil Engineering Bachelor**

**Bachelor Studies (Programme Regulations 2022)**

**First Year Compulsory Courses**

**First Year Examinations**

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>401-0141-00L</td>
<td>Linear Algebra</td>
<td>O</td>
<td>5 credits</td>
<td>4V+1U</td>
<td>M. Akka Ginosar, R. Prohaska</td>
</tr>
<tr>
<td>151-0501-03L</td>
<td>Mechanics I</td>
<td>O</td>
<td>6 credits</td>
<td>3V+2U+1K</td>
<td>R. Hopf, E. Mazza</td>
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<tr>
<td>651-0032-00L</td>
<td>Geology and Petrography</td>
<td>O</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>K. Rauchenstein, M. O. Saar</td>
</tr>
<tr>
<td>101-0700-00L</td>
<td>Programming for Engineers</td>
<td>O</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>B. Sudret, N. Lüthen</td>
</tr>
</tbody>
</table>

**Abstract**

- **Linear Algebra**: Introduction to Linear Algebra
  - Basic knowledge of linear algebra as a tool for solving engineering problems.

- **Mechanics I**: Basics: Position of a material point, velocity, kinematics of rigid bodies, forces, reaction principle, mechanical power.
- **Geology and Petrography**: Basics: Position of a material point, velocity, kinematics of rigid bodies, forces, reaction principle, mechanical power.

- **Programming for Engineers**: This course is a hands-on introduction to programming with Matlab and Python, oriented at the needs of civil engineers. The course consists of weekly lectures and bi-weekly exercises in groups.

**Objective**

- **Linear Algebra**: Basic knowledge of linear algebra as a tool for solving engineering problems.
- **Mechanics I**: The understanding of the fundamentals of statics for engineers and their application in simple settings.
- **Geology and Petrography**: The understanding of the fundamentals of statics for engineers and their application in simple settings.
- **Programming for Engineers**: Students recognize the usefulness and power of computer tools in civil engineering, and are prepared to independently use Matlab or Python for solving relevant engineering problems.

**Content**

- **Linear Algebra**: Basics: Position of a material point, velocity, kinematics of rigid bodies, forces, reaction principle, mechanical power.
- **Mechanics I**: Statics: Groups of forces, moments, equilibrium of rigid bodies, reactions at supports, parallel forces, center of gravity, statics of systems, principle of virtual power, trusses, frames, forces in beams and cables, friction.
- **Geology and Petrography**: Statik: Äquivalenz und Reduktion von Kräftegruppen; Ruhe und Gleichgewicht, Hauptsatz der Statik; Lagerbindungen und Lagerkräfte, Lager bei Balkenträgern und Wellen, Vorgehen zur Ermittlung der Lagerkräfte, Parallelle Kräfte und Schwerpunkt; Statik der Systeme, Behandlung mit Hauptsatz, mit Prinzip der virtuellen Leistungen, statisch unbestimmte Systeme; Statisch bestimmte Fachwerke, ideale Fachwerke, Pendelstützen, Knotengleichgewicht, räumliche Fachwerke; Reibung, Haftreibung, Gleireibung, Gelenk und Lagerreibung, Rollreibung; Seilstatik; Beanspruchung in Stabträgern, Querkraft, Normalkraft, Biege- und Torsionsmoment
- **Programming for Engineers**: This course is a hands-on introduction to programming with Matlab and Python, oriented at the needs of civil engineers. The course consists of weekly lectures and bi-weekly exercises in groups.

**Literature**

- **Linear Algebra**: Larson, Ron. Elementary linear algebra. Nelson Education, 2016. (English)
- **Mechanics I**: K. Nipp, D. Stoffer, Lineare Algebra, VdF Hochschulverlag ETH
- **Geology and Petrography**: Sayir, M.B., Dual J., Kaufmann S., Mazza E., Ingenieurmechanik 1: Grundlagen und Statik, Springer
The course is structured into six modules. The first five are using Matlab, while the last introduces Python.

1. Getting to know Matlab: Matlab as a calculator; variables and arrays
2. Programming basics I: iterating and branching
3. Programming basics II: input and output, functions, visualization
4. Introduction to scientific programming: implementing simple algorithms from numerics, statistics and discrete math; validation, testing and debugging
5. From structures to objects to GUI: basics of object-oriented programming, introduction to interactive programming and graphical user interfaces (GUI)
6. Introduction to programming with Python

A script will be provided. The students will discover the topics of each module through E.Tutorials that they will follow at their own pace online.

### Literature

**Additional book (not mandatory):**


ISBN: 978-0-12-420228-3

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
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<tbody>
<tr>
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<tr>
<td>Self-direction and Self-management fostered</td>
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</table>

### Lecture notes

There are "Lecture Notes" (in German) for this course.

### Literature

**1. Getting to know Matlab:**


Urs Stammbach, "Analysis II" (erhältlich im ETH Store); [https://people.math.ethz.ch/~stammb/analysisskript.html](https://people.math.ethz.ch/~stammb/analysisskript.html)

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**First Year Examination Block B**

### Number 401-0241-00L** Analysis I**

<table>
<thead>
<tr>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>7</td>
<td>4V+2U</td>
<td>M. Akveld, G.-I. Ionita</td>
</tr>
</tbody>
</table>

**Abstract**

Mathematical tools for the engineer

**Objective**

Mathematics as a tool to solve engineering problems. Basic mathematical knowledge for engineers.

**Content**

Complex numbers. Calculus for functions of one variable with applications. Simple Mathematical models in engineering.

**Lecture notes**

Wird auf der Vorlesungshomepage zu Verfügung gestellt.

**Literature**


Urs Stammbach, "Analysis II" (erhältlich im ETH Store); [https://people.math.ethz.ch/~stammb/analysisskript.html](https://people.math.ethz.ch/~stammb/analysisskript.html)
Second and Third Year Compulsory Courses

Courses of Examination Blocks

Examination Block 1

<table>
<thead>
<tr>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>401-0243-00L</td>
<td>Analysis III</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>M. Akka Ginosar</td>
</tr>
</tbody>
</table>

Abstract
We will model and solve scientific problems with partial differential equations. Differential equations which are important in applications will be classified and solved. Elliptic, parabolic and hyperbolic differential equations will be treated. The following mathematical tools will be introduced: Laplace and Fourier transforms, Fourier series, separation of variables, methods of characteristics.

Objective
Learning to model scientific problems using partial differential equations and developing a good command of the mathematical methods that can be applied to them. Knowing the formulation of important problems in science and engineering with a view toward civil engineering (when possible). Understanding the properties of the different types of partial differential equations arising in science and in engineering.

Content
Classification of partial differential equations
Study of the Heat equation general diffusion/parabolic problems using the following tools through Separation of variables as an introduction to Fourier Series.
Systematic treatment of the complex and real Fourier Series
Study of the wave equation and general hyperbolic problems using Fourier Series, D'Alembert solution and the method of characteristics.
Laplace transform and it's uses to differential equations
Study of the Laplace equation and general elliptic problems using similar tools and generalizations of Fourier series.
Application of Laplace transform for beam theory will be discussed.

Lecture notes
Lecture notes will be provided

Literature
large part of the material follow certain chapters of the following first two books quite closely.


The course material is taken from the following sources:

Stanley J. Farlow - Partial Differential Equations for Scientists and Engineers

G. Felder: Partielle Differenzialgleichungen.
https://people.math.ethz.ch/~felder/PDG/


Prerequisites / notice
Analysis I and II, insbesondere, gewöhnliche Differentialgleichungen.

402-0023-01L | Physics | O | 7 credits | 5V+2U | J. Faist

Abstract
This course gives an overview of important concepts in classical dynamics, thermodynamics, electromagnetism, quantum physics, atomic physics, and special relativity. Emphasis is placed on demonstrating key phenomena using experiments, and in developing skills for quantitative problem solving.

Objective
The goal of this course is to make students able to explain and apply the basic principles and methodology of physics to problems of interest in modern science and engineering. An important component of this is learning how to solve new, complex problems by breaking them down into parts and applying simplifications. A secondary goal is to provide to students an overview of important subjects in both classical and modern physics.

Content
Electrodynamics, Thermodynamics, Quantum physics, Waves and Oscillations, special relativity

Lecture notes
Lecture notes and exercise sheets will be distributed via Moodle

Literature
Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving assessed

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management assessed

101-0203-01L Hydraulics I
- O 5 credits 3V+1U R. Stocker

Abstract
The course teaches the basics of hydromechanics, relevant for civil and environmental engineers.

Objective
In the course “Hydraulics I”, the competency of process understanding is taught, applied and examined. Furthermore system understanding and measurement methods are taught.

Content
- Properties of water, hydrostatics, stability of floating bodies, continuity, Euler equation of motion, Navier-Stokes equations, similarity, Bernoulli principle, momentum equation for finite volumes, potential flows, ideal fluids vs. real fluids, boundary layer, pipe flow, open channel flow, flow measurements, demonstration experiments in the lecture hall

Lecture notes
Script and collection of previous problems

Literature
Bollrich, Technische Hydromechanik 1, Verlag Bauwesen, Berlin

101-0113-00L Theory of Structures I
- O 5 credits 3V+2U B. Sudret

Abstract
Introduction to structural mechanics, statically determinate beams and frame structures, trusses, stresses and deformations, statically indeterminate beams and frame structures (force method)

Objective
- Understanding the response of elastic beam and frame structures
- Ability to correctly apply the equilibrium conditions
- Understanding the basics of continuum mechanics
- Computation of stresses and deformations of elastic structures
- Ability to apply the force (flexibility) method for statically indeterminate structures

Content
- Equilibrium, reactions, static determinacy
- Internal forces (normal and shear forces, moments)
- Arches and cables
- Elastic trusses
- Influence lines
- Basics of continuum mechanics
- Stresses in elastic beams
- Deformations in Euler-Bernoulli and Timoshenko beams
- Energy theorems
- Statically indeterminate systems (Force method)

Lecture notes
Bruno Sudret, “Einführung in die Baustatik” (2021)

Literature
* Bruno Sudret, “Baustatik - Eine Einführung”, Springer Vieweg


Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed

Personal Competencies
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed

151-0503-00L Mechanics III
- O 6 credits 4V+2U D. Kochmann

Abstract
Dynamics of particles, rigid bodies, and deformable bodies: Motion of a single particle, motion of systems of particles, 2D and 3D motion of rigid bodies, vibrations, waves.

Objective
This course enables students to apply the concepts and laws governing the kinematics and kinetics of particles, rigid bodies, and elastic bodies in order to identify, formulate, and solve dynamical engineering problems. Specifically, students will be able to describe, analyze, and predict the motion of particles and bodies in space over time and to relate their motion to the applied forces for applications in (not only) mechanical and civil engineering.
Students of mechanical and civil engineering learn the fundamental concepts of the dynamics of mechanical systems. By studying the motion of a single particle, systems of particles, of rigid bodies, and of deformable bodies, we introduce essential concepts such as kinematics, kinetics, work and energy, equations of motion, and forces and torques. Further topics include the stability of equilibria and vibrations as well as an introduction to the dynamics of deformable bodies and waves in elastic rods. Throughout the course, application-oriented examples help students acquire a proficient background in engineering dynamics, further to learn and embrace problem-solving techniques for dynamical engineering problems, gain cross-disciplinary expertise (by linking concepts from, among others, mechanics, mathematics, and physics), and prepare students for advanced courses and work on engineering applications. The detailed syllabus includes:

1. Motion of a single particle: kinematics (trajectory, velocity, acceleration), forces and torques, constraints, active and reaction forces, balance of linear and angular momentum, work-energy balance, conservative systems, equations of motion.
2. Motion of systems of particles: internal and external forces, balance of linear and angular momentum, work-energy balance, rigid systems of particles, particle collisions, mass accretion/loss.
3. Motion of rigid bodies in 2D and 3D: kinematics (angular velocity, velocity and acceleration transfer, instantaneous center and axis of rotation), balance of linear and angular momentum, work-energy balance, angular momentum transport, inertial vs. moving reference frames, apparent forces, Euler equations.
5. Introduction to waves and vibrations of elastic bodies: local form of linear momentum balance, waves in slender elastic rods.

Lecture notes
Lecture notes (a complete scriptum) is available on Moodle. Students are encouraged to take their own notes during class.

Literature
Lecture notes (a complete scriptum) is available on Moodle. Further reading materials are suggested but not required for this class.

Prerequisites / notice
For students in the bachelor’s degree programme in mechanical engineering:
Precondition for this course unit are passed first year examination blocks A and B.

All course materials (including lecture notes, exercise problems, etc.) are available on Moodle.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Sensitivity to Diversity fostered
Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Examination Block 2

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<th>Type</th>
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<th>Lecturers</th>
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<tr>
<td>101-6615-00L</td>
<td>Materials in Civil Engineering I</td>
<td>O</td>
<td>5 credits</td>
<td>8G</td>
<td>R. J. Flatt, U. Angst, I. Burgert, D. Kammer, F. Wittel</td>
</tr>
</tbody>
</table>

Abstract

Objective

Die Studierenden erlernen in den Vorlesungen und in auf diese abgestimmten Laborübungen theoretische und praktische Kompetenzen für den werkstoffgerechten Einsatz und bewussten Umgang mit Baustoffen als wertvolle Ressourcen.
Content

Der Jahreskurs gliedert sich in 8 Module, die auf 2 Semester verteilt sind. Module umfassen Vorlesungen und dazugehörige Labore:

HS:
Modul 1: Physikalisches Verhalten von Materialien und ihre Charakterisierung:
L (3-4): Labore zu Bauphysik, zu Finite Elemente Methoden, bewertete Hausübung zu LCA und zur Analyse wissenschaftlicher Daten.

Modul 2: Zementöse Baustoffe:
L (5): Labore zu Betontechnologie, Mineralische Bindemittel, Stein als Baumaterial, Mauerwerk und Mikrostruktur unterschiedlicher Baustoffe.

Modul 3: Amorphe Werkstoffe:

Modul 4: Digitale Fabrikation:
V (2): Methoden der digitalen Fabrikation und additiven Fertigung.
E (1): Exkursion Emersive Design Lab / HIB

FS:
Modul 5: Metalle und Korrosion:
L (3): Labore zu metallischen Werkstoffen, Dauerhaftigkeit von Stahlbetonbauten, detektieren und orten der Korrosion und digitaler Fabrikation.

Modul 6: Holz und Holzwerkstoffe:
L (2): Labore zu Holzgegenständen auf Makro- und Mikroskopischer Ebene.

Modul 7: Baustoffe im Computer:
V (3): Grundlagen der Materialsimulation, Mikromechanik und Fallstudien zu Materialsimulationen für Baustoffe

Modul 8: Repetitorien:

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving fostered

Social Competencies
Communication fostered
Customer Orientation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-direction and Self-management fostered

Examination Block 3

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<td>101-0315-00L</td>
<td>Geotechnical Engineering</td>
<td>O</td>
<td>5 credits</td>
<td>4G</td>
<td>A. Puzrin</td>
</tr>
</tbody>
</table>

Abstract
The course explores the fundamental principles of Geomechanics and Geotechnical Engineering, with the following objectives:
- Recognition of the basic consequences of the ground construction;
- Understanding of the important fundamental concepts of Soil mechanics and Geotechnical Engineering;
- Independent analysis of the basic geotechnical problems.

Objective
The course explores the fundamental principles of Geomechanics and Geotechnical Engineering, with the following objectives:
- Recognition of the basic consequences of the ground construction;
- Understanding of the important fundamental concepts of Soil mechanics and Geotechnical Engineering;
- Independent analysis of the basic geotechnical problems.

Content
Overview of stability problems; Bearing capacity of shallow and deep foundations; Earth pressure on retaining structures; Analysis and design of shallow and deep foundations; Soil-pressure interaction; Analysis and design of retaining walls; Excavations: dewatering, analysis and design; Soil improvement; Safety considerations.

Lecture notes
Examples
Exercises

Literature
### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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<td>Project Management</td>
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### Content

#### 101-0135-01L Steel Structures II

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<th>Objective</th>
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<tr>
<td>Students will expand the knowledge acquired during &quot;Steel Structures I&quot; and learn how to apply these skills to the design of more complex building and bridge steel and composite structures. They will acquire the fundamental background for the phenomena of plate buckling and fatigue and learn how to apply it to practical design tasks. In addition, students will learn to appreciate the importance of questions of detailing, fabrication, erection and cost calculation for the effective design of steel and composite structures.</td>
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</table>

After completion of the year-long course in Steel Structures I+II, students will have at their disposal a wide and detailed set of skills concerning the modern practice for steel and composite structures design and have a deep understanding of its theoretical & scientific background. The examples of scientific and standardisation work provided in the lectures give the students the opportunity to learn about the most current developments and see how these are used to shape the future practice in the structural engineering field.

The lecture Steel Structures II complements the knowledge acquired in part I by providing students with additional theoretical and practical knowledge, e.g. on the design of steel and composite structures against fatigue, plate buckling, as well as on the structural modelling and analysis of more complex building and bridge structures. These more theoretical topics will be exemplified and illustrated by applications to real problems in the design of bridges and multi-storey building structures. Finally, the course will provide detailed insight into aspects pertaining to structural detailing, fabrication, erection and cost estimation for constructional steelwork.

Content overview:
- Structural forms, analysis techniques and modelling of multi-storey buildings and bridges.
- Structural analysis (deformations, internal forces, stresses and strains) in steel-concrete composite girders considering the effects of creep, shrinkage and shear deformations.
- Elastic and plastic longitudinal shear transfer mechanisms and effects
- Plate buckling of unstiffened and stiffened panels
- Fatigue resistance and safe life assessment: phenomenon and design approaches
- Special topics of steel connection design
- Detailing, drafting, fabrication and erection, cost determination in constructional steelwork

#### Literature

- Corman, F.: Infrastructures and vehicle technologies of public transport systems; interaction between track and vehicles; passengers and roadways, station infrastructures; Fundamentals of the infrastructure design for lines; track geometries; switches and crossings
- Jacobi, H.: Planning problems and decision levels in network development and infrastructure planning, planning of topologies; tracks and roadways, station infrastructures; Fundamentals of the infrastructure design for lines; track geometries; switches and crossings

#### 101-0415-01L Public Transport and Railways

<table>
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<th>Objective</th>
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<tr>
<td>Teaches the basic principles of public transport network and topology design, to understand the main characteristics and differences of public transport networks, based on buses, railways, or other technologies.</td>
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</table>

Teaches students to recognize the interactions between the infrastructure design and the production processes, and various performance criteria based on various perspective and stakeholders. At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate different choices of technologies to suitable cases; optimize the use of resources in public transport.

Content

Infrastructure: Planning processes and decision levels in network development and infrastructure planning, planning of topologies; tracks and roadways, station infrastructures; Fundamentals of the infrastructure design for lines; track geometries; switches and crossings

Vehicles: Classification, design and suitability for different goals

Network design: design dilemmas, conceptual models for passenger transport on long distance, urban regional transport.

Operations: Passenger/Supply requirements for line operations; timetabling, measures of realized operations, capacity

Lecture notes

- Slides, in English, are made available some days before each lecture.

Literature

Reference material books are provided in German and English (list disseminated at lecture), plus Skript Bahninfrastruktur; System- und Netzplanung
### Systems Engineering

**Abstract**
- Systems Engineering is a way of thinking that helps engineer sustainable systems, i.e., ones that meet the needs of stakeholders in the short, medium and long term.
- This course provides an overview of the main principles of Systems Engineering, and includes an introduction to the use of operations research methods in the determination of optimal systems.

**Objective**
- The world's growing population, changing demographics, and changing climate pose formidable challenges to humanity's ability to live sustainably. Ensuring that humanity can live sustainably requires accommodating Earth's growing and changing population through the provision and operation of a sustainable and resilient built environment. This requires ensuring excellent decision-making as to how the built environment is constructed and modified.

More specifically upon completion of the course, you will have gained insight into:
- how to structure the large amount of information that is often associated with attempting to modify complex systems
- how to set goals and define constraints in the engineering of complex systems
- how to generate possible solutions to complex problems in ways that limit exceedingly narrow thinking
- how to compare multiple possible solutions over time with differences in the temporal distribution of costs and benefits and uncertainty as to what might happen in the future
- how to assess values of benefits to stakeholders that are not in monetary units
- how to assess whether it is worth obtaining more information in determining optimal solution
- how to take a step back from the numbers and qualitatively evaluate the possible solutions in light of the bigger picture
- the basics of operations research and how it can be used to determine optimal solutions to complex problems, including linear, integer and network programming, dealing with multiple objectives and conducting sensitivity analyses.

**Content**
The lectures are structured as follows:

1. Introduction – An introduction to System Engineering, a way of thinking that helps to engineer sustainable systems, i.e., ones that meet the needs of stakeholders in the short, medium and long terms. A high-level overview of the main principles of System Engineering. The expectations of your efforts throughout the semester.
2. Situation analysis – How to structure the large amount of information that is often associated with attempting to modify complex systems.
3. Goals and constraints – How to set goals and constraints to identify the best solutions as clearly as possible.
4. Generation of possible solutions – How to generate possible solutions to problems, considering multiple stakeholders.
5. The principles of net-benefit maximization and a series of methods that range from qualitative and approximate to quantitative and exact, including pairwise comparison, elimination, weighting, and expected value.
6. The idea behind the supply and demand curves and revealed preference methods.
7. The concept of equivalence, including the time value of money, interest, life times and terminal values.
8. The relationship between net-benefit and the benefit-cost ratio. How incremental cost benefit analysis can be used to determine the maximum net benefit. Internal rates of return.
9. How to consider multiple possible futures and use simple rules to help pick optimal solutions and to determine the value of more information.
10. Once quantitative analysis is used it becomes possible to use operations research methods to analyse large numbers of possible solutions. Linear programming and the simplex method.
11. How sensitivity analysis is conducted using linear programming.
12. How to use operations research to solve problems that consist of discrete values, as well as how to exploit the structure of networks to find optimal solutions to network problems.
13. How to set up and solve problems when there are multiple objectives.

The course uses a combination of qualitative and quantitative approaches.

**Lecture notes**
- The lecture materials consist of a script, the slides, example calculations in Excel, Moodle quizzes, and exercises.
- The lecture materials will be distributed via Moodle before each lecture.

**Literature**
- Appropriate literature in addition to the lecture materials will be handed out when required via Moodle.

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### Literature

<table>
<thead>
<tr>
<th>Course Code</th>
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<td>101-0031-10L</td>
<td>Systems Engineering</td>
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### Competencies

<table>
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### Method-specific Competencies

- fostered
- assessed

### Social Competencies

- Communication
- Fostered

### Personal Competencies

- Fostered

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**Data: 15.06.2024 12:39**

**Autumn Semester 2024**

**Page 172 of 2653**
### Hydrology

#### Abstract
The course introduces the students to engineering hydrology. It covers first physical hydrology, that is the description and the measurement of hydrological processes (precipitation, interception, evapotranspiration, runoff, erosion, and snow), and it introduces then the basic mathematical models of the single processes and of the rainfall-runoff transformation, thereby including flood analysis.

#### Objective
The hydrological cycle: global water resources, water balance, space and time scales of hydrological processes.

#### Content
- Precipitation: mechanisms of precipitation formation, precipitation measurements, variability of precipitation in space and time, precipitation regimes, point/basin precipitation, isochetal method, Thiessen polygons, storm rainfall, design hyetograph.
- Interception: measurement and estimation.
- Evaporation and evapotranspiration: processes, measurement and estimation, potential and actual evapotranspiration, energy balance method, empirical methods.
- Infiltration: measurement, Horton’s equation, empirical and conceptual models, phi-index and percentage method, SCS-CN method.
- Surface runoff and subsurface flow: Hortonian and Dunnian surface runoff, streamflow measurement, streamflow regimes, annual hydrograph, flood hydrograph analysis – baseflow separation, flow duration curve.
- Basin characteristics: morphology, topographic and phreatic divide, hypsometric curve, slope, drainage density.
- Rainfall-runoff models (R-R): rationale, linear model of rainfall-runoff transformation, concept of the instantaneous unit hydrograph (IUH), linear reservoir, Nash model.
- Flood estimation methods: flood frequency analysis, deterministic methods, probabilistic methods (e.g. statistical regionalisation, indirect R-R methods for flood estimation, rational method).
- Erosion and sediment transport: watershed scale erosion, soil erosion by water, estimation of surface erosion, sediment transport.

#### Lecture notes
The lecture notes as well as the lecture presentations and handouts may be downloaded from the website of the Chair of Hydrology and Water Resources Management.

#### Literature

#### Prerequisites / notice
Knowledge of statistics is a prerequisite. The required theoretical background, which is needed for understanding part of the lectures and performing part of the assignments, may be summarised as follows:
- Elementary data processing; hydrological measurements and data, data visualisation (graphical representation and numerical parameters).
- Frequency analysis: hydrological data as random variables, return period, frequency factor, probability paper, probability distribution fitting, parametric and non-parametric tests, parameter estimation.

### Examination Block 4

#### Number Title Type ECTS Hours Lecturers

| 101-0125-00L | Structural Concrete I | O | 5 credits | 4G | W. Kaufmann |

#### Abstract
- Contents: Introduction, historical development of structural concrete, materials and material behaviour (cement, concrete, reinforcing steel, prestressing steel), linear members (axial force, flexure and axial force, compression members and columns, shear, bending and shear, torsion and combined actions), strut-and-tie models and simple stress fields, detailing, basic aspects of membrane elements.

#### Objective
- Knowledge of the materials concrete and reinforcing steel and understanding their interaction;
- Understanding the response of typical structural members;
- Knowledge of elementary models and ability to apply them to practical problems;
- Ability to correctly dimension and detail simple structures.

#### Content
- Introduction, historical development of structural concrete, materials and material behaviour (cement, concrete, reinforcing steel, prestressing steel), linear members (axial force, flexure and axial force, compression members and columns, shear, bending and shear, torsion and combined actions), strut-and-tie models and simple stress fields, detailing.
### Conceptual Design/Project Work

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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>101-0007-01L</td>
<td>Project Work Conceptual Design</td>
<td>O</td>
<td>3</td>
<td>5S</td>
<td>F. Ortiz Quintana</td>
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</table>

**Abstract**

A structure to be designed serves as a mean to practice the holistic approach of conceptual design by working in parallel and iteratively on different levels of detailing. Both, requirements and scope of action, are identified by the students and serve as basis for a solution. The task group organizes itself to solve complex tasks.

**Objective**

The project work conceptual design conveys a first insight into the holistic approach to cope with typical tasks of civil engineering and introduces professional techniques of civil engineering to students. A further aim is to consolidate the knowledge gained so far in bachelor courses, to link different domains and to fill gaps with respect to work techniques. The students analyse the inventory, formulate design requirements and boundary conditions, elaborate approaches and proposals for solutions, dimension some exemplary structural elements, practise detailing and document their work by different media.

**Content**

**Topics:**

- Basics of graphic representation, Acceptance of service, Analysis of third-party documents, site survey, Conceptual design, service criteria agreement, technical specification, connections, strcutural analyse, Quantities and costs, Models

**Methodology:**

- Excursion with mission, lectures, autonomous work, role playing, presentations, deliveries, final presentation, exhibition.

**Lecture notes**

Lecture notes

**Literature**

Codes SIA 260, 261, 400, 112, 103

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Project Management

- **Method-specific Competencies**
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity

- **Social Competencies**
  - Negotiation

- **Personal Competencies**
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Self-awareness and Self-reflection

**Bachelor’s Thesis**

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<td>Bachelor’s Thesis</td>
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<td>8</td>
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**Abstract**

The Bachelor Programme concludes with the Bachelor Thesis. This project is supervised by a professor. Writing up the Bachelor Thesis encourages students to show independence and to produce scientifically structured work and to apply engineering working methods.

**Objective**

Encourages students to show independence, to produce scientifically structured work and to apply engineering working methods.

**Content**

The contents base upon the fundamentals of the Bachelor Programme. Students can choose from different subjects and tasks. The thesis consists of both a written report and an oral presentation.

### Science in Perspective

**Science in Perspective**

- **see Science in Perspective: Type A: Enhancement of Reflection Capability**
- **Recommended Science in Perspective (Type B) for D-BAUG**

### Language Courses

**see Science in Perspective: Language Courses ETH/UZH**
### Civil Engineering Bachelor - Key for Type

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<th>Description</th>
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<td>O</td>
<td>Compulsory</td>
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<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<td>Dr</td>
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### Key for Hours

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<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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**ECTS**
- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
1. Semester

Seminar Work

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<tr>
<td>101-0007-00L</td>
<td>Project Management for Construction Projects</td>
<td>O</td>
<td>4</td>
<td>3S</td>
<td>B. Hofer</td>
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</tbody>
</table>

**Abstract**

This course is designed to lay down the foundation of the different concepts, techniques, and tools for successful project management of construction projects.

**Objective**

The goal is that at the end of this course students should have a good understanding of the different project management knowledge areas, the phases required for successful project management, and the role of a project manager. To demonstrate this, students will work in groups in different case studies to apply the concepts, tools and techniques presented in the class.

Two 3 to 4 hours sessions towards the end of the lecture series will introduce a practical project to allow the teams to demonstrate the tools and techniques learned during the semester. The course will have a final quiz that will be graded.

The course will be supported by several external lecturers from the construction industry and demonstrations of real-life case studies.

**Content**

The main content of the course is summarized in the following topics:

- Introduction, project and organization structures
- Project scheduling
- Resource management
- Risk management
- Project estimating and budgeting
- Project financing and Public-Private Partnerships (PPP)
- Construction Process management and controlling
- Sustainability management
- Reporting and Communication
- Interpersonal skills and leadership in Construction projects
- Advanced Topics in Construction Project management (BIM / 5D planning, Ki)
- Project Evaluation and Closure

**Lecture notes**

The slides for the class will be available for download from Moodle at least one day before each class. Copies of all necessary documents will be distributed at appropriate times.

**Literature**

Relevant readings will be recommended throughout the course (and made available to the students via Moodle).

**Prerequisites / notice**

The students will be randomly assigned to teams. Students will be graded as a team based on the final Project proposal with the in-class oral presentation as well as a final exam (50% exam and 50% project). Homework will not be graded but your final report and presentation will consist mostly of your homework assignments consolidated and put in a report and presentation format.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories fostered
  - Techniques and Technologies fostered

- **Method-specific Competencies**
  - Analytical Competencies fostered
  - Decision-making assessed
  - Problem-solving assessed
  - Project Management assessed

- **Social Competencies**
  - Communication assessed
  - Cooperation and Teamwork assessed
  - Customer Orientation assessed
  - Leadership and Responsibility assessed
  - Self-presentation and Social Influence fostered
  - Sensitivity to Diversity fostered
  - Negotiation assessed

- **Personal Competencies**
  - Adaptability and Flexibility fostered
  - Creative Thinking fostered
  - Critical Thinking fostered
  - Integrity and Work Ethics fostered
  - Self-awareness and Self-reflection assessed
  - Self-direction and Self-management assessed

**Major Courses**

**Major in Construction and Maintenance Management**

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<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
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<td>151-8011-00L</td>
<td>Building Physics: Theory and Applications</td>
<td>W</td>
<td>4</td>
<td>3V+1U</td>
<td>A. Kubilay, X. Zhou, L. Fei, A. Rubin</td>
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</table>

**Abstract**

Principles of heat and mass transport, hygro-thermal performance, durability of the building envelope and interaction with indoor and outdoor climates, applications.

**Objective**

The students will acquire in the following fields:

- Indoor and outdoor climate and driving forces.
- Hygrothermal properties of building materials.
- Building envelope solutions and their construction.
- Hygrothermal performance and durability.

**Content**

Principles of heat and mass transport, hygro-thermal performance, durability of the building envelope and interaction with indoor and outdoor climates, applications.

**Lecture notes**

Handouts, supporting material and exercises are provided online via Moodle.

**Prerequisites / notice**

Priority will be given to students in Integrated Building Systems Master (MIBS). Please send an email to the main lecturer, if you are not a MIBS student.

**Competencies**

- Subject-specific Competencies fostered
  - Concepts and Theories fostered

**Major Courses**

**Major in Construction and Maintenance Management**

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<tr>
<th>Number</th>
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<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>066-0427-00L</td>
<td>Building Physics: Theory and Applications</td>
<td>W</td>
<td>4</td>
<td>3V+1U</td>
<td>A. Kubilay, X. Zhou, L. Fei, A. Rubin</td>
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Handouts, supporting material and exercises are provided online via Moodle.

**Prerequisites / notice**

Priority will be given to students in Integrated Building Systems Master (MIBS). Please send an email to the main lecturer, if you are not a MIBS student.

**Competencies**

- Subject-specific Competencies fostered
  - Concepts and Theories fostered

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Autumn Semester 2024

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# Public Transport Design and Operations

**101-0427-01L**

<table>
<thead>
<tr>
<th>Public Transport Design and Operations</th>
<th>W</th>
<th>6 credits</th>
<th>4G</th>
<th>F. Corman</th>
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## Abstract

This course aims at analyzing, designing, improving public transport systems, as part of the overall transport system. Lectures on six compact aspects gaining importance in a increasingly specialised, complex and international surrounding.

## Objective

Participants will come to understand how they can best navigate the design and building process, especially in relation to understanding their profession, gaining a thorough knowledge of rules and regulations, as well as understanding how involved parties’ minds work. They will also have the opportunity to investigate ways in which they can relate to, understand, and best respond to their clients’ wants and needs. Finally, course participants will come to appreciate the various tools and instruments, which are available to them when implementing their projects. The course will guide the participants, bringing the individual pieces of knowledge into a superordinate relationship.

## Content

Design and Building Process MIBS is a brief manual for prospective architects and engineers covering the competencies and the responsibilities of involved parties through the design and building process. Three compact chapters regarding the established building culture are gaining importance in an increasingly specialised, complex and international surrounding. Lectures on the topics of competence, organisation, agility, monitoring, interest, and the environment will guide the participants, bringing the individual pieces of knowledge into a superordinate relationship. The course introduces the key figures, depicts the criteria of the project and highlights the proved services of the consultants. In addition to discussing the basics, the terminologies and the tendencies, the lecture units will refer to the studios as well as the practice: Teaching-based workshops will compliment and deepen the understanding of the three selected aspects of profession, methodology, and environment. The course is presented as a moderated seminar to allow students the opportunity for individual input: active collaboration between the students and their tutor therefore required.

## Literature

F. Corman

Design and Building Process MIBS is a brief manual for prospective architects and engineers covering the competencies and the responsibilities of involved parties through the design and building process. Two compact chapters regarding the established building culture are gaining importance in an increasingly specialised, complex and international surrounding. Lectures on the topics of competence, organisation, agility, monitoring, interest, and the environment will guide the participants, bringing the individual pieces of knowledge into a superordinate relationship. The course introduces the key figures, depicts the criteria of the project and highlights the proved services of the consultants. In addition to discussing the basics, the terminologies and the tendencies, the lecture units will refer to the studios as well as the practice: Teaching-based workshops will compliment and deepen the understanding of the three selected aspects of profession, methodology, and environment. The course is presented as a moderated seminar to allow students the opportunity for individual input: active collaboration between the students and their tutor therefore required.

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<td>Self-direction and Self-management</td>
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## Course Information

- **101-0427-01L**
- **Public Transport Design and Operations**
- **W**: 6 credits
- **4G**: F. Corman
- **Autumn Semester 2024**
- **Lecture notes**: Lecture slides are provided.
### Competencies

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### Lecture notes

- The lecture materials consist of handouts and the slides.
- The lecture materials will be distributed via Moodle by the beginning of each lecture.
- The questions to be discussed in the discussion session will be distributed by the end of the day on the Monday before the discussion session.

### Literature

- **Ceder, Avi:** Public Transit Planning and Operation, CRC Press, 2015. ISBN 978-1466563919 (English)
- **Walker, Jarrett:** Human Transit – How clearer thinking about public transit can enrich our communities and our lives, ISLAND PRESS, Washington / Covelo / London 2012, ISBN 978-1-59726-971-1 (English)
Appropriate literature will be handed out when required via Moodle.

Literature

This course has no prerequisites.

Prerequisites

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies fostered
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving fostered
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

An Introduction to Sustainable Development in the Built Environment

O 3 credits 2G

G. Habert, E. Zea Escamilla

Abstract

In 2015, the UN Conference in Paris shaped future world objectives to tackle climate change. This decarbonization strategy is additional to Sustainable Development goals formulated the same year by the UN general assembly.

What does that mean for the built environment?

This course provides an introduction to the notion of sustainable development when applied to our built environment.

Objective

At the end of the semester, the students have an understanding of the term of sustainable development, its history, the current political and scientific discourses and its relevance for our built environment.

In order to address current challenges of climate change mitigation and resource depletion, students will learn a holistic approach of sustainable development. Ecological, economical and social constraints will be presented and students will learn about methods for argumentation and tools for assessment (i.e. life cycle assessment).

For this purpose an overview of sustainable development is presented with an introduction to the history of sustainability and its today definition as well as the role of cities, urbanisation and material resources (i.e. energy, construction material) in social economic and environmetal aspects.

The course aims to promote an integral view and understanding of sustainability and describing different spheres (social/cultural, ecological, economical, and institutional) that influence our built environment.

Students will acquire critical knowledge and understand the role of involved stakeholders, their motivations and constraints, learn how to evaluate challenges, identify deficits and define strategies to promote a more sustainable construction.

After the course students should be able to define the relevance of specific local, regional or territorial aspects to achieve coherent and applicable solutions toward sustainable development.

The course offers an environmental, socio-economic and socio-technical perspective focussing on buildings, cities and their transition to resilience with sustainable development. Students will learn on theory and application of current scientific pathways towards sustainable development.

Content

The following topics give an overview of the themes that are to be worked on during the lecture.

- Overview on the history and emergence of sustainable development
- Overview on the current understanding and definition of sustainable development and beyond

Methods

- Method 1: Life cycle assessment (planning, construction, operation/use, deconstruction)
- Method 2: Life Cycle Costing
- Method 3: Labels and certification
- Method 4: Material Flow Analysis

Main issues:
- Operation energy at building, urban and national scale
- Mobility and density questions
- Embodied energy for developing and developed world

- Synthesis: Transition to sustainable development

Lecture notes

All relevant information will be online available before the lectures. For each lecture slides of the lecture will be provided.

Literature

A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.
### Major in Geotechnical Engineering

#### 101-0317-00L Tunnelling I

**Number**: 101-0317-00L  
**Title**: Tunnelling I  
**Type**: W+  
**ECTS**: 3 credits  
**Hours**: 2G  
**Lecturers**: G. Anagnostou, A. Nordas, E. Pimentel

**Abstract**  
Basic aspects of design and analysis of underground structures. Conventional tunnel construction methods. Auxiliary measures (ground improvement and drainage, forepoling, face reinforcement). Numerical analysis methods.

**Objective**  
Basic aspects of design and analysis of underground structures. Conventional tunnel construction methods. Auxiliary measures (ground improvement and drainage, forepoling, face reinforcement). Numerical analysis methods.

**Content**  
Numerical analysis methods in tunnelling.  
Conventional excavation methods (full face, top heading and bench, side drift method, ...)  
Auxiliary measures:  
- Injections  
- Jet grouting  
- Ground freezing  
- Drainage  
- Forepoling  
- Face reinforcement

**Lecture notes**  
Autographieblätter

**Literature**  
Empfehlungen

**Prerequisites / notice**  
This course will continue to be offered in German up to and including HS24.

#### 101-0357-00L Theoretical and Experimental Soil Mechanics

**Number**: 101-0357-00L  
**Title**: Theoretical and Experimental Soil Mechanics  
**Prerequisites**: Mechanics I, II and III.

**Abstract**  
The number of participants is limited to 60 due to the existing laboratory equipment! Students with major in Geotechnical Engineering have priority. Registrations will be accepted in the order they are received.

**Objective**  
(1) Extend knowledge of theoretical approaches that can be used to describe soil behaviour.  
(2) Offer the opportunity to perform hands on element tests required for constitutive model calibration.  
(3) Enable students to select an appropriate constitutive model and calibrate it using element test performed in the lab.  
(4) Enable students to carry out FE analyses for realistic geotechnical applications.

**Content**  
Overview of soil behaviour  
Explanation of typical applications: reality, modelling, lab tests with transfer of results to practical examples  
Consolidation theory and typical applications  
Triaxial tests: consolidation & shear, drained & undrained response  
Plasticity theory & Critical State Soil Mechanics, Cam Clay  
Application of plasticity theory  
Introduction to physical modelling

**Lecture notes**  
Printed script with web support

**Literature**  
https://moodle-app2.let.ethz.ch/

**Prerequisites / notice**  
Pre-requisites: Fundamental knowledge of solid and soil mechanics.

The theoretical part of the course will be covered by problem-based lectures. The experimental part will be covered by hands-on element tests performed by the students in the laboratory. These experimental results will be instrumental in the calibration of advanced soil constitutive models. The connection between the experimental and theoretical parts of the course will be facilitated by means of numerical investigations (i.e., FE analyses), including the selection and calibration of relevant constitutive models. The numerical investigations shall be documented by the students in a final report.

Laboratory equipment will be available for 60 students. Students registered for the Geotechnics Specialty in Masters will be given priority as follows: (1) 2nd year students; (2) 1st year students, (3) doctoral students taking the class for their qualifying exam; Further students will be admitted on a first-come-first-served basis.

#### 101-0307-00L Design and Construction in Geotechnical Engineering

**Number**: 101-0307-00L  
**Title**: Design and Construction in Geotechnical Engineering  
**Type**: W  
**ECTS**: 4 credits  
**Hours**: 3G  
**Lecturers**: I. Anastasopoulos, K. Kassas, A. Marin, L. Sakellariadis

The experimental part will be covered by hands-on element tests performed by the students in the laboratory. These experimental results will be instrumental in the calibration of advanced soil constitutive models.
Abstract
This lecture deals with the practical application of the knowledge gained in the fundamental lectures from the Bachelor degree. The basics of planning and design of geotechnical structures will be taught for the main topics geotechnical engineers are faced to in practice.

Objective
Transfer of the fundamental knowledge taught in the Bachelor degree to practical application. Ability to plan and design geotechnical structures based on the state of the art.

Content
Introduction to Swisscode SIA
Foundations and settlements
Pile foundations
Excavations
Slopes
Soil nailing
Reinforced geosystems
Ground improvement
River levees

Lecture notes
Script in the form of chapters and powerpoint overheads with web support (moodle-app2.let.ethz.ch)
Exercises

Literature
Relevant literature will be stated during the lectures

Prerequisites / notice
Pre-condition: Successful examinations (pass) in the geotechnical studies (soil mechanics and ground engineering, each 5 credits) in the Bachelor degree of Civil Engineering (ETH), or equivalent for new students.

The lecture contains at least one presentation from practice.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Abstract
In this course selected famous geotechnical failures are investigated with the following purpose: (a) to deepen understanding of the geotechnical risks and possible solutions; (b) to practice design and analysis methods; (c) to learn the techniques for investigation of failures; (d) to learn the techniques for mitigation of the failure damage.

Objective
In this course selected famous geotechnical failures are investigated with the following purpose: (a) to deepen understanding of the geotechnical risks and possible solutions; (b) to practice design and analysis methods; (c) to learn the techniques for investigation of failures; (d) to learn the techniques for mitigation of the failure damage.

Content
Failure due to the loading history
Failure due to excessive settlements
Failure due to the leaning instability
Bearing capacity failure
Excavation failure
Failure in the creeping landslides
Failure evolution in submarine landslides
Construction in the landslide influence zone
Delayed failure in snow avalanches

Lecture notes
Lecture notes
Exercises

Literature

Prerequisites / notice
The course is given in the first MSc semester.
Prerequisite: Basic knowledge in Geotechnical Engineering (Course content of "Grundbau" or similar lecture).
Granular materials have the ability to sustain stresses like a solid or flow like a fluid depending on the applied solicitation and boundary conditions. This course aims to provide a basic understanding of the mechanics and rheology of granular matter. It includes fundamental concepts as well as recent progress in research with main focus on related engineering and natural hazards applications. Small experiments are performed in class to illustrate important processes and state-of-the-art numerical modeling tools are introduced and used.

### Objective
Granular materials have the ability to sustain stresses like a solid of flow like a fluid depending on the applied solicitation and boundary conditions. This course targets civil, geotechnical and mechanical engineering students, who are interested in discovering the fascinating and sometimes surprising world of granular media, the second most used material in industry and in learning novel modeling approaches. After this class, the students should know how to describe inter-particle interactions at the grain scale, the statics of granular materials, the transition towards fluid states through classical frictional plastic laws and the rheology of granular flows. Furthermore, the students should know the basics of the Discrete Element Method (DEM), its advantage and limitations and should be able to use a commercial software for different types of application.

### Content
This course covers grain-scale interactions, statics and rheology of granular materials based on a mix between classical lectures, on-board developments, presentation of small experiments, analytical and numerical exercises. We present the domains of application of granular mechanics through examples taken from the industry or research. In addition, the Discrete Element Method (DEM) together with state-of-the-art contact models will be presented and used to simulate standard tests such as the granular column collapse, shear flows but also more complex industrial or geophysical problems. Calibration of model parameters based on laboratory experiments will be discussed. The course will not cover aspects related to granular gasses and kinetic theory.

### Lecture notes
Lecture slides and lecture notes will be provided on Moodle.

### Literature
Books:
1. Granular Media: Between Fluid and Solid by Bruno Andreotti, Olivier Pouliquen, and Yoël Forterre
2. Particulate Discrete Element Modelling: A Geomechanics Perspective by Catherine O'Sullivan

### Prerequisites
Basic knowledge of physics, mechanics and soil mechanics is required.
Abstract
This course supplements the courses Structural Concrete I and II regarding the analysis and dimensioning of reinforced and prestressed concrete structures. It focuses on limit analysis methods for walls, beams, slabs and shells, particularly regarding their applicability to the safety assessment of existing structures and their computer-aided implementation.

Objective
Within this course, the students are able to:
- deepen their understanding of structural concrete models and apply them to general design problems, including the assessment of existing structures.
- enhance their knowledge about the load-deformation response of reinforced and prestressed concrete structures.
- identify and assess the limits of applicability of limit analysis methods.
- recognise the assumptions of models suitable for computer-aided structural design and use in a critical way structural concrete design software.
- evaluate the long-term behaviour and the behaviour under fire conditions of concrete structures.
- assess the behaviour of fibre reinforced concrete structures.

Content
Fundamentals (structural analysis, theorems of limit analysis, applicability of limit analysis methods); walls and beams (stress fields and strut-and-tie models, compatibility and deformation capacity, membrane elements with yield conditions and load-deformation behaviour, computer-aided structural design); slabs (equilibrium solutions, yield conditions, shear and punching shear, sustainability); long term effects; steel fibre reinforced concrete (mechanical behaviour, applications); fire behaviour.

Lecture notes
Lecture notes see: http://www.concrete.ethz.ch

Literature
In Steel Structures III, students will deepen and expand their theoretical background and practical knowledge of the design and construction of steel and composite structures. The focus of the course lies on design tasks and solutions in modern, multi-storey, steel-framed buildings driven by architectural needs, as well as on certain special fields of application of steel structures. Students will learn how to solve complex structural engineering tasks in larger building projects, e.g., through the use and correct design of large-span slim-floor girders and ultra-slimmer composite columns, or the use of glazing and cable structures as principal load-carrying components. They learn how steel structures behave under fire conditions and how they can be protected and designed accordingly. Finally, students learn about the fundamental aspects governing the design of specialty steel structures, such as thin-walled cold-formed sections, crane girders, masts and storage tanks.

The examples of scientific and standardisation work provided in the lectures give the students the opportunity to learn about the most current developments and see how these are used to shape the future practice in the structural engineering field.

| Objective | In Steel Structures III, students will deepen and expand their theoretical background and practical knowledge of the design and construction of steel and composite structures. The focus of the course lies on design tasks and solutions in modern, multi-storey, steel-framed buildings driven by architectural needs, as well as on certain special fields of application of steel structures. Students will learn how to solve complex structural engineering tasks in larger building projects, e.g., through the use and correct design of large-span slim-floor girders and ultra-slimmer composite columns, or the use of glazing and cable structures as principal load-carrying components. They learn how steel structures behave under fire conditions and how they can be protected and designed accordingly. Finally, students learn about the fundamental aspects governing the design of specialty steel structures, such as thin-walled cold-formed sections, crane girders, masts and storage tanks. |
| Content | Steel Structures III provides in-depth theoretical background and practical knowledge on advanced design topics in steel and composite structures. The focus of the course lies on design tasks and solutions in modern, multi-storey, steel-framed buildings driven by architectural needs, as well as on certain special fields of application of steel structures. The course discusses the use and design of large-span slim-floor girders and ultra-slimmer composite columns, as well as the use of glazing and cable structures as principal load-carrying components. The design of steel structures under elevated temperatures (fire conditions) is treated, as well as special topics of design for serviceability. In addition, fundamental concepts of the design of cold-formed steel framed structures are discussed. Finally, the course will give an overview on the design of specialty steel structures, such as crane girders, masts and storage tanks. |
| Lecture notes | Slides and lecture notes. Worked examples. Handouts and formula collections. |
| Literature | Stahlbaukalender (various editions), Ernst + Sohn, Berlin |
| Prerequisites / notice | Prerequisites: Steel Structures I and II |

<table>
<thead>
<tr>
<th>101-0187-00L</th>
<th>Structural Reliability and Risk Analysis</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>S. Marelli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Structural reliability aims at quantifying the probability of failure of systems due to uncertainties in their design, manufacturing and environmental conditions. Risk analysis combines this information with the consequences of failure in view of optimal decision making. The course presents the underlying probabilistic modelling and computational methods for reliability and risk assessment.</td>
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<tr>
<td>Objective</td>
<td>The goal of this course is to provide the students with a thorough understanding of the key concepts behind structural reliability and risk analysis. After this course the students will have refreshed their knowledge of probability theory and statistics to model uncertainties in view of engineering applications. They will be able to analyze the reliability of a structure and to use risk assessment methods for decision making under uncertain conditions. They will be aware of the state-of-the-art computational methods and software in this field.</td>
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<tr>
<td>Content</td>
<td>Engineers are confronted every day to decision making under limited amount of information and uncertain conditions. When designing new structures and systems, the design codes such as SIA or Euro- codes usually provide a framework that guarantees safety and reliability. However the level of safety is not quantified explicitly, which does not allow the analyst to properly choose between design variants and evaluate a total cost in case of failure. In contrast, the framework of risk analysis allows one to incorporate the uncertainty in decision making.</td>
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<tr>
<td>Lecture notes</td>
<td>Slides of the lectures are available online every week. A printed version of the full set of the slides is proposed to the students at the beginning of the semester.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Basic course on probability theory and statistics</td>
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<table>
<thead>
<tr>
<th>101-0157-01L</th>
<th>Structural Dynamics and Vibration Problems</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>M. Vassiliou, V. Ntirtimanis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Fundamentals of structural dynamics are presented. Computing the response of elastic single and multiple DOF structural systems subjected to harmonic, periodic, pulse, and impulse excitation is discussed. Practical solutions to vibration problems in flexible structures under diverse excitations are developed.</td>
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<tr>
<td>Objective</td>
<td>After successful completion of this course the students will be able to:</td>
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<tr>
<td>1.</td>
<td>Explain the dynamic equilibrium of structures under dynamic loading.</td>
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<td>2.</td>
<td>Use second-order differential equations to theoretically and numerically model the dynamic equilibrium of structural systems.</td>
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<tr>
<td>4.</td>
<td>Compute the dynamic response of structural system to harmonic, periodic, pulse, and impulse excitation using time-history and response-spectrum methods.</td>
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<tr>
<td>5.</td>
<td>Use dynamics of structures to identify the basis for structural design code provisions related to dynamic loading.</td>
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<tr>
<td>Content</td>
<td>This is a course on structural dynamics, an extension of structural analysis for loads that induce significant inertial forces and vibratory response of structures. Dynamic responses of elastic and inelastic single-degree-of-freedom and multiple-degree-of-freedom structural systems subjected to harmonic, periodic, pulse, and impulse excitation are discussed. Theoretical background and engineering guidelines for practical solutions to vibration problems in flexible structures caused by humans, machinery, wind or explosions are presented.</td>
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<tr>
<td>Lecture notes</td>
<td>The class will be taught mainly on the blackboard. Accompanying electronic material will be uploaded to ILIAS and available through myStudies.</td>
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</table>

All the material can be found in Anil Chopra's comprehensive textbook given in the literature below.
Moisture Transport in Porous Media

Objective
- Basic knowledge of moisture transport and related degradation processes in porous materials
- Knowledge of experimental determination of moisture transport properties
- Application of knowledge to moisture transport in cracked materials, drying of porous materials and microclimate in urban street canyons

Content
1. Introduction
Moisture damage: problem statement, durability
Applications: building materials, soil science, geoscience

2. Moisture transport: theory and application
Description of moisture transport
Determination of moisture transport properties
Exercises on moisture transport properties

3. Special topics
Liquid transport in cracked materials, Drying of porous materials, Microclimate in urban street canyons

Lecture notes
All material is provided online via Moodle.

Literature
Handouts, supporting material and exercises are provided online via Moodle.

Competencies
subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Fibre Composite Materials in Structural Engineering

Abstract
1) Lamina and Laminate Theory
2) FRP Manufacturing and Testing Methods
3) Design and Application of Externally Bonded Reinforcement to Concrete, Timber, and metallic Structures
4) FRP Reinforced Concrete, All FRP Structures
5) Measurement Techniques and Structural Health Monitoring

Objective
At the end of the course, you shall be able to
1) Design advanced FRP composites for your structures,
2) To consult owners and clients with necessary testing and SHM techniques for FRP structures,
3) Continue your education as a PhD student in this field.

Content
Fibre Reinforced Polymer (FRP) composites are increasingly being used in civil infrastructure applications, such as reinforcing rods, tendons and FRP profiles as well as wraps for seismic upgrading of columns and repair of deteriorated structures. The objective of this course is on one hand to provide new generation of engineering students with an overall awareness of the application and design of FRP reinforcing materials for internal and external strengthening (repair) of reinforced concrete structures. The FRP strengthening of other structures such as metallic and timber will also be shortly discussed. On the other hand the course will provide guidance to students seeking additional information on the topic. Many practical cases will be presented analyzed and discussed. An ongoing structural health monitoring of these new materials is necessary to ensure that the structures are performing as planned, and that the safety and integrity of structures is not compromised. The course outlines some of the primary considerations to keep in mind when designing and utilizing structural health monitoring technologies. During the course, students will have the opportunity to design FRP strengthened concrete beams and columns, apply the FRP by themselves, and finally test their samples up to failure.

Lecture notes
Power Point Presentations available online at www.empa.ch/abt303

Literature
3) fib bulletin 19, Externally applied FRP reinforcement for concrete structures, technical report, 2019
4) SIA166 (2004) Klebewerbehren (Externally bonded reinforcement), Schweizerischer Ingenieur- und Architektenverein SIA.

Timber Structures I

Abstract
1) Laboratory Tours and Demonstrations: Empa Structural Engineering Laboratory including FRP Composites, Shape Memory Alloys, Timber Elements, Large Scale Testing of Structural Components
2) Working with Composite Materials in the Laboratory (application, testing, etc)

Objective
1) Design advanced FRP composite beams for your structures,
2) To consult owners and clients with necessary testing and SHM techniques for FRP structures,
3) Continue your education as a PhD student in this field.

Content
Fibre Reinforced Polymer (FRP) composites are increasingly being used in civil infrastructure applications, such as reinforcing rods, tendons and FRP profiles as well as wraps for seismic upgrading of columns and repair of deteriorated structures. The objective of this course is on one hand to provide new generation of engineering students with an overall awareness of the application and design of FRP reinforcing materials for internal and external strengthening (repair) of reinforced concrete structures. The FRP strengthening of other structures such as metallic and timber will also be shortly discussed. On the other hand the course will provide guidance to students seeking additional information on the topic. Many practical cases will be presented analyzed and discussed. An ongoing structural health monitoring of these new materials is necessary to ensure that the structures are performing as planned, and that the safety and integrity of structures is not compromised. The course outlines some of the primary considerations to keep in mind when designing and utilizing structural health monitoring technologies. During the course, students will have the opportunity to design FRP strengthened concrete beams and columns, apply the FRP by themselves, and finally test their samples up to failure.

Lecture notes
Power Point Presentations available online at www.empa.ch/abt303

Literature
3) fib bulletin 19, Externally applied FRP reinforcement for concrete structures, technical report, 2019
4) SIA166 (2004) Klebewerbehren (Externally bonded reinforcement), Schweizerischer Ingenieur- und Architektenverein SIA.
Abstract

Design of timber structures.

Objective

Comprehension and application of basic knowledge of structural timber design including material behaviour especially anisotropy, moisture and long duration effects and their consideration in structural analysis and detailing.

Design of timber buildings.

Content

Field of application of timber structures; Timber as building material (wood structure, physical and mechanical properties of wood and wood-based products); Durability; Principles of design.

Lecture notes

Autography Timber Structures

Copies of lecture slides

Literature

Timber design tables HBT 1, Lignum

Swiss Standard SIA 265

Swiss Standard SIA 265/1

Eurocode 5

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

assessed

assessed

101-0617-02L

Computational Science Investigation for Material Mechanics

W

4 credits

2S

D. Kammer, F. Wittel

Abstract

Introduction to computational sciences with focus on numerical modeling of the mechanics of materials. Simulation of material damage, fracture and failure with various material models.

Objective

Learning from mistakes and failures is as old as the engineering discipline. Understanding why things went wrong is essential for improvement, but often impossible without the help of numerical modelling. Real world problems are often highly nonlinear, dependent on multiple physical fields, involve fundamental material behavior far from equilibrium and reversibility, and can often only be understood by addressing different relevant scales.

In this course, we will use real-life cases to learn how to deal with such problems. Starting from the problem description with governing equations, you will learn how to tackle non-linear and multi-field problems using numerical simulations. A particular focus will be on fracture. We will investigate the conditions and mechanisms that lead to material failure and analyze the contributions of plastic behavior, size effects, randomness in the underlying material micro-structure, and various other non-linear material behavior. You will learn various approaches to model the mechanics of complex heterogeneous materials and to implement your model in Python code to run numerical simulations.

Content

1 Introduction to (numeric) forensic engineering

2 The nature of engineering problems (governing equations)

3 Numerical recipes for dealing with non-linear problems

4 Multi-field problems (HTM)

5 Creep and relaxation

6 On the nature of failure - Physics of damage and fracture

7 Cracks and growth in structures (LEFM and beyond)

8 Damage and fracture in heterogeneous materials

9 Mechanics of fatigue

10 Student -Project presentation

Lecture notes

Will be provided during the lecture via moodle.

Literature

Will be provided during the lecture.

Competencies

Subject-specific Competencies

Concepts and Theories

assessed

Techniques and Technologies

assessed

Method-specific Competencies

Analytical Competencies

assessed

Decision-making

assessed

Problem-solving

assessed

Social Competencies

Communication

assessed

Personal Competencies

Adaptability and Flexibility

fostered

Creative Thinking

assessed

Critical Thinking

assessed

Integrity and Work Ethics

fostered

Self-direction and Self-management

fostered

Major in Transport Systems

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0427-01L</td>
<td>Public Transport Design and Operations</td>
<td>O</td>
<td>6</td>
<td>4G</td>
<td>F. Corman</td>
</tr>
</tbody>
</table>

Abstract

This course aims at analyzing, designing, improving public transport systems, as part of the overall transport system.

Objective

Public transport is a key driver for making our cities more livable, clean and accessible, providing safe, and sustainable travel options for millions of people around the globe. Proper planning of public transport system also ensures that the system is competitive in terms of speed and cost. Public transport is a crucial asset, whose social, economic and environmental benefits extend beyond those who use it regularly; it reduces the amount of cars and road infrastructure in cities; reduces injuries and fatalities associated to car accidents, and gives transport accessibility to very large demographic groups.

Goal of the class is to understand the main characteristics and differences of public transport networks. Their various performance criteria based on various perspective and stakeholders. The most relevant decision making problems in a planning tactical and operational point of view

At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate possible improvements to existing networks of public transport and the management of those networks; optimize the use of resources in public transport.

General structure:
general introduction of transport, modes, technologies, system design and line planning for different situations, mathematical models for design and line planning
timetabling and tactical planning, and related mathematical approaches
operations, and quantitative support to operational problems, evaluation of public transport systems.
Content
Basics for line transport systems and networks
Passenger/Supply requirements for line operations
Objectives of system and network planning, from different perspectives and users, design dilemmas
Conceptual concepts for passenger transport: long-distance, urban transport, regional, local transport
Planning process, from demand evaluation to line planning to timetables to operations
Matching demand and modes
Line planning techniques
Timetabling principles
Allocation of resources
Management of operations
Measures of realized operations
Improvements of existing services

Lecture notes
Lecture slides are provided.

Literature
Ceder, Avi: Public Transit Planning and Operation, CRC Press, 2015, ISBN 978-1466563919 (English)

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management fostered

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Customer Orientation assessed
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

101-0437-00L Traffic Engineering O 6 credits 4G A. Kouvelas
Abstract
Fundamentals of traffic flow theory and control.

Objective
The objective of this course is to fully understand the fundamentals of traffic flow theory in order to effectively manage traffic operations. By the end of this course students should be able to apply basic techniques to model different aspects of urban and inter-urban traffic performance, including congestion.

Content
Introduction to fundamentals of traffic flow theory and control. Includes understanding of traffic data collection and processing techniques, as well as data analysis, traffic modeling, and methodologies for traffic control.

Lecture notes
The lecture notes and additional handouts will be provided during the lectures.

Literature
Additional literature recommendations will be provided during the lectures.

Prerequisites / notice
Verkehr III - Road Transport Systems 6th Sem. BSc (101-0415-00L)
Special permission from the instructor can be requested if the student has not taken Verkehr III

101-0417-00L Transport Planning Methods W 6 credits 4G E. Heinen
Abstract
The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis.

Objective
- Knowledge and understanding of statistical methods and algorithms commonly used in transport planning
- Comprehend the reasoning and capabilities of transport models
- Ability to independently develop a transport model able to solve / answer planning problem
- Getting familiar with cost-benefit analysis as a decision-making supporting tool
Content

The course provides the necessary knowledge to develop models supporting the solution of given planning problems and also introduces cost-benefit analysis as a decision-making tool. Examples of such planning problems are the estimation of traffic volumes, prediction of estimated utilization of new public transport lines, and evaluation of effects (e.g. change in emissions of a city) triggered by building new infrastructure and changes to operational regulations.

To cope with that, the problem is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis. Interim lab session take place regularly to guide and support students with the applied part of the course.

Lecture notes

Moodle platform (enrollment needed)

Literature


### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Cooperation and Teamwork</td>
<td>Creative Thinking</td>
</tr>
<tr>
<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Fostered</td>
<td>Assessed</td>
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<td>Assessed</td>
<td>Problem-solving</td>
<td>Fostered</td>
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<tr>
<td>Fostered</td>
<td>Project Management</td>
<td>Fostered</td>
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<tr>
<td>Fostered</td>
<td>Media and Digital Technologies</td>
<td>Assessed</td>
<td>Self-direction and Self-management</td>
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<td>Assessed</td>
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### 151-0227-00L Basics of Air Transport (Aviation I)

**W 4 credits 3G P. Wild**

**Abstract**
In general the course explains the main principles of air transport and elaborates on simple interdisciplinary topics. Working on broad 14 different topics like aerodynamics, manufacturers, airport operations, business aviation, business models etc. the students get a good overview in air transportation. The program is taught in English and we provide 11 different experts/lecturers.

**Objective**
The goal is to understand and explain basics, principles and contexts of the broader air transport industry. Further, we provide the tools for starting a career in the air transport industry. The knowledge may also be used for other modes of transport. Ideal foundation for Aviation II - Management of Air Transport.

**Content**
Weekly: 1h independent preparation; 2h lectures and 1 h training with an expert in the respective field

### Lecture notes
Preparation materials & slides are provided prior to each class

### Literature
Literature will be provided by the lecturers, respectively there will be additional Information upon registration (normally available in Moodle)

### Prerequisites / notice
The lecture is planned as class teaching.

### Competencies

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<tr>
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### 227-0523-00L Railway Systems I

**W 6 credits 4G M. Meyer**

**Abstract**
Basic characteristics of railway vehicles and their interfaces with the railway infrastructure:
- Transportation tasks and vehicle types
- Running dynamics
- Mechanical part of rail vehicles
- Brakes
- Traction chain and auxiliary supply
- Railway power supply
- Signalling systems
- Standards
- Availability and safety
- Traffic control and maintenance

**Objective**
- Overview of the technical characteristics of railway systems
- Interrelationship between different fields of engineering sciences (mechanics, electro and information technology, transport systems)
- Understanding tasks and opportunities of engineers working in an environment which has strong economical and political boundaries
- Insight into the activities of the railway vehicle industry and railway operators in Switzerland
- Motivation of young engineers to start a career in the railway industry or with railway operators
The objective of this course is to provide an overview of the infrastructure management process. The high-level process can be used as a functioning processes. More specifically upon completion of the course, students had their first experience with establishing basic rules and principles to ensure an infrastructure management organisation is running well. The weekly lectures are structured as follows:

1. Introduction: An introduction to infrastructure management and the project.
2. Service: Determination of what service you are trying to provide with an infrastructure network is important in justifying the interventions you think are required and ensuring that investment decisions are aligned throughout an infrastructure management organisation. This lecture introduces the concept of serve and connects it to measurable indicators.
3. Help session 1: This session provides time for your group to ask questions as you define the service you want your infrastructure network to provide
4. Presentation 1: 4 groups will present their ideas on how they want their networks to provide services
5. Interventions: Justifying the interventions you want to execute to ensure you continue to provide the defined service requires you to model deterioration, determining economically justifiable strategies and explain which interventions will be postponed if you can’t do all you would like. This lecture is focused on explaining the main principles behind each of these concepts.
6. Help session 3: This session provides time for your group to ask questions as you justify the interventions you want to execute on your infrastructure network over time and explain what you will postpone if you cannot do all of them.
7. Presentation 2: 4 groups will present how they have justified interventions and how they have selected the ones they would like to postpone if required
8. Monitoring: To ensure you the infrastructure network is providing what you expect you need to monitor its performance and how projects are being done. This lecture is focused on the principles to ensure a monitoring system is set up that ensures that the infrastructure system is providing the expected service.
9. Help session 4: This session provides time for your group to ask questions on how to establish the monitoring systems for your infrastructure networks.
10. Presentation 3: 4 groups will present how they intended to ensure well-functioning organisations and well-functioning processes.
11. Organisation: Managing infrastructure only works well with great teams of people with great processes. This lecture focuses on the principles of ensuring a well function organisation and well-functioning processes.
12. Help session 4: This session provides time for your group to ask questions on how to ensure well-functioning organisations and well-functioning processes.
13. Presentation 4: 4 groups will present how they intended to ensure well-functioning organisations and well-functioning processes.
Appropriate literature will be handed out when required via Moodle.

M. Köthenbürger

Subject-specific Competencies fostered

Concepts and Theories fostered
Techniques and Technologies fostered

Method-specific Competencies fostered

Analytical Competencies fostered
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving fostered

Social Competencies fostered

Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies fostered

Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

This course is an introduction to urban and regional economics. It focuses on the formation and development of urban systems, and as such deserve our attention.

In general, this class focuses on the latest research developments in urban and regional economics, though it does not require prior knowledge in this field. It pays particular attention to economic approaches, which are based on theoretical frameworks with strong micro-foundations and allow for precise policy recommendations.

In the second part, I discuss the planning and pricing of transport networks, moving from simple local models to more complex transport models at a global scale. The key aspects include: the first and second best road pricing, the public provision of transport networks and the demographic effects of transport networks.

In the third part, I combine the previous two parts and analyze the interaction between urban systems and transportation. Thereby, the main focus is to understand the economic mechanisms that can lead to a general equilibrium of all actors involved. However, as the study of the historical development of urban systems and transport networks provides interesting insights, I will discuss how their interaction in the past shapes today’s economic geography.

Finally, I broaden the scope of the course and explore related topics. There will be a particular emphasis on the relation between urban systems and fiscal federalism as well as environmental policies. Both aspects are important determinants of the contemporary developments of urban systems, and as such deserve our attention.

In general, this class focuses on the latest research developments in urban and regional economics, though it does not require prior knowledge in this field. It pays particular attention to economic approaches, which are based on theoretical frameworks with strong micro-foundations and allow for precise policy recommendations.

Lecture slides will be made available to students prior to each class.

Course slides will be made available to students.

Subject-specific Competencies fostered

Concepts and Theories assessed

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed

Analytical Competencies fostered

Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

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In general, this class focuses on the latest research developments in urban and regional economics, though it does not require prior knowledge in this field. It pays particular attention to economic approaches, which are based on theoretical frameworks with strong micro-foundations and allow for precise policy recommendations.
The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their 

Weirs: Weir stability, gates, inflatable dams, appurtenant structures, fish up- and downstream passages.

Conduits: Design of headraces, pressure shafts, and penstocks, structural details and construction.

Hydropower plants: Powerhouse and turbine types, design, functionality, construction processes.

Dams: Types, appurtenant structures (river diversion, spillways, bottom and low-level outlets), dam type selection criteria, layout and design of gravity dams, buttress dams, arch dams, rockfill dams with central core or concrete face, reservoir sedimentation and sediment management, dam surveillance.

Artificial reservoirs: Purpose, layout, sealing, appurtenant structures, environmental aspects.

Economical aspects of hydraulic infrastructure

101-0267-01L Numerical Hydraulics O 3 credits 2G E. Secchi, D. Vanzo

Abstract
In the course Numerical Hydraulics the basics of numerical modelling of flows are presented.

Objective
The goal of the course is to develop the understanding of the students for numerical simulation of flows to an extent that they can later use commercial software in a responsible and critical way.

Content
The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their applicability is discussed. Using the example of non-steady state pipe flow numerical methods such as the method of characteristics and finite difference methods are introduced. The finite volume method as well as the method of characteristics are used for the solution of the shallow water equations. Special aspects such as wave propagation and turbulence modelling are also treated.

All methods discussed are applied practically in exercises. This is done using programs in MATLAB which partially are programmed by the students themselves. Further, some generally available softwares such as BASEMENT for non-steady shallow water flows are used.

Lecture notes Slides from the lectures and programs used can be downloaded.

101-0258-00L River Engineering O 3 credits 2G V. Weitbrecht, I. Schalko, K. Sperger

Abstract
The lecture addresses the fundamentals of river engineering to quantitatively describe the flow of water, transport of sediment and wood, and morphological changes such as erosion and deposition processes associated with river structures. In addition, design guidelines for river engineering structures are introduced.

Objective
At the end of the course, the students will be able to:
- recall and describe the fundamentals of transport processes in rivers,
- apply different calculation approaches and methods to tackle river engineering problems and tasks such as the discharge capacity of a river, scour estimation, or sediment budget of a river,
- design and dimension river engineering works needed to influence the processes in watercourses, and
- determine the interaction between flow (discharge), sediment transport, wood transport and the resulting channel evolution.

Content
The first part of the lecture introduces the fundamentals of river engineering, such as methods to determine and calculate the river discharge, or sampling methods to characterize the bed material. In addition, the transport processes of sediment (bedload and suspended load) and wood in rivers will be examined, including the principles of incipient motion, and initiation of erosion or deposition processes.

In the second part of the lecture, the methods will be explained to quantify the bed load budget and the morphological changes (erosion, deposition) in river systems. Specifically, natural channel formation processes, different bed forms and plan forms of rivers (straight, meandering, braided) are examined.

The last part of the lecture focuses on the design of river engineering structures, including examples from an ongoing flood and river rehabilitation project at the Alpine Rhine in Austria and Switzerland.

Lecture notes Lecture slides can be downloaded via Moodle.

1. Erosion and Sedimentation; Pierre Y. Julien

2. River Mechanics; Pierre Y. Julien

Prerequisites / notice Recommended lectures: Hydrology (102-0293-AAL), Hydraulics I (101-0203-01L), and Hydraulic Engineering (101-0206-00L).

Short practical exercises (voluntary) will be offered throughout the semester to improve the application of the learned subjects.
### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

#### Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: assessed
- Self-direction and Self-management: fostered

### 102-0468-10L Watershed Modelling

**W 6 credits 4G**

**P. Molnar, A. Costa, S. Sinclair**

#### Abstract
Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

#### Objective
The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies. A comprehensive exercise block builds on the lectures with a series of 4 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 50% by performance in the graded exercises and 50% by a semester-end oral examination (30 mins) on watershed modelling concepts.

#### Content
The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models students build their own simple bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focused on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models at larger scales. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns.

#### Lecture notes
There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

#### Literature
Literature consist of collections from standard hydrological textbooks and research papers, collected by the instructors on the course moodle page.

#### Prerequisites / notice
Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences). Basic knowledge of Matlab (Python), ArcGIS (Q-GIS).

### 101-0250-00L Solving Partial Differential Equations in Parallel on GPUs

**W 4 credits 3G**

**I. Utkin, S. Omlin, L. Räss, M. Werder**

#### Abstract
This course aims to cover state-of-the-art methods in modern parallel computing on Graphics Processing Unit (GPU), supercomputing and code development with applications to natural sciences and engineering.

#### Objective
When quantitative assessment of physical processes governing natural and engineered systems relies on numerically solving differential equations, fast and accurate solutions require performant algorithms leveraging parallel hardware. The goal of this course is to offer a practical approach to solve systems of differential equations in parallel on GPUs using the Julia language. Julia combines high-level language conciseness to low-level language performance which enables efficient code development.

The course will be taught in a hands-on fashion, putting emphasis on you writing code and completing exercises; lecturing will be kept at a minimum. In a final project you will solve a solid mechanics or fluid dynamics problem of your interest, such as the shallow water equation, the shallow ice equation, acoustic wave propagation, nonlinear diffusion, viscous flow, elastic deformation, viscous or elastic poromechanics, frictional heating, and more. Your Julia GPU application will be hosted on a git-platform and implement modern software development practices.

#### Content
**Part 1 - Discovering a modern parallel computing ecosystem**
- Learn the basics of the Julia language;
- Learn how to solve diffusion, wave propagation and advection processes;
- Implement efficient iterative algorithms;
- Get started with software development tools: version control.

**Part 2 - Developing your own parallel algorithms on GPUs**
- Implement wave propagation and porous convection;
- Apply spatial and temporal discretisation (finite-differences, various time-stepper);
- Understand the practical challenges of parallel computing: GPUs, multi-core CPUs;
- Learn about main simulation performance limits;
- Implement software development tooling: unit tests, continuous integration (CI).

**Part 3 - Multi-GPU computing projects**
- Understand the practical challenges of distributed parallel computing on multi-GPUs;
- Implement shared (on CPU and GPU) and distributed memory parallelisation (multi-GPUs/CPUs);
- Automate the software tooling using remote runners.

**Final projects**
- Apply your new skills in a final project;
- Implement advanced physical processes (solid and fluid dynamic - elastic and viscous solutions).
Major in Materials and Mechanics

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<td>Concrete Technology</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>F. Nägele, G. Martinola, T. Wangler</td>
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**Abstract**
Opportunities and limitations of concrete technology. Commodities and leading edge specialties.

**Objective**
Advanced education in concrete technology for civil engineers who are designing, specifying and executing concrete structures.

**Content**
Based on the lecture 'Werkstoffe' students receive deep concrete technology training. Comprehensive knowledge of the most important properties of conventional concrete and the current areas of research in concrete technology will be presented. The course covers various topics, including:

- concrete components
- concrete properties
- concrete mix design
- production, transport, casting
- demoulding, curing and additional protective measures
- durability
- standards
- chemical admixtures
- alternative binders
- specialty concretes such as: self compacting concrete, fiber reinforced concrete, fast setting concrete
- the role of sustainability in concrete technology
- new research in digital fabrication with concrete

**Lecture notes**
Slides provided for download.

**Competencies**

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<td>Moisture Transport in Porous Media</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>J. Carmeliet, A. Kubilay, A. Rubin, D. A. Strebel</td>
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**Abstract**

**Objective**
- Basic knowledge of moisture transport and related degradation processes in porous materials
- Knowledge of experimental determination of moisture transport properties
- Application of knowledge to moisture transport in cracked materials, drying of porous materials and microclimate in urban street canyons

**Content**
1. Introduction
- Moisture damage: problem statement, durability
  - Applications: building materials, soil science, geoscience
  2. Moisture transport: theory and application
  - Description of moisture transport
  - Determination of moisture transport properties
  - Exercises on moisture transport properties
  3. Special topics
    - Liquid transport in cracked materials, Drying of porous materials, Microclimate in urban street canyons

**Lecture notes**
Handouts, supporting material and exercises are provided online via Moodle.

**Literature**
All material is provided online via Moodle.
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

101-0617-01L Advances in Building Materials

Abstract
The course on Advances in Building Materials provides an introductory overview of the needs and future of materials science in the building sector. Focus topics concern sustainability, durability, thermal insulation, coatings, sealants, adhesives, flame retardancy and the future perspective and developments of concrete and wood with regard to smart material development and ecological concerns.

Objective
In this course, the students will gain a broad overview of the use of materials in the building sector, with a particular focus on concrete and wood. Current limitations and in particular sustainability related challenges will be detailed with the objective of laying the grounds to discuss future developments anticipated in this field.

Content
This course for civil engineers lays the grounds in the specialization Materials and Mechanics and complements the second introductory course of the specialization on Numerical Mechanics of Materials. The course also addresses master students in Materials Science and other study programs interested in deepening their understanding of application-relevant properties of engineering materials and sustainability related challenges.

The following topics are covered:
1. Material selection
2. Materials and sustainability 1
3. Materials and sustainability 2
4. Recyclability
5. Material science of wood durability
6. Material science of concrete durability
7. Foams in construction and thermal insulation
8. Sealants and adhesives in construction
9. Coatings
10. Flame retardants
11. Future of wood – 1
12. Future of wood – 2
13. Future of concrete – 1
14. Future of concrete – 2

Lecture notes
Handouts will be provided for each lecture.

101-0617-02L Computational Science Investigation for Material Mechanics

Abstract
Introduction to computational sciences with focus on numerical modeling of the mechanics of materials. Simulation of material damage, fracture and failure with various material models.

Objective
Learning from mistakes and failures is as old as the engineering discipline. Understanding why things went wrong is essential for improvement, but often impossible without the help of numerical modelling. Real world problems are often highly nonlinear, dependent on multiple physical fields, involve fundamental material behavior far from equilibrium and reversibility, and can often only be understood by addressing different relevant scales.

In this course, we will use real-life cases to learn how to deal with such problems. Starting from the problem description with governing equations, you will learn how to tackle non-linear and multi-field problems using numerical simulations. A particular focus will be on fracture. We will investigate the conditions and mechanisms that lead to material failure and analyze the contributions of plastic behavior, size effects, randomness in the underlying material micro-structure, and various other non-linear material behavior. You will learn various approaches to model the mechanics of complex heterogeneous materials and to implement your model in Python code to run numerical simulations.

Content
1 Introduction to (numeric) forensic engineering
2 The nature of engineering problems (governing equations)
3 Numerical recipes for dealing with non-linear problems
4 Multi-field problems (HTM)
5 Creep and relaxation
6 On the nature of failure - Physics of damage and fracture
7 Cracks and growth in structures (LEFM and beyond)
8 Damage and fracture in heterogeneous materials
9 Mechanics of fatigue
10 Student -Project presentation

Lecture notes
Will be provided during the lecture via moodle.

Literature
Will be provided during the lecture.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed

Social Competencies
- Communication: assessed

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

151-0353-00L Mechanics of Composite Materials

W 4 credits 2V+1U G. Pappas
The courses treat aspects related to elastic behavior of unidirectional and multidirectional laminates, micromechanics, failure and damage analysis, analysis and design of composite structures. The focus is on laminated fiber-reinforced polymer composites.

The objective is to introduce the basic concept of composite materials and provide a thorough understanding of the mechanical response of such materials and structures particularly made from fiber reinforced polymer composites, including elastic behavior, failure, fracture and damage analysis as well as structural design aspects. The ultimate goal is to provide the necessary skills to address the design and analysis of modern lightweight composite structures.

The course is addressing following topics:
- Introduction
- Elastic anisotropy
- Micromechanics & Homogenization
- Classical Laminate Theory (CLT)
- Strength, failure and damage analysis
- Thin ply composite shells & effects of material non-linearity
- Analysis and design of composite structures

The lecture series will be conducted in English and is aimed at students of master's programs, particularly in civil engineering and MIBS. No lecture will be given during Seminar week.

Abstract

Objective

Content

The course is addressing following topics:
- Introduction
- Elastic anisotropy
- Micromechanics & Homogenization
- Classical Laminate Theory (CLT)
- Strength, failure and damage analysis
- Thin ply composite shells & effects of material non-linearity
- Analysis and design of composite structures

The course will be structured into two parts, each making up about half of the semester.

Part I: Exercises with lectures on demand

The first six individual courses will follow the "lectures on demand" approach. Small "hands-on" exercises focusing on one specific aspect will be given out and the necessary background knowledge will be provided in the form of short input lectures when questions arise. The following topics will be discussed during the first part:
1. LCA basic introduction
2. System boundaries, functional unit, end of life
3. Carbon budget and LCA benchmarks
4. BIM-LCA, available calculation tools and databases
5. Integrated analysis of environmental and cost assessment
6. Bio-based carbon storage

Part II: Project-based learning

In the second part, the students will work on their individual project in groups of three. For the design task, the students will bring their own project and work on improving it. The projects can be chosen depending on the students background and range from buildings to infrastructure projects. Intermediate presentations will ensure the continuous work and make sure all groups are on the same level and learn from each other. During this part, the following hands-on tutorials will be given:
1. Introduction to Rhinoceros 6 and 7
2. Introduction to Grasshopper
3. Integrated assessment tools (ladybug tools)
4. Introduction to in-house Grasshopper plugin for LCA analysis

Lecture notes

As the course follows a lecture on demand approach, the lecture slides will be provided after each course.

Literature

A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.

Prerequisites / notice

The lecture series will be conducted in English and is aimed at students of master's programs, particularly in civil engineering and MIBS. No lecture will be given during Seminar week.

Autumn Semester 2024

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An Introduction to Sustainable Development in the Built Environment

In 2015, the UN Conference in Paris shaped future world objectives to tackle climate change. This decarbonization strategy is additional to Sustainable Development goals formulated the same year by the UN general assembly.

What does that mean for the built environment?

This course provides an introduction to the notion of sustainable development when applied to our built environment.

Objective

At the end of the semester, the students have an understanding of the term of sustainable development, its history, the current political and scientific discourses and its relevance for our built environment.

In order to address current challenges of climate change mitigation and resource depletion, students will learn a holistic approach of sustainable development. Ecological, economical and social constraints will be presented and students will learn about methods for argumentation and tools for assessment (i.e. life cycle assessment).

For this purpose an overview of sustainable development is presented with an introduction to the history of sustainability and its today definition as well as the role of cities, urbanisation and material resources (i.e. energy, construction material) in social economic and environmetal aspects.

The course aims to promote an integral view and understanding of sustainability and describing different spheres (social/cultural, ecological, economical, and institutional) that influence our built environment.

Students will acquire critical knowledge and understand the role of involved stakeholders, their motivations and constraints, learn how to evaluate challenges, identify deficits and define strategies to promote a more sustainable construction.

After the course students should be able to define the relevance of specific local, regional or territorial aspects to achieve coherent and applicable solutions toward sustainable development.

The course offers an environmental, socio-economic and socio-technical perspective focussing on buildings, cities and their transition to resilience with sustainable development. Students will learn on theory and application of current scientific pathways towards sustainable development.

Content

The following topics give an overview of the themes that are to be worked on during the lecture.

- Overview on the history and emergence of sustainable development
- Overview on the current understanding and definition of sustainable development and beyond

Methods

- Method 1: Life cycle assessment (planning, construction, operation/use, deconstruction)
- Method 2: Life Cycle Costing
- Method 3: Labels and certification
- Method 4: Material Flow Analysis

Main issues:

- Operation energy at building, urban and national scale
- Mobility and density questions
- Embodied energy for developing and developed world

- Synthesis: Transition to sustainable development

Lecture notes

All relevant information will be online available before the lectures. For each lecture slides of the lecture will be provided.

Literature

A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.
In the fall semester 2024 we will focus on applying artificial intelligence (AI) and extended reality (XR) to the circular design workflow and.

The course is about digital innovation towards a circular economy in the built environment. How can we bring together two worlds that are often too distinct: low-impact construction and digital innovation? Bringing digital tools already used in other sectors into the construction sector, students will learn about circular construction (e.g., reuse of materials) through hands-on learning practices.

By the end of this course, students will be able to use augmented computational design enabling circular construction, with a view to environmental implications. They will be able to assess the challenges and opportunities of low-carbon, circular construction and evaluate possible solutions using digital technologies to enable a circular built environment (more specifically, with reused building materials). To achieve this, they need to be able to do the following:

1. Apply circular principles using recovered building materials.
2. Compare different digital technologies applied in circular construction (e.g., LiDAR scanning, drone imagery, photogrammetry, computational design, AI, computer vision, XR, LCA tools etc.)
3. Understand the potential and limitations of AI for circular construction, e.g. use machine learning to detect and digitize materials (computer vision) or to support creativity in the early design phases of circular construction (generative AI).
4. Communicate the importance and urgency of circular construction.
5. Assess the environmental impact implications of their design and technology decisions through a preliminary Life Cycle Assessment (LCA).

Students will receive an introduction to circular principles by experts from the building industry and visit of (de-)construction sites where circular construction is exemplified. They will explore how to use digital technologies such as LiDAR scanning, photogrammetry, scan-to-BIM, computer vision, computational design, digital fabrication, blockchain technology and learn about the design implications using reclaimed building materials. This course is meant as an overview/introduction of many digital technologies that could be useful for circular construction and gives the tools to students to further study the technologies they are most interested in on their own. Creativity in writing, filmmaking, design, construction, etc. is expected from the students. This course will give the tools to students to learn more on LCA if they wish to deepen their knowledge further.

Language: English
Courses are on Tuesday afternoons in Kunsthalle or a room at ETH, but also require out-of-the-semester work and significant homework and site visits outside of class hours.

The course will be taught at the Kunsthalle Zurich as part of an exhibition.

All students who register go on a waiting list until 11.09.2024. To register:
1. Enroll before 05.09.2024
2. Send a short motivation letter (max. 300 words) and a 1-page CV to cxa-course@ibi.baug.ethz.ch by 05.09.2024
3. MIBS students: This course is mandatory and there is no need to send your application documents

Please only register for the course if you really intend to participate on all course dates (see course catalog), otherwise, you will deprive someone else of a place.
On successful completion of this course students will be able to:

### Subject-specific Competencies

<table>
<thead>
<tr>
<th>Competency</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>assessed</td>
</tr>
<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Project Management</td>
<td>assessed</td>
</tr>
</tbody>
</table>

### Social Competencies

<table>
<thead>
<tr>
<th>Competency</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
</tr>
<tr>
<td>Customer Orientation</td>
<td>assessed</td>
</tr>
<tr>
<td>Leadership and Responsibility</td>
<td>assessed</td>
</tr>
<tr>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
</tr>
<tr>
<td>Negotiation</td>
<td>assessed</td>
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</tbody>
</table>

### Personal Competencies

<table>
<thead>
<tr>
<th>Competency</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
</tr>
<tr>
<td>Creative Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
</tr>
<tr>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
</tr>
<tr>
<td>Self-direction and Self-management</td>
<td>assessed</td>
</tr>
</tbody>
</table>

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### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed
  - Project Management: assessed

- **Social Competencies**
  - Communication: assessed
  - Cooperation and Teamwork: assessed
  - Customer Orientation: assessed
  - Leadership and Responsibility: assessed
  - Self-presentation and Social Influence: assessed
  - Sensitivity to Diversity: assessed
  - Negotiation: assessed

- **Personal Competencies**
  - Adaptability and Flexibility: assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: assessed
  - Self-direction and Self-management: assessed

---

**Literature**


**Prerequisites / notice**

Interest in Digitalisation and Construction. Flexibility: This is a hands-on course, where students explore digital technologies and opportunities/challenges of reuse. Flexibility (e.g. adapting to unforeseen circumstances), responsibility (e.g. arriving on time for safety briefing), and spontaneity (e.g. finding innovative solutions) is expected from the students to adapt to the contingencies from demolition and construction sites with reused materials. The course is mandatory for MIBS students. If you are a first year MIBS student, please do not apply, you are automatically accepted. All other students from other departments should apply. Please only register for the course if you really intend to participate on all course dates (see course catalog). Please only register for the course if you are willing to send us a letter of motivation and really intend to participate; otherwise, you will deprive someone else of a place. All non-MIBS students who register go onto a waiting list until 11.09.2024 and up to 25 of them will be selected by the lecturer.

To register:
1. Enroll before 05.09.2024.
2. Send a short letter of motivation (max. 300 words) and a 1-page CV to cea-course@ibi.baug.ethz.ch by 05.09.2024.

Collaborators: Kunsthalle Zürich, ETH AI Center, Design++

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### Major in Geotechnical Engineering

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>101-0329-00L</td>
<td>Tunnelling III</td>
<td>W</td>
<td>4 credits</td>
<td>2G</td>
<td>G. Anagnostou, E. Pimentel, M. Ramoni</td>
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<tr>
<td>Abstract</td>
<td>Deepen the knowledge on selected topics of underground construction as well as learning working out conceptual solutions of complex problems.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Objective</td>
<td>Lecture: Deepen the knowledge on selected topics of underground construction. Exercises: Conceptual solutions of complex problems.</td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

**Lecture notes**

Autographieblätter

**Literature**

Empfehlungen

**Prerequisites / notice**

Prerequisite: BSc course "Tunnelling", MSc courses "Tunnelling I" and "Tunnelling II".

This course will continue to be offered in German up to and including HS24.

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**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed

- **Method-specific Competencies**
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed

---

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed

- **Method-specific Competencies**
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed

---

**Number**

101-0339-00L

**Title**

Environmental Geotechnics – Polluted Sites and Waste Disposal

**Type**

W

**ECTS**

3 credits

**Hours**

2G

**Lecturers**

M. Plötze

**Abstract**

The practice of landfilling, remediation of polluted sites and the disposal of radioactive waste are based on the same concepts of environmental protection. Understanding the contaminants behaviour and how to reduce their release to the environment is the key to remediating polluted sites and designing multi-barrier systems.

**Objective**

On successful completion of this course students will be able to:
- Assess the risk to the environment from landfills, contaminated sites and radioactive waste repositories in terms of the fate and transport of contaminants.
- Describe the technologies available to minimise environmental contamination.
- Describe the principles of dealing with polluted sites and propose and evaluate appropriate remediation techniques.
- Explain the concepts underlying radioactive waste management practices.
This lecture course consists of lectures with exercises and case studies.

- An overview of the principles of environmental protection in waste management and how this is applied in legislation.
- An overview of the chemistry underlying the release and transport of contaminants from the landfilled/contaminated material/radioactive waste repository focusing on processes controlling mobility of heavy metals and organic compounds
- Introduction to contaminant transport in porous adsorbing media
- Design and function of engineered barriers. Clay as a barrier.
- Polluted site remediation: Site investigation, assessment, and remediation technologies
- Concepts and safety in radioactive waste management
- Role of the geological and engineered barriers and radionuclide transport in geological media.

### Competencies

<table>
<thead>
<tr>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
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<tr>
<td>Structural Masonry</td>
<td>3</td>
<td>2G</td>
<td>N. Mojsilovic</td>
</tr>
</tbody>
</table>

### Literature

According to the bibliography in the submitted documents

### Prerequisites / notice

Basic knowledge in “soil mechanics”.

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### Major in Structural Engineering

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>101-0367-00L</td>
<td>Geotechnical Engineering in Transportation and Pavement Design</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>D. Hauswirth</td>
</tr>
</tbody>
</table>

### Objective

Students should be able to recognise basic structural and material-related connections in traffic route engineering as well as be able to design pavements. This includes knowledge of the interrelation of local conditions such as soil properties, climate, water, as well as the mechanical behaviour of the selected construction materials and the quality of the design models involved.

This knowledge is conveyed through lectures, practical demonstrations, moderated exercises and assignments (to be completed independently).

### Content

- The content of the lecture is divided into the parts “geotechnical fundamentals in transportation”, “construction technology and materials” and “pavement design”. In the first part, soil stabilization, artificial compaction, testing of soils as well as the effects of frost are discussed for traffic route engineering. Thereafter, knowledge of the building materials and construction methods used in transportation is imparted with reference to European and national standards. After conveying some introductory concepts on the structural behaviour of asphalt, different design methods and models for pavements are subsequently examined.

## Lecture notes

Slides, exercise and homework sheets, handouts

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### Content

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

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Autumn Semester 2024
Introduction to non destructive evaluation tools and quantitative structural analyses and verifications for condition assessment of existing structures and subsequent decisions on their rehabilitation. The concepts are introduced via theory, numerical examples, demonstrators and computer labs in Python (starting Fall 2021).

Upon completion of the course, the participants will be able to:
- Recognize when linear elastic analysis is insufficient
- Solve nonlinear dynamics problems, which form the core for limit state calculations (e.g. ultimate capacity, failure) of structures
- Numerically simulate fracture; a dominant failure phenomenon for structural systems.
- Nonlinear Dynamics
- Geometric Nonlinearity (Large Displacement Problems)
- Material Nonlinearity (Plasticity)
- Integrity and Work Ethics
- Self-awareness and Self-reflection

The course specifically covers the treatment of the following phenomena:
- Geometric Nonlinearity (Large Displacement Problems)
- Material Nonlinearity (Plasticity)
- Nonlinear Dynamics
- Fracture Mechanics
- Sensitivity to Diversity
- Negotiation

The concepts are introduced via theory, numerical examples, demonstrators and computer labs in Python (starting Fall 2021).

See the class webpage for more information:

The course slides serve as Script. These are openly available on: http://www.chatzi.ibk.ethz.ch/education/method-of-finite-elements-ii.html
Cooperation and Teamwork

This course completes the series of courses on dynamic analysis and seismic design of structures at ETHZ. Building on the material assessed

Analytical Competencies

Moodle is used to manage the course learning material. These include the lecture presentations, additional reading, exercise problems and

Course Slides (Script): http://www.chatzi.ibk.ethz.ch/education/method-of-finite-elements-ii.html

Prerequisites / notice

Prerequisites:
- 101-0158-01 Method of Finite Elements I (FS)
- A good knowledge of Python is necessary for attending this course.

Competencies

Subject-specific Competencies
Concepts and Theories assessed

Method-specific Competencies
Analytical Competencies assessed

Social Competencies
Cooperation and Teamwork assessed

Personal Competencies
Adaptability and Flexibility assessed

Creative Thinking assessed

Critical Thinking assessed

Integrity and Work Ethics assessed

Self-awareness and Self-reflection assessed

101-0189-00L Seismic Design of Structures II
W 4 credits 2G B. Stojadinovic

Number of participants limited to 18.
All students go on a waiting list. Final registration based on an application letter (information given in the first lecture). Priority will be given to students who completed Seismic Design of Structures I (101-0188-00 G) and are in the primary target group (majoring in Structural Engineering and/or doing project-based coursework for other majors).

Abstract
In this course the students will learn how to do performance-based seismic design of building structures. This is a project-based course. The students will, in parallel, acquire the basis knowledge about the seismic behavior and non-linear response modeling of structures, and apply this knowledge in a project focused on design of a new building.

Objective
After successfully completing this course, the students will be able to:

1. Model and explain the seismic behavior of new structures with moment frame, braced frame and shear wall structural systems.
2. Evaluate the performance of new structures under earthquake loading using modern risk-informed performance assessment methods and analysis tools.
3. Use the knowledge of nonlinear dynamic response of structures to interpret the design code provisions and apply it in seismic design of structural systems.
4. Successfully design such systems to achieve the performance objectives stipulated by the design codes

Content
This course completes the series of courses on dynamic analysis and seismic design of structures at ETHZ. Building on the material covered in Structural Dynamics and Seismic Design of Structures I, the following advanced topics will be covered in this course: 1) behavior and non-linear response modeling of structural systems under earthquake excitation; 2) displacement-based inelastic design of new building structures; 3) seismic design of moment frame, braced frame and shear wall structures. These topics will be discussed from the standpoint of risk-informed performance-based seismic design.

Lecture notes
Moodle is used to manage the course learning material. These include the lecture presentations, additional reading, exercise problems and solutions, example models of structures in OpenSees system for earthquake engineering simulation, and example designs.

Literature

Earthquake Engineering: From Engineering Seismology to Performance-Based Engineering, Borzorgnia, Y. and Bertero, V. Eds., CRC Press, 2004

Prerequisites / notice

ETH Seismic Design of Structures I course, or equivalent. Students are expected to understand the seismological nature of earthquakes, to characterize the ground motion excitation, to analyze the response of elastic single- and multiple-degree-of-freedom systems to earthquake excitation, to use the concept of response and design spectrum, to compute the equivalent seismic loads on simple structures, and to perform code-based seismic design of simple structures. Familiarity with structural analysis software, such as SAP2000 or OpenSees, and general-purpose software, such as Python and Matlab, is expected.

Number of participants limited to 10. All students go on a waiting list. Final registration based on an application letter (information given in the first lecture). Priority will be given to students who completed Seismic Design of Structures I (101-0188-00 G) and are in the primary target group (majoring in Structural Engineering and/or doing project-based coursework for other majors).
### Seismic and Vibration Isolation

**Abstract**
This course will cover the analysis and design of isolation systems to mitigate earthquakes and other forms of vibrations. The course will cover:
1. Conceptual basis of seismic isolation, seismic isolation types, mechanical characteristics of isolators.
3. Design approaches and code requirements

**Objective**
After successfully completing this course the students will be able to:
1. Understand the mechanics of and design isolator bearings.
2. Understand the dynamics of and design an isolated structure.

**Content**
1. Introduction: Overview of seismic isolation; review of structural dynamics and earthquake engineering principles. Viscoelastic behavior.
2. Linear theory of seismic isolation
3. Types of seismic isolation devices - Modelling of seismic isolation devices – Nonlinear response analysis of seismically isolated structures in Matlab
4. Behavior of rubber isolators under shearing and compression
5. Behavior of rubber isolators under bending
6. Buckling and stability of rubber isolators
7. Code provisions for seismically isolated buildings

**Lecture notes**
The electronic copies of the learning material will be uploaded to ILIAS and available through myStudies. The learning material includes: reading material, and (optional) exercise problems and solutions.

**Literature**
There is no single textbook for this course. However, most of the lectures are based on parts of the following books:
- Dynamics of Structures, Theory and Applications to Earthquake Engineering, 4th edition, Anil Chopra, Prentice Hall, 2017
- Design of seismic isolated structures: from theory to practice, Farzad Naeim and James M. Kelly, John Wiley & Sons, 1999
- Mechanics of rubber bearings for seismic and vibration isolation, James M. Kelly and Dimitrios Konstantinidis, John Wiley & Sons, 2011

**Prerequisites**
101-0157-01 Structural Dynamics and Vibration Problems course, or equivalent, or consent of the instructor. Students are expected to know basic modal analysis, elastic spectrum analysis and basic structural mechanics.

### Structural Design

**Abstract**
The goal of the course is to introduce students to Structural Design. The course fosters the development of a design thinking that emerges from the coexistence of a number of design parameters and performance criteria related to force flow, construction technologies, material use, and spatial qualities.

**Objective**
After a successful completion of the course, students will be able to:
1. Critically evaluate structural design concepts based on their impact and implications beyond the sole structural performance
2. Identify the most relevant design parameters and performance criteria for a given design task and select adequate tools to effectively integrate them as part of the design process
3. Develop structural systems in compliance with structural, spatial, and environmental design aspects simultaneously

**Content**
The goal of the course is to introduce students to Structural Design. The course fosters the development of a design thinking that emerges from the coexistence of a number of design parameters and performance criteria related to force flow, construction technologies, material use, and spatial qualities. Students will learn about diverse tools that allow for controlling such a complex blend of parameters and criteria at the interface between different disciplines such as structural engineering and architecture. These tools will include physical models, graphical methods, and digital tools. After a series of lectures and workshops, students will work on a design exercise that represents the core of the entire course. The design exercise is an opportunity to deal with an open-ended task that does not admit a univocal answer. In fact, besides structural performance, design options will be discussed and evaluated through a set of criteria including spatial qualities, constructability, and environmental footprint.

### Timber Structures III

**Abstract**
This course will cover the analysis and design of isolation systems to mitigate earthquakes and other forms of vibrations. The course will cover:
1. Conceptual basis of seismic isolation, seismic isolation types, mechanical characteristics of isolators.
3. Design approaches and code requirements

**Objective**
After a successful completion of the course, students will be able to:
1. Understand the mechanics of and design isolator bearings.
2. Understand the dynamics of and design an isolated structure.

**Content**
1. Introduction: Overview of seismic isolation; review of structural dynamics and earthquake engineering principles. Viscoelastic behavior.
2. Linear theory of seismic isolation
3. Types of seismic isolation devices - Modelling of seismic isolation devices – Nonlinear response analysis of seismically isolated structures in Matlab
4. Behavior of rubber isolators under shearing and compression
5. Behavior of rubber isolators under bending
6. Buckling and stability of rubber isolators
7. Code provisions for seismically isolated buildings

**Lecture notes**
The electronic copies of the learning material will be uploaded to ILIAS and available through myStudies. The learning material includes: reading material, and (optional) exercise problems and solutions.

**Literature**
There is no single textbook for this course. However, most of the lectures are based on parts of the following books:
- Mechanics of rubber bearings for seismic and vibration isolation, James M. Kelly and Dimitrios Konstantinidis, John Wiley & Sons, 2011
- Mechanics of rubber bearings for seismic and vibration isolation, James M. Kelly and Dimitrios Konstantinidis, John Wiley & Sons, 2011
- Mechanics of rubber bearings for seismic and vibration isolation, James M. Kelly and Dimitrios Konstantinidis, John Wiley & Sons, 2011
- Mechanics of rubber bearings for seismic and vibration isolation, James M. Kelly and Dimitrios Konstantinidis, John Wiley & Sons, 2011

**Prerequisites**
101-0157-01 Structural Dynamics and Vibration Problems course, or equivalent, or consent of the instructor. Students are expected to know basic modal analysis, elastic spectrum analysis and basic structural mechanics.

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Prerequisite: Timber Structures I (101-0168-00L).

Students who have not completed Holzbau I require a special permission from the lecturer.

Abstract
Consolidation and supplementation of the basic knowledge acquired in Timber Structures I + II. Treatment of current topics and innovations in timber engineering. Structural design and refurbishment of complex timber structures with high requirements for earthquake resistance, sound insulation and fire protection. Description, analysis and discussion of an existing timber structure in groups.

Objective
In-depth understanding of the theoretical and design aspects of timber construction. Dimensioning, structural design, optimisation and refurbishment of complex timber structures with high requirements for earthquake resistance, sound insulation and fire protection.

Content
Multi-storey timber buildings (general, cross laminated timber, high-rise buildings, fire protection, sound insulation), Post-tensioned timber constructions, building with hardwood, robustness of timber structures, earthquake-resistant timber structures, maintenance and renovation of structures.

Lecture notes
Autography Timber Structures
Copies of lecture slides

Literature
Timber design tables HBT 1, Lignum
Swiss Standard SIA 265
Swiss Standard SIA 265/1
Eurocode 5

Prerequisites / notice
Timber Structures I + II

<table>
<thead>
<tr>
<th>101-0120-00L</th>
<th>Structural Glass Design and Façade Engineering</th>
<th>W</th>
<th>3 credits</th>
<th>3G</th>
<th>V.-A. Silvestru</th>
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</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>The course gives an introduction to structural glass design and related façade engineering aspects. It will focus on the properties of the material glass and glass products, as well as on the structural design of glass elements and their supporting systems and connections.</td>
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</tr>
<tr>
<td><strong>Objective</strong></td>
<td>After successful completion of the course, students will be able to:</td>
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<tr>
<td></td>
<td>- Understand and apply the fundamentals of the material glass and glass products, the basic principles for using glass as a load-carrying building material for structural applications and the types of connections used for glass elements;</td>
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</tr>
<tr>
<td></td>
<td>- Recognize requirements for glass elements depending on their application area and chose the appropriate glass products and assemblies accordingly;</td>
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<td></td>
<td>- Structurally design out-of-plane loaded glass elements based on available standards, both by hand calculations and specific software applications;</td>
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<td>- Apply selected approaches for the structural design of in-plane loaded glass elements;</td>
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<td>- Select suitable supporting systems (post-and-beam façade, curtain wall, etc.) and connections (point fixings, brackets, etc.) for the glass elements and structurally design them.</td>
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<tr>
<td><strong>Content</strong></td>
<td>This course introduces civil engineering students to structural glass design and related façade engineering aspects. It aims to provide the students the knowledge required in engineering offices to design glass elements but at the same time, the necessary fundamentals for later performing research in this field. To achieve this, the course includes lectures, design exercises and a design project.</td>
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<tr>
<td><strong>Lectures:</strong></td>
<td>The lectures will cover the following contents:</td>
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<td>- Production methods and properties of the material glass and glass products and their structurally relevant properties (annealed glass, thermally tempered glass, chemically tempered glass, laminated glass, insulating glass, curved glass);</td>
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<td></td>
<td>- Connection principles and types for glass elements (mechanical fixing, adhesive bonding);</td>
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<td>- Requirements for glass elements depending on the application area (vertical glazing, overhead glazing, walk-on glazing, barrier glazing);</td>
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<td></td>
<td>- Structural design of glass elements based on standards and research results (out-of-plane loaded glass elements and in-plane loaded glass elements);</td>
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<td></td>
<td>- Typologies and design of structural systems for transparent façades;</td>
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<td></td>
<td>- Requirements and functions for transparent facades.</td>
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<tr>
<td><strong>Design exercises:</strong></td>
<td>The principles and methods presented in the lectures are practiced with the students in design exercises. Hand calculation methods and their limitations as well as the software for structural glass design Sj Mepla are used for out-of-plane loaded glass elements. For in-plane loaded glass elements, the specifics of numerical calculation procedures are exemplified with the software Abaqus.</td>
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<tr>
<td><strong>Design project:</strong></td>
<td>The students will consolidate the knowledge gained in the theory-lectures and in the design exercises by working on a small design task (e.g. a glass canopy, a glass façade, a glass pavilion) in the form of a group work (ideally groups of 2-3 students). Within this task, the students will: conceptually design the structure and selected connection details; identify requirements for the glass elements and define their assembly; structurally design selected glass components, their support systems and their connections. The students will work on the design task in the second half of the semester and will get feedback on their progress in weekly review sessions. At the end of the semester, the groups will submit a project report and give an oral presentation of their projects.</td>
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<tr>
<th>Prerequisites / notice</th>
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<tbody>
<tr>
<td><strong>Literature:</strong></td>
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<table>
<thead>
<tr>
<th>101-0139-00L</th>
<th>Scientific Machine and Deep Learning for Design and Construction</th>
<th>W</th>
<th>3 credits</th>
<th>4G</th>
<th>B. Bickel, A. Müller, M. Piovacci</th>
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<tbody>
<tr>
<td><strong>Subject-specific Competencies</strong></td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<td><strong>Method-specific Competencies</strong></td>
<td>Analytical Competencies</td>
<td>fostered</td>
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<td>Decision-making</td>
<td>fostered</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>fostered</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<td><strong>Social Competencies</strong></td>
<td>Communication</td>
<td>assessed</td>
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<td>Cooperation and Teamwork</td>
<td>assessed</td>
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<tr>
<td><strong>Personal Competencies</strong></td>
<td>Creative Thinking</td>
<td>fostered</td>
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<td></td>
<td>Critical Thinking</td>
<td>fostered</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 204 of 2653
Abstract
This course will present methods of scientific machine and deep learning (ML / DL) for applications in design and construction. After providing proper background on ML and the scientific ML (SciML) track, several applications of SciML together with their computational implementation during the design and construction process of the built environment are examined.

Objective
This course aims to provide a graduate-level introduction to machine learning, with a particular focus on scientific machine learning for applications in the design and construction phases of projects from architecture and civil engineering.

Upon completion of the course, the students will be able to:
1. Understand main ML background theory and methods.
2. Assess a problem and apply ML and DL in a computational framework accordingly.
3. Incorporate scientific domain knowledge in the SciML process.
4. Define, plan, conduct and present a SciML project.

Content
The course will include theory and algorithms for SciML, programming assignments, as well as a final project assessment.

The topics to be covered are:
2. Incorporation of Domain Knowledge into ML and DL.
4. ML training, validation and testing pipelines for academic and research projects.

A comprehensive series of computer/lab exercises and in-class demonstrations will take place, providing a “hands-on” feel for the course topics.

Lecture notes
The course script is composed by lecture slides, which are available online and will be continuously updated throughout the duration of the course.

Literature
Suggested Reading:
Marc Peter Deisenroth, A Aldo Faisal, and Cheng Soon Ong Mathematics for Machine Learning
S. Guido, A. Mller: Introduction to machine learning with python. O'Reilly Media, 2016
O. Martin: Bayesian analysis with python. Packt Publishing Ltd, 2016

Prerequisites / notice
Familiarity with Python is advised.

Competencies
<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Creative Thinking</td>
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<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
<td>Critical Thinking</td>
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<td>Media and Digital Technologies</td>
<td>Project Management</td>
<td>Self-direction and Self-management</td>
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<td>Problem-solving</td>
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<td>Project Management</td>
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101-0138-11L Bridge Design: Project Competition

Abstract
This module offers the possibility to apply the fundamentals of the course Bridge Design in a conceptual design project. The scenario is set as a design competition: The students (group of two) will get a basic documentation (service criteria agreement, plans, digital terrain model, geotechnical report, photo documentation, etc.) and will develop a conceptual design suitable for the given site.

Objective
At the end of the course, students will have developed a convincing bridge design that satisfies following criteria:
1. Consideration of governing boundary conditions and constraints.
2. Conception of an efficient structural system with an adequate aesthetic expression considering the environment.
3. Definition of the relevant actions and decisive load cases.
4. Proof of feasibility by dimensioning the main structural elements.
5. Schematic overview of construction processes.
6. Appropriate presentation and visualisation of the proposed bridge design.

Content
The module is built up as follows:
0. Presentation of problem statement / project. (1st week of semester)
1. Introduction to design tools & working methods.
   ... a. Define requirements and boundary conditions.
   ... b. Study of references and possible concepts
   ... c. Choice of best variant
2. Working on project (milestones):
   ... d. Structural modelling & calculations
   ... e. Plans & visualisation
3. Presentation of your work in a mid-term and a final critique.
4. Submission

Prerequisites / notice
101-0138-00L Bridge Design or an equivalent attestation of knowledge in bridge design.


**Major in Transport Systems**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0469-00L</td>
<td>Road Safety</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>M. Deublein, P. Eberling</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>The collection and the methods of statistical and geographical analysis of road accidents are important fundamentals of this course. Safety Aspects in design of urban roads are discussed and measures for improving the safety situation are presented. Procedures of infrastructure safety management for administrations and police are another topic.</td>
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<tr>
<td></td>
<td>Objective</td>
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<td>Imparting knowledge about road safety and the event of accident, presenting possibilities to increase road safety</td>
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<td>Content</td>
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<td>Accident origin, collection of road accidents, statistical (descriptive and multivariate, accident prediction models) and geographical analysis of road accidents, risk analysis and rehabilitation measures, road safety instruments for infrastructure with focus on road safety audit, Swiss and international transport policy</td>
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<td>Literature</td>
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<td>Further literature: will be presented during the course</td>
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| 101-0491-00L | Agent Based Modeling in Transportation                     | W    | 6    | 4G    | M. Balac, G. O. Kagho      |
|             | Abstract                                                  |      |      |       |                            |
|             | This course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based simulation models' current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in groups. |
|             | Objective                                                  |      |      |       |                            |
|             | At the end of the course, the students should:             |
|             | - have an understanding of agent-based modeling           |
|             | - have an understanding of MATSim                         |
|             | - have an understanding of the process needed to set up an agent-based study |
|             | - have practical experience of using MATSim to perform transportation studies |
|             | Content                                                   |      |      |       |                            |
|             | This course provides an introduction to agent-based models for transportation policy analysis. Four essential topics are covered: |
|             | 1) Introduction of agent-based modeling and its comparison to the traditional state of practice modeling |
|             | 2) Introduction of MATSim, an open-source agent-based model, developed at ETH Zurich and TU Berlin, and its various parts |
|             | 3) Setting up an agent-based model simulation, where different statistical methods used in the process will be introduced and explained. Here the open-source egasim framework used at ETH Zurich to set up agent-based models will be introduced |
|             | 4) Conducting a transport policy study. The case study will be performed in groups and will include a paper-like report. |
|             | Literature                                                |      |      |       |                            |
|             | Agent-based modeling in general                            |
|             | MATSim                                                    |      |      |       |                            |
|             | Additional relevant readings, primarily scientific articles, will be recommended throughout the course. |
|             | Prerequisites / notice                                     |      |      |       |                            |
|             | There are no strict preconditions regarding which lectures the students should have previously attended. However, experience with at least one high-level programming language (Java, R, Python, or other) is recommended. |
|             | For those without object-oriented programming experience, a crash course 101-0491-10 Basics of Java and Best Practices for Scientific Computing before the start of HS is recommended. |
|             | Competencies                                              |      |      |       |                            |
|             | Subject-specific Competencies                              |
|             | - Techniques and Technologies                             |
|             | - Analytical Competencies                                 |
|             | - Problem-solving                                          |
|             | - Project Management                                      |
|             | Method-specific Competencies                               |
|             | - Cooperation and Teamwork                                |
|             | Social Competencies                                       |
|             | - Critical Thinking                                       |
|             | Personal Competencies                                     |
|             | Literature                                                |      |      |       |                            |
|             | Agent-based modeling in general                            |
|             | Additional relevant readings, primarily scientific articles, will be recommended throughout the course. |

| 101-0492-00L | Microscopic Modelling and Simulation of Traffic Operations | W    | 3    | 2G    | M. Makridis                |
|             | Abstract                                                  |      |      |       |                            |
|             | The course introduces basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies. |
|             | Objective                                                  |      |      |       |                            |
|             | The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a real traffic network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication. Simulations will be implemented in Aimsun software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario. |
|             | Literature                                                |      |      |       |                            |
|             | Further literature: will be presented during the course    |
|             | Competencies                                              |      |      |       |                            |
|             | Subject-specific Competencies                              |
|             | - Understand the basic models used in microsimulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.). |
|             | - Design a road transport network inside the simulation software. |
|             | - Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network. |
|             | - Understand how to design a complete study, implement and validate it for planning purposes, e.g. creating a new road infrastructure. |
|             | - Make valid and concrete engineering proposals based on the simulation model and alternative scenarios. |
In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun. Microscopic modelling and simulation concepts will include:

1) Car following models
2) Lane change models
3) Calibration and validation methodology

Specific tasks for the project will include:

1) Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed.
2) Calibrating and validating the simulation model.
3) Redesigning/extendng the model to improve the traffic performance through Aimsun and with/without programming in Python or C++.

The course will be based on a project that each group of students will build (design, calibrate, analyze and presentation) across the semester. A mid-term and final presentation of the work will be asked from each group of students.

It consists of weekly 2-hour lectures. The students work in pairs on a group project that completes in the end of the semester. The modelling software used is Aimsun and lectures (theory and hands on experience) are taking place in a computer room.

The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.

Additional literature recommendations will be provided at the lectures.

The lecture notes and additional handouts will be provided before the lectures.

The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.

Students need to know some basic road transport concepts. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.

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Students need to know some basic road transport concepts. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.
1 - Railway technology
   Track, power supply / catenaries, information technology, safety / interlockings / dispatching

2 - Interaction
   Interaction between track and vehicles, vehicle dynamics

3 - Railway Track
   Stress; track construction including special features of railway bridges and tunnels

4 - Starting up
   Goals, methods, procedures

5 - Diagnostics, maintenance strategies
   Track diagnostics and forecast

6 - Track maintenance
   Maintenance strategies, fundamentals of track maintenance and related methods

Lecture notes
   The slides will be made available.

Literature
   A list with related technical literature will be handed out.

Prerequisites / notice
   Prerequisite: 101-0419-01 Railway Infrastructures 1 (FS)

Competencies
   Subject-specific Competencies
     Concepts and Theories: assessed
     Techniques and Technologies: fostered
   Method-specific Competencies
     Analytical Competencies: assessed
     Decision-making: assessed
     Problem-solving: fostered
   Social Competencies
     Customer Orientation: assessed
     Sensitivity to Diversity: fostered
   Personal Competencies
     Adaptability and Flexibility: fostered
     Creative Thinking: fostered
     Critical Thinking: fostered
     Integrity and Work Ethics: assessed

101-0491-10L Basics of Java and Best Practices for Scientific Computing
   W 1 credit 1U M. Balac

Abstract
   This course provides an introduction to programming in Java, version control, and cloud computing.

Objective
   At the end of the course, the students should
   ● Have acquired object-oriented programming skills with a focus on Java.
   ● Have an understanding of version control using git
   ● Have learned to deploy java applications on servers

Content
   This course provides an introduction to object-oriented programming with Java. Four topics are covered:
   ● Basics of Java (objects, classes, interfaces, abstract classes, static classes, static methods,...)
   ● Injection (traditional vs. Guice)
   ● Code versioning
   ● Java application deployment on servers

Literature
   Intro to Java Programming, Comprehensive Version (10th Edition) by Y. Daniel Liang

101-0249-00L Hydraulic Engineering III
   Prerequisites: 101-0247-01L Hydraulic Engineering II or equivalent course.

Number Title Type ECTS Hours Lecturers
101-0249-00L Hydraulic Engineering III W 3 credits 2S R. Boes

Abstract
   The lecture focuses on selected topics in hydraulic engineering, water management and aquatic ecology relating to hydropower and flood protection projects.

Objective
   The overarching goal of the course is to broaden and enhance knowledge on special aspects in hydraulic engineering and its links to aquatic ecology and to understand the procedures and the planning sequence of large-scale projects.

Content
   Selected topics in hydraulic engineering will be focused on, e.g. dam safety, materials in dam construction, possible problems at reservoirs like hazards from impulse waves and dam breaching, the hydraulics of spillways and intake structures at dams and weirs and the link between hydropower and ecology. Another focus will be put on typical approaches and procedures in the planning process of large-scale hydraulic engineering projects at the national and international level.

Lecture notes
   Lecture handouts will be available online. Parts of the lectures will also be covered by a manuscript that will be available in electronic form.

Literature
   External speakers will be involved to present current topics and projects in Switzerland and abroad.

Competencies
   Subject-specific Competencies
     Concepts and Theories: assessed
     Techniques and Technologies: assessed
   Method-specific Competencies
     Analytical Competencies: fostered
     Decision-making: fostered
     Problem-solving: fostered
     Project Management: fostered
   Social Competencies
     Communication: assessed
   Personal Competencies
     Adaptability and Teamwork: fostered
     Creative Thinking: fostered
     Critical Thinking: assessed
     Self-direction and Self-management: fostered

101-0289-00L Applied Glaciology
   W 4 credits 2G D. Farinotti, A. Bauder, M. Werder
Abstract

The course transmits fundamental knowledge for treating applied glaciological problems. Topics include climate-glacier interactions, glacier ice flow, glacier hydrology, ice avalanches, and lake ice.

Objective

The objectives of the courses are to:
- learn about fundamental glaciological processes, including glacier mass balance, ice dynamics, and glacier-related hazards;
- apply the above knowledge to some case studies inspired by contract-works performed at ETH's Glaciology section;
- generate the own computer code to solve the above case studies, and interpret the results;
- understand, both in class and in the field, the practical relevance of glaciology, with a focus on the Swiss applications.

Content

The course will develop along the following outline:
- How glaciology became a scientific discipline
- Glaciology and hydropower
- Glacier mechanics and ice flow
- Gravitational glacier instabilities
- Glacier hydrology and glacier lake outbursts
- Lake ice and ice bearing capacity
- Field excursion to Jungfraujoch
- Discussion of the exercises performed during the semester

Lecture notes

Digital lecture handouts will be distributed prior to each class.

Literature

Links to relevant literature will be provided during the classes.

Prerequisites / notice

Completed BSc studies. Basic knowledge in computer scripting in any language (e.g. Python, R, Julia, Matlab, IDL, ...) will be advantageous for solving the exercises. The exercises will be performed in groups. A minimal level of fitness is required for the field excursion.

Competencies

Subject-specific Competencies

Concepts and Theories
- assessed
Techniques and Technologies
- assessed

Method-specific Competencies

Analytical Competencies
- assessed
Decision-making
- assessed
Media and Digital Technologies
- assessed
Problem-solving
- assessed
Project Management
- fostered

Social Competencies

Communication
- fostered
Cooperation and Teamwork
- assessed
Self-presentation and Social Influence
- fostered
Sensitivity to Diversity
- fostered

Personal Competencies

Adaptability and Flexibility
- fostered
Creative Thinking
- assessed
Critical Thinking
- assessed
Integrity and Work Ethics
- assessed
Self-awareness and Self-reflection
- fostered
Self-direction and Self-management
- assessed

101-1249-00L  Hydraulics of Engineering Structures  W  3 credits  2G  I. Albayrak, F. Evers

Abstract

Hydraulic fundamentals are applied to hydraulic structures for wastewater, flood protection and hydropower. Typical case studies from engineering practice are further described.

Objective

Understanding and quantification of fundamental hydraulic processes with particular focus on hydraulic structures for wastewater, flood protection and hydropower.

In the course "Hydraulics of Engineering Structures", the competencies of process understanding, system understanding and measurement methods are taught, applied and examined. The competencies modeling, concept development and data analysis & interpretation are taught and data analysis & interpretation is applied in addition.

Content

1. Introduction & Basic equations
2. Losses in flow & Maximum discharge
3. Uniform flow & Critical flow
4. Hydraulic jump & Stilling basin
5. Backwater curves
6. Weirs & End overfall
7. Sidewer & Side channel
8. Bottom opening, Venturi & Culverts, Restrictors, Inverted siphons
9. Fall manholes & Vortex drop
10. Supercritical flow & Special manholes
11. Aerated flows & Low level outlets
12. Hydraulics of sediment bypass tunnels
13. Vegetated flows - Introduction & Application
14. Summary

Lecture notes

Text books


Literature

Exhaustive references are contained in the suggested text book.

102-0215-00L  Urban Water Management II  W  4 credits  2G  P. Staufer

Abstract


Objective

Vertiefung der Grundlagen für die Dimensionierung anspruchsvoller Bauwerke mithilfe der numerischen Simulation und Darstellung der Ergebnisse für Zielgruppen in der schweizerischen Wasserwirtschaft.

Content

Generelle Entwässerungsplanung (GEP)
- Siedlungshydrologie: Niederschlag, Abflussbildung
- Stofftransport in der Kanalisation
- Emissions- und Immissionsbetrachtungen, Einleitbedingungen
- Versickerung von Regenwasser
- Blau-grüne Infrastrukturen (BiG)

Lecture notes

Die schriftlichen Unterlagen stehen digital zur Verfügung.

Prerequisites / notice

Als Voraussetzung wird der Besuch der Lernveranstaltung "Siedlungswasserwirtschaft GZ" empfohlen.
101-1250-00L Transport Processes in Torrents W 3 credits 2V I. Schalko

Abstract
This course focuses on the various transport processes in torrents. This includes discharge, bedload, debris flow, and large wood. Differences between transport processes in rivers versus torrents will be discussed. Special focus will be put on the (1) analysis of the interaction between the transport processes (cascading processes) and the (2) design of countermeasures.

Objective
At the end of the course, the students will be able to:
(1) Describe the different transport processes in torrents, such as flow discharge or bedload transport,
(2) discuss how cascading processes affect the resulting natural hazard, and
(3) derive solutions for a sustainable hazard management.

Content
The first part of the lecture introduces the different transport processes in torrents such as discharge, bedload, debris flow, and large wood. This will include methods to determine and calculate the discharge, characterize debris flow, and quantify wood load.

In the second part of the lecture, special focus will be put on the cascading effects (what happens if multiple transport processes occur at once) and their implications on the resulting natural hazards.

The last part of the lecture focuses on the design of countermeasures such as check dams and will include examples from selected catchments in Switzerland.

Two field trips are planned to illustrate the transport processes and existing countermeasures.

Lecture notes
Lecture slides can be downloaded via Moodle.

Literature

Prerequisites / notice
Recommended lectures:
Hydrology (102-0293-AAL), Hydraulics I (101-0203-01L), Hydraulic Engineering (101-0206-00L), River Engineering (101-0258-00L)

Compentencies

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<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
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Major in Materials and Mechanics

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<td>101-0639-01L</td>
<td>Science and Engineering of Glass and Natural Stone in Construction</td>
<td>W</td>
<td>3</td>
<td>2G</td>
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</table>

Abstract
The course offers an overview of relevant practical issues and present technological challenges for glass and natural stones in constructions. Students gain a good knowledge of the basics of glasses and natural stones, their potential as engineering materials and learn to apply them in the design of civil engineering constructions and to evaluate concepts.
Objective

Glass is increasingly used in constructions to ease the construction process, as functional insulation barrier, even for structural applications of impressive size. While everyone has experienced the innovation potential of glass in the last decade, products from natural stone suffer from an unjustified traditional image that often originates from a lack of understanding of the material and its combination with other materials. Culturally important structures often are made from natural stone and their conservation demands an understanding of their deterioration mechanisms, the concepts of which can be applied to other civil engineering materials. Designers and engineers need the knowledge to reconcile materials and system behavior with the entire processing, handling, integration and life time in mind. In this module students are provided with a broad fundamental as well as practice-oriented education on glass and natural stone in civil engineering applications. Present and future construction and building concepts demand for such materials with optimized properties. Based on the fundamentals from the Bachelor course in materials by the end of this module, you should be able to:

- recognize and choose specific applications from the broad overview you were provided with,

- relate processing technologies to typical products and building applications and recognize (and explain typical damage related to wrong material choice or application,

- explain the nature of glassy and crystalline materials and interpret their physical behavior against this background,

- explain the major deterioration mechanisms in natural stone and how this relates to durability,

- analyze material combinations and appraise their application in future products as well as integration in existing constructions,

- summarize with appropriate guidance publications on a related topic in an oral presentation and short report.

Content

Lecture 1: An introduction to science and engineering of glass and natural stone in construction (FW/TW)

Lecture 2: Glass chemistry including historical development of glass composition, use of raw materials, melts, chemical stability and corrosion. (FW)

Lecture 3: Geology and mineralogy of stones used in construction. Formation processes, chemistry, crystal structure. (TW)

Lecture 4: Microscopic models for glassy materials. Physics of vitrification. From microscopic physical models to thermodynamics, rheology and mechanics of glassy materials. (FW)

Lecture 5: Stone properties and behavior: microstructure, density, porosity, mechanical properties (TW)

Lecture 6: Glass physics: Optical properties (transmission, reflection, emission, refraction, polarization and birefringence, testing methods); Mechanical properties (density, thermal, mechanical, electric properties, glass testing) (FW)

Lecture 7: Stone properties and durability: transport, moisture and thermal cycling (TW)

Lecture 8: Forming and processing of glass: (plate and molded glass, drawing, slumping, profiling etc.; Processing: Cutting, mechanical processing, tempering, gluing, bending, laminating of glass Surface treatments: coating, sputtering, enameling, printing, etching, chemical pre-stressing.) (FW)

Lecture 9: Durability: Salt crystallization, freezing, biodeterioration (TW)

Lecture 10: Glass products for civil engineering applications: (Molded glasses, fiber glass, foam glass, plate glass); construction glass (insulation glass, structural glass, protective glass, intelligent glass, codes); (FW)

Lecture 11: Conservation: Consolidation, cleaning, and other treatments (TW).

Lecture 12: Glass in constructions. (modelling, application and regulation, typical damage in glass) (FW)

Lecture 13: Student presentations; exam questions (FW/TW)

Lab1: Durability of natural stone (FW/TW)

Lab2: Fracture of glass (FW/TW)

Will be handed out in the lectures

Literature

Werkstoffe II script (download via the IFB homepage). Rest will be handed out in the lectures

Prerequisites / notice

Werkstoffe I/II of the bachelor studies or equivalent introductory materials lecture.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Project Management assessed

Social Competencies

Communication assessed
Self-presentation and Social Influence assessed

Personal Competencies

Creative Thinking assessed
Critical Thinking assessed
Self-direction and Self-management assessed

101-0659-01L Durability and Maintenance of Reinforced Concrete

W 4 credits 2V U. Angst, Z. Zhang

We look at the durability of reinforced concrete structures, covering common deterioration processes such as reinforcement corrosion, frost damage, ASR, etc. The course spans the range from fundamental mechanisms to aspects of engineering practice. New methods and materials for preventative measures, condition assessment and repair techniques are treated. Examples from real cases are shown.
After this course you will have profound understanding about:

- the different mechanisms of deterioration of concrete structures, in particular reinforcement corrosion
- the relevant parameters affecting durability of reinforced concrete (cover depth, concrete quality, moisture, etc.)

Furthermore, you will know:

- current engineering approaches for durability design (according to standards) and their limitations
- refined models for enhanced durability design and service life predictions
- preventive measures to improve durability (e.g. stainless steel reinforcement, concrete surface coatings, etc.)
- the particular durability challenges with post-tensioned structures and ways to overcome them (electrically isolated tendons)
- methods for inspection and condition assessment of existing, ageing structures (including non-destructive techniques and monitoring with sensors)
- repair methods for deteriorated concrete structures such as conventional repair and electrochemical methods (in particular cathodic protection)
- possible future problems for durability that may arise with modern materials and construction technologies

Content

- Socio-economic challenges related to ageing infrastructures
- Degradation mechanisms for concrete: sulphate attack, ASR, frost attack.
- Inspection and condition assessment: Chloride analyses, carbonation depth, etc. Non-destructive tests, particularly potential mapping to detect corrosion. New developments (for example, monitoring with sensors).
- Stainless steel as reinforcing steel for concrete: Different types of stainless steels. Coupling with black reinforcing steel. Examples of application. Life-cycle-costs.
- Modern materials and construction technologies: Discussion of expected implications for the durability of structures today and in the future.

Excursion:
- We generally try to organize a site-visit (depending on availability of construction sites). Presumably, we will visit an installation site of cathodic protection on a concrete structure in the Zurich area.

The course is based on the book


Slides of the lectures will be distributed in advance

Special handouts and reprints for particular topics will be distributed

The course is based on the book


Slides of the lectures will be distributed in advance

Special handouts and reprints for particular topics will be distributed

The course is a lecture that contains frequent discussion and interaction between students and lecturer. You will see and work on many examples from engineering practice, both during the lectures and in the form of exercises to be solved at home.

Report:
Each student will work on a small case study and deliver a report during the semester. The report will be graded.

Excursion:
**Objective**

This course will begin with a brief introduction about hydration and microstructure development in cement paste and concrete. The students will learn the main causes of cracking at early ages, namely plastic, drying, thermal and autogenous shrinkage, with special emphasis on the driving mechanisms. The importance of concrete curing, especially in the first few days after casting, will be stressed and explained.

Building on the knowledge of the driving forces of shrinkage, the way of action of shrinkage-reducing admixtures will be clarified and different applications illustrated. As an extension of external curing, the students will become familiar with internal water curing by means of saturated lightweight aggregates and superabsorbent polymers.

**Content**

Most concrete members are restrained by adjacent structures. When shrinkage is restrained, cracks may develop. The students will learn how to apply different criteria for assessing concrete cracking and how to retrieve the mechanical properties of the concrete, especially stiffness and creep, which are needed for the calculations of self-induced stresses and risk of cracking.

In addition to macroscopic cracks, microcracking may occur in the cement paste due to inner restraint offered by the aggregates. Both macroscopic cracks and diffuse microcracking within a concrete may facilitate the ingress of harmful substances (e.g., chloride and sulfate ions) into the concrete; these may react with the concrete or with the reinforcement and create further deterioration. The students will acquire an understanding of the mechanisms of transport through cracked concrete, with special focus on experimental evidence and on techniques able to visualize the transport process and follow it in time.

As a final outcome of the course, the students will be able to estimate the impact of cracking on the expected durability of concrete structures and to implement different types of measures to reduce the extent of cracking.

Advances in concrete technology over the past decades have led to the practical use of concrete with a low water to binder ratio and with different types of mineral and organic admixtures. Another recent development is self-compacting concrete, which avoids concrete vibration and reduces labor during placing. Unfortunately, these concretes are especially prone to cracking at early ages, unless special precautions are taken. Proper curing becomes in this case the key to achieve better performance in various environmental and load conditions.

Specific topics covered by the course:
- Hydration and microstructure development
- Plastic shrinkage
- Development of mechanical properties
- Thermal deformation
- Autogenous deformation
- Drying shrinkage
- Creep and relaxation
- Curing
- Shrinkage-reducing admixtures
- Internal curing: saturated lightweight aggregates and superabsorbent polymers
- Fracture and microcracking
- Transport in cracked concrete
- Impact of cracking on concrete durability
- Self-healing of cracks

**Lecture notes**

In addition, one or two research papers for each lecture will be indicated as supportive information.

**Literature**

Copies of one to two research papers relevant to the topic of each lecture will be provided to the students as supportive information.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>W</th>
<th>Credits</th>
<th>G</th>
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<tr>
<td>101-0537-10L</td>
<td>Wood Structure and Function</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>I. Burgert, G. von Arx</td>
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<td>101-0537-20L</td>
<td>Wood Processing</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>I. Burgert, S. Koch, M. Schubert</td>
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<tr>
<td>101-0159-00L</td>
<td>Method of Finite Elements II</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>E. Chatzi, K. Tatsis</td>
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</table>

A basic knowledge of concrete technology is preferable.
This class overviews advanced topics of the Method of Finite Elements, beyond linear elasticity. Such phenomena are particularly linked to excessive loading effects and energy dissipation mechanisms. Their understanding is necessary for reliably computing structural capacity. In this course, instead of blindly using generic structural analysis software, we offer an explicit understanding of what goes on behind the curtains, by explaining the algorithms that are used in such software.

The course specifically covers the treatment of the following phenomena:
- Material Nonlinearity (Plasticity)
- Geometric Nonlinearity (Large Displacement Problems)
- Nonlinear Dynamics
- Fracture Mechanics

The concepts are introduced via theory, numerical examples, demonstrators and computer labs in Python (starting Fall 2021).

Upon completion of the course, the participants will be able to:
- Recognize when linear elastic analysis is insufficient
- Solve nonlinear dynamics problems, which form the core for limit state calculations (e.g. ultimate capacity, failure) of structures
- Numerically simulate fracture; a dominant failure phenomenon for structural systems.

See the class webpage for more information:

Useful (optional) Reading:

Prerequisites:
-101-0158-01 Method of Finite Elements I (FS)
- A good knowledge of Python is necessary for attending this course.

The course slides serve as Script. These are openly available on: http://www.chatzi.ibk.ethz.ch/education/method-of-finite-elements-ii.html

Course Slides (Script): http://www.chatzi.ibk.ethz.ch/education/method-of-finite-elements-ii.html

Competencies

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<td>Concepts and Theories</td>
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Prerequisites / notice

Lecture notes

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<td>Project on Construction Engineering</td>
<td>W</td>
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<td>Content</td>
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101-0317-00L  
Tunnelling I  
W  3 credits  
2G  
G. Anagnostou, A. Nordas, E. Pimentel

Abstract

Objective
Basic aspects of design and analysis of underground structures. Conventional tunnel construction methods. Auxiliary measures (ground improvement and drainage, forepoling, face reinforcement). Numerical analysis methods.

Content
Numerical analysis methods in tunnelling. Conventional excavation methods (full face, top heading and bench, side drift method, ...)

Auxiliary measures:
- Injections
- Jet grouting
- Ground freezing
- Drainage
- Forepoling
- Face reinforcement

Lecture notes
Autographieblätter

Literature
Empfehlungen

Prerequisites / notice
This course will continue to be offered in German up to and including HS24.

Competencies
Subject-specific Competencies
Concepts and Theories assessed

Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed

Decision-making assessed

101-0187-00L  
Structural Reliability and Risk Analysis  
W  3 credits  
2G  
S. Marelli

Abstract
Structural reliability aims at quantifying the probability of failure of systems due to uncertainties in their design, manufacturing and environmental conditions. Risk analysis combines this information with the consequences of failure in view of optimal decision making. The course presents the underlying probabilistic modelling and computational methods for reliability and risk assessment.

Objective
The goal of this course is to provide the students with a thorough understanding of the key concepts behind structural reliability and risk analysis. After this course the students will have refreshed their knowledge of probability theory and statistics to model uncertainties in view of engineering applications. They will be able to analyze the reliability of a structure and to use risk assessment methods for decision making under uncertain conditions. They will be aware of the state-of-the-art computational methods and software in this field.

Content
Engineers are confronted every day to decision making under limited amount of information and uncertain conditions. When designing new structures and systems, the design codes such as SIA or Euro- codes usually provide a framework that guarantees safety and reliability. However the level of safety is not quantified explicitly, which does not allow the analyst to properly choose between design variants and evaluate a total cost in case of failure. In contrast, the framework of risk analysis allows one to incorporate the uncertainty in decision making.

The first part of the course is a reminder on probability theory that is used as a main tool for reliability and risk analysis. Classical concepts such as random variables and vectors, dependence and correlation are recalled. Basic statistical inference methods used for building a probabilistic model from the available data, e.g. the maximum likelihood method, are presented.

The second part is related to structural reliability analysis, i.e. methods that allow one to compute probabilities of failure of a given system with respect to prescribed criteria. The framework of reliability analysis is first set up. Reliability indices are introduced together with the first order-second moment method (FOSM) and the first order reliability method (FORM). Methods based on Monte Carlo simulation are then reviewed and illustrated through various examples. By-products of reliability analysis such as sensitivity measures and partial safety coefficients are derived and their links to structural design codes is shown. The reliability of structural systems is also introduced as well as the methods used to reassess existing structures based on new information.

The third part of the course addresses risk assessment methods. Techniques for the identification of hazard scenarios and their representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. Elements of Bayesian decision making, i.e. pre-, post and pre-post risk assessment methods are presented.

Lecture notes
The course also includes a tutorial using the UQLab software dedicated to real world structural reliability analysis.

Literature

S. Marelli, R. Schöbi, B. Sudret, UQLab user manual - Structural reliability (rare events estimation), Report UQLab-V0.92-107.

Prerequisites / notice
Basic course on probability theory and statistics

101-0437-00L  
Traffic Engineering  
W  6 credits  
4G  
A. Kouvelas

Abstract
Fundamentals of traffic flow theory and control. The objective of this course is to fully understand the fundamentals of traffic flow theory in order to effectively manage traffic operations. By the end of this course students should be able to apply basic techniques to model different aspects of urban and inter-urban traffic performance, including congestion.

Objective
Introduction to fundamentals of traffic flow theory and control. Includes understanding of traffic data collection and processing techniques, as well as data analysis, traffic modeling, and methodologies for traffic control.

Content
The lecture notes and additional handouts will be provided during the lectures. Additional literature recommendations will be provided during the lectures.

Lecture notes
Verkehr III - Road Transport Systems 6th Sem. BSc (101-0415-00L)

Special permission from the instructor can be requested if the student has not taken Verkehr III

101-0417-00L  
Transport Planning Methods  
W  6 credits  
4G  
E. Heinen

Abstract
The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis.

Objective
- Knowledge and understanding of statistical methods and algorithms commonly used in transport planning
- Comprehend the reasoning and capabilities of transport models
- Ability to independently develop a transport model able to solve / answer planning problem
- Getting familiar with cost-benefit analysis as a decision-making supporting tool
The course provides the necessary knowledge to develop models supporting the solution of given planning problems and also introduces cost-benefit analysis as a decision-making tool. Examples of such planning problems are the estimation of traffic volumes, prediction of estimated utilization of new public transport lines, and evaluation of effects (e.g. change in emissions of a city) triggered by building new infrastructure and changes to operational regulations.

To cope with that, the problem is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis. Interim lab session take place regularly to guide and support students with the applied part of the course.

Lecture notes
Moodle platform (enrollment needed)

Literature


<table>
<thead>
<tr>
<th>101-0491-00L</th>
<th>Agent Based Modeling in Transportation</th>
<th>W</th>
<th>6 credits</th>
<th>4G</th>
<th>M. Balac, G. O. Kagho</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based simulation models’ current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in groups.</td>
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<td><strong>Objective</strong></td>
<td>At the end of the course, the students should:</td>
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<tr>
<td>-</td>
<td>have an understanding of agent-based modeling</td>
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<td>-</td>
<td>have an understanding of MATSim</td>
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<td>have an understanding of the process needed to set up an agent-based study</td>
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<td>-</td>
<td>have practical experience of using MATSim to perform transportation studies</td>
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<tr>
<td><strong>Content</strong></td>
<td>This course provides an introduction to agent-based models for transportation policy analysis. Four essential topics are covered:</td>
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<tr>
<td>1)</td>
<td>Introduction of agent-based modeling and its comparison to the traditional state of practice modeling</td>
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<td>2)</td>
<td>Introduction of MATSim, an open-source agent-based model, developed at ETH Zurich and TU Berlin, and its various parts</td>
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<td>3)</td>
<td>Setting up an agent-based model simulation, where different statistical methods used in the process will be introduced and explained.</td>
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<td>4)</td>
<td>Conducting a transport policy study. The case study will be performed in groups and will include a paper-like report.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>Agent-based modeling in general</td>
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<tr>
<td>-</td>
<td>MATSim</td>
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<td>Additional relevant readings, primarily scientific articles, will be recommended throughout the course.</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>There are no strict preconditions regarding which lectures the students should have previously attended. However, experience with at least one high-level programming language (Java, R, Python, or other) is recommended.</td>
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<td>For those without object-oriented programming experience, a crash course 101-0491-10 Basics of Java and Best Practices for Scientific Computing before the start of HS is recommended.</td>
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<td><strong>Competencies</strong></td>
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<td>Techniques and Technologies</td>
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<td>Analytical Competencies</td>
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<td>-</td>
<td>Problem-solving</td>
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<td>Social Competencies</td>
<td>Project Management</td>
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<td>Personal Competencies</td>
<td>Cooperation and Teamwork</td>
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<td>-</td>
<td>Critical Thinking</td>
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<td>**101-0267-01L</td>
<td>Numerical Hydraulics</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>E. Secchi, D. Vanzo</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>In the course Numerical Hydraulics the basics of numerical modelling of flows are presented.</td>
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<td><strong>Objective</strong></td>
<td>The goal of the course is to develop the understanding of the students for numerical simulation of flows to an extent that they can later use commercial software in a responsible and critical way.</td>
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<td><strong>Content</strong></td>
<td>The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their applicability is discussed. Using the example of non-steady state pipe flow numerical methods such as the method of characteristics and finite difference methods are introduced. The finite volume method as well as the method of characteristics are used for the solution of the shallow water equations. Special aspects such as wave propagation and turbulence modelling are also treated.</td>
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<td>All methods discussed are applied practically in exercises. This is done using programs in MATLAB which partially are programmed by the students themselves. Further, some generally available softwares such as BASEMENT for non-steady shallow water flows are used.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Slides from the lectures and programs used can be downloaded.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>Given in lecture</td>
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</table>
The Method of Finite Elements II is a continuation of Method of Finite Elements I. Here, we explore the theoretical and numerical implementation concepts for the finite element analysis beyond the linear elastic behavior. This course aims to offer students with the skills to perform nonlinear FEM simulations using coding in Python.

This course offers no introduction to commercial software.

This class overviews advanced topics of the Method of Finite Elements, beyond linear elasticity. Such phenomena are particularly linked to excessive loading effects and energy dissipation mechanisms. Their understanding is necessary for reliably computing structural capacity. In this course, instead of blindly using generic structural analysis software, we offer an explicit understanding of what goes on behind the curtains, by explaining the algorithms that are used in such software.

The course specifically covers the treatment of the following phenomena:
- Material Nonlinearity (Plasticity)
- Geometric Nonlinearity (Large Displacement Problems)
- Nonlinear Dynamics
- Fracture Mechanics

The concepts are introduced via theory, numerical examples, demonstrators and computer labs in Python (starting Fall 2021).

Upon completion of the course, the participants will be able to:
- Recognize when linear elastic analysis is insufficient
- Solve nonlinear dynamics problems, which form the core for limit state calculations (e.g. ultimate capacity, failure) of structures
- Numerically simulate fracture; a dominant failure phenomenon for structural systems.

See the class webpage for more information:

Useful (optional) Reading:

Prerequisites / notice

Prerequisites:
- 101-0158-01 Method of Finite Elements I (FS)
- A good knowledge of Python is necessary for attending this course.

Competencies

Subject-specific Competencies
- Concepts and Theories
  - assessed
- Techniques and Technologies
  - assessed

Method-specific Competencies
- Analytical Competencies
  - assessed
- Decision-making
  - fostered
- Problem-solving
  - assessed

Social Competencies
- Communication
  - fostered
- Cooperation and Teamwork
  - fostered

Personal Competencies
- Critical Thinking
  - assessed
- Integrity and Work Ethics
  - fostered

101-0159-00L Method of Finite Elements II W 3 credits 2G E. Chatzi, K. Tatsis

Abstract
The Method of Finite Elements II is a continuation of Method of Finite Elements I. Here, we explore the theoretical and numerical implementation concepts for the finite element analysis beyond the linear elastic behavior. This course aims to offer students with the skills to perform nonlinear FEM simulations using coding in Python.

Objective
This class overviews advanced topics of the Method of Finite Elements, beyond linear elasticity. Such phenomena are particularly linked to excessive loading effects and energy dissipation mechanisms. Their understanding is necessary for reliably computing structural capacity. In this course, instead of blindly using generic structural analysis software, we offer an explicit understanding of what goes on behind the curtains, by explaining the algorithms that are used in such software.

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Prerequisites / notice

Prerequisites:
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- A good knowledge of Python is necessary for attending this course.

Competencies

Subject-specific Competencies
- Concepts and Theories
  - assessed

Method-specific Competencies
- Analytical Competencies
  - assessed
- Problem-solving
  - assessed

Social Competencies
- Communication
  - fostered
- Cooperation and Teamwork
  - fostered

Personal Competencies
- Critical Thinking
  - assessed
- Integrity and Work Ethics
  - fostered

101-0617-02L Computational Science Investigation for Material Mechanics W 4 credits 2S D. Kammer, F. Wittel

Abstract
Introduction to computational sciences with focus on numerical modeling of the mechanics of materials. Simulation of material damage, fracture and failure with various material models.

Objective
Learning from mistakes and failures is as old as the engineering discipline. Understanding why things went wrong is essential for improvement, but often impossible without the help of numerical modelling. Real world problems are often highly nonlinear, dependent on multiple physical fields, involve fundamental material behavior far from equilibrium and reversibility, and can only often be understood by addressing different relevant scales.

In this course, we will use real-life cases to learn how to deal with such problems. Starting from the problem description with governing equations, you will learn how to tackle non-linear and multi-field problems using numerical simulations. A particular focus will be on fracture. We will investigate the conditions and mechanisms that lead to material failure and analyze the contributions of plastic behavior, size effects, randomness in the underlying material micro-structure, and various other non-linear material behavior. You will learn various approaches to model the mechanics of complex heterogeneous materials and to implement your model in Python code to run numerical simulations.

Content
1 Introduction to (numeric) forensic engineering
2 The nature of engineering problems (governing equations)
3 Numerical recipes for dealing with non-linear problems
4 Multi-field problems (HTM)
5 Creep and relaxation
6 On the nature of failure - Physics of damage and fracture
7 Cracks and growth in structures (LEFM and beyond)
8 Damage and fracture in heterogeneous materials
9 Mechanics of fatigue
10 Student - Project presentation

Lecture notes
Will be provided during the lecture via moodle.

Literature
Will be provided during the lecture.
### 101-0250-00L Solving Partial Differential Equations in Parallel on GPUs

**Objective**

Upon completion of the course, the students will be able to:

1. Understand main ML background theory and methods.
2. Assess a problem and apply ML and DL in a computational framework accordingly.
3. Incorporate scientific domain knowledge in the SciML process.
4. Define, plan, conduct and present a SciML project.

**Content**

- Part 1 - Discovering a modern parallel computing ecosystem
  - Learn the basics of the Julia language;
  - Learn how to solve diffusion, wave propagation and advection processes;
  - Implement efficient iterative algorithms;
  - Get started with software development tools: git, version control.

- Part 2 - Developing your own parallel algorithms on GPUs
  - Implement wave propagation and porous convection;
  - Apply spatial and temporal discretisation (finite-differences, various time-stepper);
  - Understand the practical challenges of parallel computing: GPUs, multi-core CPUs;
  - Learn about main simulation performance limits;
  - Implement software development tooling: unit tests, continuous integration (CI).

- Part 3 - Multi-GPU computing projects
  - Understand the practical challenges of distributed parallel computing on multi-GPUs;
  - Implement shared (on CPU and GPU) and distributed memory parallelisation (multi-GPUs/CPUs);
  - Automatise the software tooling using remote runners.

**Final projects**

- Apply your new skills in a final project;
- Implement advanced physical processes (solid and fluid dynamic - elastic and viscous solutions).

**Lecture notes**

Digital lecture notes, interactive Julia notebooks, online material.

**Literature**

Links to relevant literature will be provided during classes.

**Prerequisites / notice**

Completed BSc studies. Interest in and basic knowledge of numerics, applied mathematics, and physics/engineering sciences. Basic programming skills (in e.g. Matlab, Python, Julia); advanced programming skills are a plus.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>fostered</td>
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<td>Decision-making</td>
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<td>Problem-solving</td>
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<td>Social Competencies</td>
<td>Communication</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
<td>assessed</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<td>Self-direction and Self-management</td>
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### 101-0139-00L Scientific Machine and Deep Learning for Design and Construction

**Objective**

This course aims to provide a graduate-level introduction to machine learning, with a particular focus on scientific machine learning for applications in the design and construction phases of projects from architecture and civil engineering.

Upon completion of the course, the students will be able to:

1. Understand main ML background theory and methods.
2. Assess a problem and apply ML and DL in a computational framework accordingly.
3. Incorporate scientific domain knowledge in the SciML process.
4. Define, plan, conduct and present a SciML project.
The course will include theory and algorithms for SciML, programming assignments, as well as a final project assessment.

The topics to be covered are:
2. Incorporation of Domain Knowledge into ML and DL.
4. ML training, validation and testing pipelines for academic and research projects.

A comprehensive series of computer/lab exercises and in-class demonstrations will take place, providing a "hands-on" feel for the course topics.

The course script is composed by lecture slides, which are available online and will be continuously updated throughout the duration of the course.

Subject-specific Competencies

After successful completion of the course, students will be able to:

1. Understand and apply the fundamentals of the material glass and glass products, the basic principles for using glass as a load-carrying building material for structural applications and the types of connections used for glass elements;
2. Recognize requirements for glass elements depending on their application area and chose the appropriate glass products and assemblies accordingly;
3. Structurally design out-of-plane loaded glass elements based on available standards, both by hand calculations and specific software applications;
4. Apply selected approaches for the structural design of in-plane loaded glass elements;
5. Select suitable supporting systems (post-and-beam façade, curtain wall, etc.) and connections (point fixings, brackets, etc.) for the glass elements and structurally design them.

Content

The course introduces civil engineering students to structural glass design and related façade engineering aspects. It aims to provide the students the knowledge required in engineering offices to design glass elements but at the same time, the necessary fundamentals for later performing research in this field. To achieve this, the course includes lectures, design exercises and a design project.

Lectures:
The lectures will cover the following contents:
- Production methods and properties of the material glass and glass products and their structurally relevant properties (annealed glass, thermally tempered glass, chemically tempered glass, laminated glass, insulating glass, curved glass);
- Connection principles and types for glass elements (mechanical fixing, adhesive bonding);
- Requirements for glass elements depending on the application area (vertical glazing, overhead glazing, walk-on glazing, barrier glazing);
- Structural design of glass elements based on standards and research results (out-of-plane loaded glass elements and in-plane loaded glass elements);
- Typologies and design of structural systems for transparent façades;
- Requirements and functions for transparent façades.

Design exercises:
The principles and methods presented in the lectures are practiced with the students in design exercises. Hand calculation methods and their limitations as well as the software for structural glass design SJ Mepla are used for out-of-plane loaded glass elements. For in-plane loaded glass elements, the specifics of numerical calculation procedures are exemplified with the software Abaqus.

Design project:
The students will consolidate the knowledge gained in the theory-lectures and in the design exercises by working on a small design task (e.g. a glass canopy, a glass façade, a glass pavilion) in the form of a group work (ideally groups of 2-3 students). Within this task, the students will: conceptually design the structure and selected connection details; identify requirements for the glass elements and define their assembly; structurally design selected glass components, their support systems and their connections. The students will work on the design task in the second half of the semester and will get feedback on their progress in weekly review sessions. At the end of the semester, the groups will submit a project report and give an oral presentation of their projects.

Lecture notes

The lectures are based on lecture slides and handouts.

Recommended and supplementary literature:

Prior knowledge of structural analysis, especially steel structures is necessary. Prior basic knowledge on the method of finite elements is recommended.
### 101-0492-00L Microscopic Modelling and Simulation of Traffic Operations

**W** 3 credits  **2G**  
M. Makridis

**Abstract**
The course introduces basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies. The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.

**Objective**
The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a real traffic network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication.

Simulations will be implemented in Aimsun software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario.

Upon completion of the course, the students will:
- Understand the basic models used in microsimulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.).
- Design a road transport network inside the simulation software.
- Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network.
- Understand how to design a complete study, implement and validate it for planning purposes, e.g. creating a new road infrastructure.
- Make valid and concrete engineering proposals based on the simulation model and alternative scenarios.

**Content**
In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun.

Microscopic modelling and simulation concepts will include:
1. Car following models
2. Lane change models
3. Calibration and validation methodology

Specific tasks for the project will include:
1. Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed.
2. Calibrating and validating the simulation model.
3. Redesigning/extend the model to improve the traffic performance through Aimsun and with/without programming in Python or C++.

The course will be based on a project that each group of students will build (design, calibrate, analyze and presentation) across the semester. A mid-term exam will be given after the first half of the semester. A final examination will be given at the end of the semester.

The modelling software used is Aimsun and lectures (theory and hands on experience) are taking place in a computer room.

The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.

**Lecture notes**
The lecture notes and additional handouts will be provided before the lectures.

**Literature**
Additional literature recommendations will be provided at the lectures.

**Prerequisites / notice**
Students need to know some basic road transport concepts. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.

**Competencies**

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<thead>
<tr>
<th><strong>Subject-specific Competencies</strong></th>
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<th><strong>Method-specific Competencies</strong></th>
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<td>Analytical Competencies</td>
<td>fostered</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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### 102-0468-10L Watershed Modelling

**W** 6 credits **4G**  
P. Molnar, A. Costa, S. Sinclair

**Abstract**
Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

**Objective**
The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies. A comprehensive exercise block builds on the lectures with a series of 4 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 50% by performance in the graded exercises and 50% by a semester-end oral examination (30 mins) on watershed modelling concepts.

**Content**
The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models students build their own single bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focused on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models at larger scales. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns.

**Lecture notes**
There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

**Literature**
Literature consist of collections from standard hydrological textbooks and research papers, collected by the instructors on the course moodle page.
Prerequisites / notice
Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences). Basic knowledge of Matlab (Python), ArcGIS (Q-GIS).

Competencies
Subject-specific Competencies
Concepts and Theories assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving fostered

Social Competencies
Communication fostered

Personal Competencies
Cooperation and Teamwork assessed

Competencies
Subject-specific Competencies
Concepts and Theories assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving fostered

Social Competencies
Communication fostered

Personal Competencies
Cooperation and Teamwork assessed

101-0491-10L Basics of Java and Best Practices for Scientific Computing W 1 credit 1U M. Balac

Abstract
This course provides an introduction to programming in Java, version control, and cloud computing.

Objective
At the end of the course, the students should
● Have acquired object-oriented programming skills with a focus on Java.
● Have an understanding of version control using git
● Have learned to deploy java applications on servers

Content
This course provides an introduction to object-oriented programming with Java. Four topics are covered:
● Basics of Java (objects, classes, interfaces, abstract classes, static classes, static methods,...)
● Injection (traditional vs. Guice)
● Code versioning
● Java application deployment on servers

Literature
Intro to Java Programming, Comprehensive Version (10th Edition) by Y. Daniel Liang

401-0647-00L Introduction to Mathematical Optimization W 5 credits 2V+1U D. Adjiaashvili

Abstract
Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering.

Objective
The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.

Content
Topics covered in this course include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.

Literature
Information about relevant literature will be given in the lecture.

Prerequisites / notice
This course is meant for students who did not already attend the course "Mathematical Optimization", which is a more advance lecture covering similar topics. Compared to "Mathematical Optimization", this course has a stronger focus on modeling and applications.

101-0307-00L Design and Construction in Geotechnical Engineering W 4 credits 3G I. Anastasopoulos, K. Kassas, A. Marin, L. Sakellariadis

Abstract
This lecture deals with the practical application of the knowledge gained in the fundamental lectures from the Bachelor degree. The basics of planning and design of geotechnical structures will be taught for the main topics geotechnical engineers are faced to in practice.

Objective
Transfer of the fundamental knowledge taught in the Bachelor degree to practical application.
Ability to plan and design geotechnical structures based on the state of the art.

Content
Introduction to Swisscode SIA
Foundations and settlements
Pile foundations
Excavations
Slopes
Soil nailing
Reinforced geosystems
Ground improvement
River levees

Lecture notes
Script in the form of chapters and powerpoint overheads with web support (moodle-app2.let.ethz.ch)

Exercises

Literature
Relevant literature will be stated during the lectures

Prerequisites / notice
Pre-condition: Successful examinations (pass) in the geotechnical studies (soil mechanics and ground engineering, each 5 credits) in the Bachelor degree of Civil Engineering (ETH), or equivalent for new students.

The lecture contains at least one presentation from practice.
This course aims to provide a basic understanding of the mechanics and rheology of granular matter. It includes fundamental concepts as well as recent progress in research with main focus on related engineering and natural hazards applications. Small experiments are performed in class to illustrate important processes and state-of-the-art numerical modeling tools are introduced and used.

In this course students will see what the BIM method entails for a civil engineer and learn how to create a parametric model yourself including associated steel, precast concrete, in-situ concrete, reinforcement and masonry parts based on a practical example. Students will also learn how to automatically create formwork plans, parts lists and data for digital prefabrication and construction sites. They will thus acquire the necessary basis for their future work as engineers and how their work interacts with draughtsmen, designers and master builders in a digital working environment.

Courses covered grain-scale interactions, statics and rheology of granular materials based on a mix between classical lectures, on-board developments, presentation of small experiments, analytical and numerical exercises. We present the domains of application of granular mechanics through examples taken from the industry or research. In addition, the Discrete Element Method (DEM) together with state-of-the-art contact models will be presented and used to simulate standard tests such as the granular column collapse, shear flows but also more complex industrial or geophysical problems. Calibration of model parameters based on laboratory experiments will be discussed. The course will not cover aspects related to granular gasses and kinetic theory.

For the BIM, Parametric Modeling and Digital Construction for Civil Engineers course, students will learn about BIM2Field applications such as "Stake out from model" and "Lay reinforcement based on model". They will also acquire the necessary basis for their future work as engineers and how their work interacts with draughtsmen, designers and master builders in a digital working environment. Students will furthermore learn how to automatically create formwork plans, parts lists and data for digital prefabrication and construction sites.

For the Granular Mechanics course, students will learn about the mechanics and rheology of granular matter, including the transition towards fluid states through classical frictional plastic laws and the rheology of granular flows. The course will not cover aspects related to granular gazes and kinetic theory.

Books:
1. Granular Media: Between Fluid and Solid by Bruno Andreotti, Olivier Pouliquen, and Yoël Forterre
2. Particulate Discrete Element Modelling: A Geomechanics Perspective by Catherine O'Sullivan

Prerequisites / notice
Basic knowledge of physics, mechanics and soil mechanics is required.
This module offers the possibility to apply the fundamentals of the course Bridge Design in a conceptual design project. The scenario is set as a design competition: The students (group of two) will get a basic documentation (service criteria agreement, plans, digital terrain model, geotechnical report, photo documentation, etc.) and will develop a conceptual design suitable for the given site.

At the end of the course, students will have developed a convincing bridge design that satisfies following criteria:

- Consideration of governing boundary conditions and constraints.
- Conception of an efficient structural system with an adequate aesthetic expression considering the environment.
- Definition of the relevant actions and decisive load cases.
- Proof of feasibility by dimensioning the main structural elements.
- Schematic overview of construction processes.
- Appropriate presentation and visualisation of the proposed bridge design.

The module is built up as follows:

1. Presentation of problem statement / project. (1st week of semester)
2. Introduction to design tools & working methods.
3. Working on project (milestones):
   - a. Define requirements and boundary conditions.
   - b. Study of references and possible concepts
   - c. Choice of best variant
   - d. Structural modelling & calculations
   - e. Plans & visualisation
4. Submission

The course will be taught at the Kunsthalle Zurich as part of an exhibition.

Please only register for the course if you really intend to participate on all course dates (see course catalog), otherwise, you will deprive someone else of a place.

The course is about digital innovation towards a circular economy in the built environment. How can we bring together two worlds that are often too distinct: low-impact construction and digital innovation? Bringing digital tools already used in other sectors into the construction sector, students will learn about circular construction (e.g., reuse of materials) through hands-on learning practices.

In the fall semester 2024 we will focus on applying artificial intelligence (AI) and extended reality (XR) to the circular design workflow and. The course will be taught at the Kunsthalle Zurich as part of an exhibition.

By the end of this course, students will be able to use augmented computational design enabling circular construction, with a view to environmental implications. They will be able to assess the challenges and opportunities of low-carbon, circular construction and evaluate possible solutions using digital technologies to enable a circular built environment (more specifically, with reused building materials). To achieve this, they need to be able to do the following:

1. Apply circular principles using recovered building materials.
2. Compare different digital technologies applied in circular construction (e.g., LiDAR scanning, drone imagery, photogrammetry, computational design, AI, computer vision, XR, LCA tools etc.)
3. Understand the potential and limitations of AI for circular construction, e.g. use machine learning to detect and digitize materials (computer vision) or to support creativity in the early design phases of circular construction (generative AI).
4. Communicate the importance and urgency of circular construction.
5. Assess the environmental impact implications of their design and technology decisions through a preliminary Life Cycle Assessment (LCA).

Students will receive an introduction to circular principles by experts from the building industry and visit of (de-)construction sites where circular construction is exemplified. They will explore how to use digital technologies such as LiDAR scanning, photogrammetry, scan-to-BIM, computer vision, computational design, digital fabrication, blockchain technology and learn about the design implications using reclaimed building materials. This course is meant as an overview/introduction of many digital technologies that could be useful for circularity and gives the tools to students to further study the technologies they are most interested in on their own. Creativity in writing, filmmaking, design, construction, etc. is expected from the students. This course will give the tools to students to learn more on LCA if they wish to deepen their knowledge further.

Language: English

Courses are on Tuesday afternoons in Kunsthalle or a room at ETH, but also require out-of-the-semester work and significant homework and site visits outside of class hours.
The lecture focuses on selected topics in hydraulic engineering, water management and aquatic ecology relating to hydropower and flood protection projects. The overarching goal of the course is to broaden and enhance knowledge on special aspects in hydraulic engineering and its links to aquatic ecology and to understand the procedures and the planning sequence of large-scale projects. Selected topics in hydraulic engineering will be focused on, e.g. dam safety, materials in dam construction, possible problems at reservoirs like hazards from impulse waves and dam breaching, the hydraulics of spillways and intake structures at dams and weirs and the link between hydropower and ecology. Another focus will be put on typical approaches and procedures in the planning process of large-scale hydraulic engineering projects at the national and international level.

Lecture notes: Lecture handouts will be available online. Parts of the lectures will also be covered by a manuscript that will be available in electronic form. Literature: External speakers will be involved to present current topics and projects in Switzerland and abroad.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>101-0249-00L</td>
<td><strong>Hydraulic Engineering III</strong></td>
<td>W</td>
<td>3</td>
<td>2S</td>
<td>R. Boes</td>
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**Prerequisites**

Interest in Digitalisation and Construction. Flexibility: This is a hands-on course, where students explore digital technologies and opportunities/challenges of reuse. Flexibility (e.g., adapting to unforeseen circumstances), responsibility (e.g., arriving on time for safety briefing), and spontaneity (e.g., finding innovative solutions) is expected from the students to adapt to the contingencies from demolition and construction sites with reused materials. The course is mandatory for MIBS students. If you are a first-year MIBS student, please do not apply, you are automatically accepted. All other students from other departments should apply. Please only register for the course if you really intend to participate on all course dates (see course catalog). Please only register for the course if you are willing to send us a letter of motivation and really intend to participate; otherwise, you will deprive someone else of a place. All non-MIBS students who register go onto a waiting list until 11.09.2024 and up to 25 of them will be selected by the lecturer.

To register:
1. Enroll before 05.09.2024.
2. Send a short letter of motivation (max. 300 words) and a 1-page CV to cea-course@ibi.baug.ethz.ch by 05.09.2024.

Collaborators: Kunsthalle Zürich, ETH AI Center, Design++

**Competencies**

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<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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<td>Problem-solving</td>
<td>Leadership and Responsibility</td>
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**Project Based Courses**

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<tr>
<td>101-0608-00L</td>
<td><strong>Design-Integrated Life Cycle Assessment</strong></td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>G. Habert, A. Rodionova</td>
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Abstract: Currently, Life Cycle Assessment (LCA) is applied as an ex-post design evaluation of buildings, but rarely used to improve the building during the design process. The aim of this course is to apply LCA during the design of buildings by means of a digital, parametric tool. The necessary fundamentals of the LCA method will be taught following a lecture on demands approach.

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Autumn Semester 2024
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The course will follow two main objectives and a third optional objective, depending on the design projects the students' choose. At the end of the course, the students will:

1. Know the methodology of LCA
2. Be able to apply LCA in the design process to assess and improve the environmental performance of their projects
3. Be able to use the parametric LCA tool and link it to additional performance assessment tools for a holistic optimisation

The course will be structured into two parts, each making up about half of the semester.

Part I: Exercises with lectures on demand
The first six individual courses will follow the "lectures on demand" approach. Small "hands-on" exercises focusing on one specific aspect will be given out and the necessary background knowledge will be provided in the form of short input lectures when questions arise. The following topics will be discussed during the first part:
1) LCA basic introduction
2) System boundaries, functional unit, end of life
3) Decision-making
4) Media and Digital Technologies
5) BIM-LCA, available calculation tools and databases
6) Integrated analysis of environmental and cost assessment

Part II: Project-based learning
In the second part, the students will work on their individual project in groups of three. For the design task, the students will bring their own project and work on improving it. The projects can be chosen depending on the students background and range from buildings to infrastructure projects. Intermediate presentations will ensure the continuous work and make sure all groups are on the same level and learn from each other. During this part, the following hands-on tutorials will be given:
1) Introduction to Rhinoceros 6 and 7
2) Introduction to grasshopper
3) Integrated assessment tools (ladybug tools)
4) Introduction to in-house grasshopper plugin for LCA analysis

The course will present methods of scientific machine and deep learning (ML / DL) for applications in design and construction. After providing proper background on ML and the scientific ML (SciML) track, several applications of SciML together with their computational implementation during the design and construction process of the built environment are examined.

The students are expected to work out of class as well. The course time will be used by the teachers to answer project-specific questions.

The lecture series will be conducted in English and is aimed at students of master's programs, particularly in civil engineering and MIBS. No lecture will be given during Seminar week.

The students are expected to work out of class as well. The course time will be used by the teachers to answer project-specific questions.

The lecture series will be conducted in English and is aimed at students of master's programs, particularly in civil engineering and MIBS. No lecture will be given during Seminar week.

### Competencies

<table>
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<tr>
<th>101-0329-00L Tunnelling III</th>
<th>W</th>
<th>4 credits</th>
<th>2G</th>
<th>G. Anagnostou, E. Pimentel, M. Ramoni</th>
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**Subject-specific Competencies**

- Techniques and Technologies: assessed
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed

**Method-specific Competencies**

- System boundaries: assessed
- Field measurements: Principles, monitoring layout, applications, interpretation.
- Caverns: Geometry, construction methods, support.
- Shafts: Construction methods, support.
- Urban tunnelling: Boundary conditions, system choice, alignment, design.
- Cut and cover tunnels: Modelling, design.
- Exercising conceptual solution of complex tunnelling problems based upon discussion of current tunnel cases with particularly demanding problems in small groups.

**Social Competencies**

- Communication: assessed
- Cooperation and Teamwork: assessed
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**

- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed

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**101-0139-00L Scientific Machine and Deep Learning for Design and Construction**

**Abstract**

This course will present methods of scientific machine and deep learning (ML / DL) for applications in design and construction. After providing proper background on ML and the scientific ML (SciML) track, several applications of SciML together with their computational implementation during the design and construction process of the built environment are examined.
Objective

This course aims to provide a graduate-level introduction to machine learning, with a particular focus on scientific machine learning for applications in the design and construction phases of projects from architecture and civil engineering.

Upon completion of the course, the students will be able to:
1. Understand main ML background theory and methods.
2. Assess a problem and apply ML and DL in a computational framework accordingly.
3. Incorporate scientific domain knowledge in the SciML process.
4. Define, plan, conduct and present a SciML project.

Content

The course will include theory and algorithms for SciML, programming assignments, as well as a final project assessment.

The topics to be covered are:
2. Incorporation of Domain Knowledge into ML and DL.
4. ML training, validation and testing pipelines for academic and research projects.

A comprehensive series of computer/lab exercises and in-class demonstrations will take place, providing a "hands-on" feel for the course topics.

Lecture notes

The course script is composed by lecture slides, which are available online and will be continuously updated throughout the duration of the course.

Literature

Suggested Reading:
Marc Peter Deisenroth, A Aldo Faisal, and Cheng Soon Ong Mathematics for Machine Learning
S. Guido, A. Müller: Introduction to machine learning with python. O'Reilly Media, 2016
O. Martin: Bayesian analysis with python. Packt Publishing Ltd, 2016

Prerequisites / notice

Familiarity with Python is advised.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed
Project Management assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking fostered
Self-direction and Self-management fostered

101-0357-00L

Theoretical and Experimental Soil Mechanics ■

Prerequisites: Mechanics I, II and III.

W 6 credits 4G

I. Anastasopoulos, R. Herzog, E. Korre, A. Marin, L. Sakellariadis, M. Schneider

Abstract

Overview of soil behaviour
Explanation of typical applications: reality, modelling, lab tests with transfer of results to practical examples
Consolidation theory and typical applications
Triaxial tests: consolidation & shear, drained & undrained response
Plasticity theory & Critical State Soil Mechanics, Cam Clay
Application of plasticity theory
Introduction to physical modelling

Objective

(1) Extend knowledge of theoretical approaches that can be used to describe soil behaviour.
(2) Offer the opportunity to perform hands on element tests required for constitutive model calibration.
(3) Enable students to select an appropriate constitutive model and calibrate it using element test performed in the lab.
(4) Enable students to carry out FE analyses for realistic geotechnical applications.

Content

Overview of soil behaviour
Discussion of general gaps between basic theory and soil response
Stress paths in practice & in laboratory tests
Explanation of typical applications: reality, modelling, laboratory tests with transfer of results to the practical examples
Consolidation theory for incremental and continuous loading oedometer tests and typical applications in practice
Triaxial & direct shear tests: consolidation & shear, drained & undrained response
Plasticity theory & Critical State Soil Mechanics, Cam Clay
Application of plasticity theory
Introduction to physical modelling with emphasis on centrifuge modelling

Lecture notes

Printed script with web support
Exercises

Literature

https://moodle-app2.let.ethz.ch/

Pre-requisites: Fundamental knowledge of solid and soil mechanics.

The theoretical part of the course will be covered by problem-based lectures. The experimental part will be covered by hands-on element tests performed by the students in the laboratory. These experimental results will be instrumental in the calibration of advanced soil constitutive models. The connection between the experimental and theoretical parts of the course will be facilitated by means of numerical investigations (i.e, FE analyses), including the selection and calibration of relevant constitutive models. The numerical investigations shall be documented by the students in a final report.

Laboratory equipment will be available for 60 students. Students registered for the Geotechnics Specialty in Masters will be given priority as follows: (1) 2nd year students; (2) 1st year students; (3) doctoral students taking the class for their qualifying exam; Further students will be admitted on a first-come-first-served basis.
V. Concepts and Theories

After successful completion of the course, students will be able to:

- Understand and apply the fundamentals of the material glass and glass products, the basic principles for using glass as a load-carrying building material for structural applications and the types of connections used for glass elements;
- Recognize requirements for glass elements depending on their application area and chose the appropriate glass products and assemblies accordingly;
- Structurally design out-of-plane loaded glass elements based on available standards, both by hand calculations and specific software applications;
- Apply selected approaches for the structural design of in-plane loaded glass elements;
- Select suitable supporting systems (post-and-beam façade, curtain wall, etc.) and connections (point fixings, brackets, etc.) for the glass elements and structurally design them.

Content

This course introduces civil engineering students to structural glass design and related façade engineering aspects. It aims to provide the students the knowledge required in engineering offices to design glass elements but at the same time, the necessary fundamentals for later performing research in this field. To achieve this, the course includes lectures, design exercises and a design project.

Lectures:

The lectures will cover the following contents:

- Production methods and properties of the material glass and glass products and their structurally relevant properties (annealed glass, thermally tempered glass, chemically tempered glass, laminated glass, insulating glass, curved glass);
- Connection principles and types for glass elements (mechanical fixing, adhesive bonding);
- Requirements for glass elements depending on the application area (vertical glazing, overhead glazing, walk-on glazing, barrier glazing);
- Structural design of glass elements based on standards and research results (out-of-plane loaded glass elements and in-plane loaded glass elements);
- Typologies and design of structural systems for transparent façades;
- Requirements and functions for transparent façades.

Design exercises:

The principles and methods presented in the lectures are practiced with the students in design exercises. Hand calculation methods and their limitations as well as the software for structural glass design SJ Mepla are used for out-of-plane loaded glass elements. For in-plane loaded glass elements, the specifics of numerical calculation procedures are exemplified with the software Abaqus.

Design project:

The students will consolidate the knowledge gained in the theory-lectures and in the design exercises by working on a small design task (e.g. a glass canopy, a glass façade, a glass pavilion) in the form of a group work (ideally groups of 2-3 students). Within this task, the students will: conceptually design the structure and selected connection details; identify requirements for the glass elements and define their assembly; structurally design selected glass components, their support systems and their connections. The students will work on the design task in the second half of the semester and will get feedback on their progress in weekly review sessions. At the end of the semester, the groups will submit a project report and give an oral presentation of their projects.

Lecture notes

The lectures are based on lecture slides and handouts.

Literature

Recommended and supplementary literature:


Prerequisites / notice

Prior knowledge of structural analysis, especially steel structures is necessary. Prior basic knowledge on the method of finite elements is recommended.

Competencies

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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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Assessed

101-0250-00L

Solving Partial Differential Equations in Parallel on GPUs

Abstract

This course aims to cover state-of-the-art methods in modern parallel computing on Graphics Processing Unit (GPU), supercomputing and code development with applications to natural sciences and engineering.

Objective

When quantitative assessment of physical processes governing natural and engineered systems relies on numerically solving differential equations, fast and accurate solutions require performant algorithms leveraging parallel hardware. The goal of this course is to offer a practical approach to solve systems of differential equations in parallel on GPUs using the Julia language. Julia combines high-level language conciseness to low-level language performance which enables efficient code development.

The course will be taught in a hands-on fashion, putting emphasis on you writing code and completing exercises; lecturing will be kept at a minimum. In a final project you will solve a solid mechanics or fluid dynamics problem of your interest, such as the shallow water equation, the shallow ice equation, acoustic wave propagation, nonlinear diffusion, viscous flow, elastic deformation, viscous or elastic poromechanics, frictional heating, and more. Your Julia GPU application will be hosted on a git-platform and implement modern software development practices.
Part 1 - Discovering a modern parallel computing ecosystem
- Learn the basics of the Julia language;
- Learn how to solve diffusion, wave propagation and advection processes;
- Implement efficient iterative algorithms;
- Get started with software development tools: git, version control.

Part 2 - Developing your own parallel algorithms on GPUs
- Implement wave propagation and porous convection;
- Apply spatial and temporal discretisation (finite-differences, various time-stepper);
- Understand the practical challenges of parallel computing: GPUs, multi-core CPUs;
- Learn about main simulation performance limiters;
- Implement software development tooling: unit tests, continuous integration (CI).

Part 3 - Multi-GPU computing projects
- Understand the practical challenges of distributed parallel computing on multi-GPUs;
- Implement shared (on CPU and GPU) and distributed memory parallelisation (multi-GPUs/CPUs);
- Automate the software tooling using remote runners.

Final projects
- Apply your new skills in a final project;
- Implement advanced physical processes (solid and fluid dynamic - elastic and viscous solutions).

Lecture notes
Digital lecture notes, interactive Julia notebooks, online material.

Links to relevant literature will be provided during classes.

We look at the durability of reinforced concrete structures, covering common deterioration processes such as reinforcement corrosion, frost damage, ASR, etc. The course spans the range from fundamental mechanisms to aspects of engineering practice. New methods and materials for preventative measures, condition assessment and repair techniques are treated. Examples from real cases are shown.

- Modern materials and construction technologies: Discussion of expected implications for the durability of structures today and in the future.
- Socio-economic challenges related to ageing infrastructures.
- Degradation mechanisms for concrete: sulphate attack, ASR, frost attack.
- Inspection and condition assessment: Chloride analyses, carbonation depth, etc. Non-destructive tests, particularly potential mapping to detect corrosion. New developments (for example, monitoring with sensors).
- Pre-stressed and post-tensioned structures: problem with existing structures. New systems with polymer ducts / electrically isolated tendons.
- Repair methods for deteriorated concrete structures such as conventional repair and electrochemical methods (in particular cathodic protection) and possible future problems for durability that may arise with modern materials and construction technologies.
- Stainless steel as reinforcing steel for concrete: Different types of stainless steels. Coupling with black reinforcing steel. Examples of application. Life-cycle-costs.
- Modern materials and construction technologies: Discussion of expected implications for the durability of structures today and in the future.

Excursion:
- We generally try to organize a site-visit (depending on availability of construction sites). Presumably, we will visit an installation site of cathodic protection on a concrete structure in the Zurich area.

The course is based on the book

Slides of the lectures will be distributed in advance

Special handouts and reprints for particular topics will be distributed
The course is based on the book Corrosion of steel in concrete - prevention diagnosis repair (WILEY 2013) by L. Bertolini, B. Elsener, P. Pedeferri and R. Polder

Slides of the lectures will be distributed in advance

Special handouts and reprints for particular topics will be distributed

Form of teaching:
The course is a lecture that contains frequent discussion and interaction between students and lecturer. You will see and work on many examples from engineering practice, both during the lectures and in the form of exercises to be solved at home.

Report:
Each student will work on a small case study and deliver a report during the semester. The report will be graded.

Excursion:
We generally try to organize a site-visit (depending on availability of construction sites). Presumably, we will visit an installation site of cathodic protection on a concrete structure in the Zurich area.

### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

**Social Competencies**
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: assessed

### Concrete Technology

**Abstract**
Opportunities and limitations of concrete technology.

Commodities and leading edge specialties.

**Objective**
Advanced education in concrete technology for civil engineers who are designing, specifying and executing concrete structures.

**Content**
Based on the lecture ‘Werkstoffe’ students receive deep concrete technology training. Comprehensive knowledge of the most important properties of conventional concrete and the current areas of research in concrete technology will be presented. The course covers various topics, including:

- concrete components
- concrete properties
- concrete mix design
- production, transport, casting
- demoulding, curing and additional protective measures
- durability
- standards
- chemical admixtures
- alternative binders
- specialty concretes such as: self compacting concrete, fiber reinforced concrete, fast setting concrete
- the role of sustainability in concrete technology
- new research in digital fabrication with concrete

**Lecture notes**
Slides provided for download.

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Problem-solving: assessed

**Social Competencies**
- Communication: assessed
- Cooperation and Teamwork: assessed

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
Objective

Public transport is a key driver for making our cities more livable, clean and accessible, providing safe, and sustainable travel options for millions of people around the globe. Proper planning of public transport system also ensures that the system is competitive in terms of speed and cost. Public transport is a crucial asset, whose social, economic and environmental benefits extend beyond those who use it regularly; it reduces the amount of cars and road infrastructure in cities; reduces injuries and fatalities associated to car accidents, and gives transport accessibility to very large demographic groups.

Goal of the class is to understand the main characteristics and differences of public transport networks. Their various performance criteria based on various perspective and stakeholders. The most relevant decision making problems in a planning tactical and operational point of view. At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate possible improvements to existing networks of public transport and the management of those networks; optimize the use of resources in public transport.

General structure:
- General introduction of transport, modes, technologies, system design and line planning for different situations, mathematical models for design and line planning, timetabling and tactical planning, and related mathematical approaches, operations, and quantitative support to operational problems, evaluation of public transport systems.

Content
- Basics for line transport systems and networks
- Passenger/Supply requirements for line operations
- Objectives of system and network planning, from different perspectives and users, design dilemmas
- Conceptual concepts for passenger transport: long-distance, urban transport, regional, local transport

Planning process, from demand evaluation to line planning to timetables to operations
- Matching demand and modes
- Line planning techniques
- Timetabling principles
- Allocation of resources
- Management of operations
- Measures of realized operations
- Improvements of existing services

Lecture notes
- Lecture slides are provided.

Literature
- Ceder, Avi: Public Transit Planning and Operation, CRC Press, 2015, ISBN 978-1466563919 (English)

Competencies
- Subject-specific Competencies: Concepts and Theories, assessed
- Techniques and Technologies, assessed
- Method-specific Competencies: Analytical Competencies, assessed
- Decision-making, assessed
- Media and Digital Technologies, fostered
- Problem-solving, assessed
- Project Management, fostered
- Social Competencies: Communication, assessed
- Cooperation and Teamwork, assessed
- Customer Orientation, assessed
- Leadership and Responsibility, fostered
- Self-presentation and Social Influence, fostered
- Sensitivity to Diversity, fostered
- Negotiation, fostered
- Personal Competencies: Adaptability and Flexibility, fostered
- Creative Thinking, assessed
- Critical Thinking, assessed
- Integrity and Work Ethics, fostered
- Self-awareness and Self-reflection, fostered
- Self-direction and Self-management, fostered

Abstract

The course introduces basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies. The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.
Objective

The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a real traffic network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication.

Simulations will be implemented in Aimsun software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario.

Upon completion of the course, the students will:
- Understand the basic models used in microsimulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.).
- Design a road transport network inside the simulation software.
- Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network.
- Understand how to design a complete study, implement and validate it for planning purposes, e.g., creating a new road infrastructure.
- Make valid and concrete engineering proposals based on the simulation model and alternative scenarios.

Content

In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun.

Microscopic modelling and simulation concepts will include:
1) Car following models
2) Lane change models
3) Calibration and validation methodology

Specific tasks for the project will include:
1) Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed.
2) Calibrating and validating the simulation model.
3) Redesigning/ extending the model to improve the traffic performance through Aimsun and with/without programming in Python or C++.

The course will be based on a project that each group of students will build (design, calibrate, analyze and present) across the semester. A mid-term and final presentation of the work will be asked from each group of students.

It consists of weekly 2-hour lectures. The students will work in pairs on a group project that completes in the end of the semester. The modelling software used is Aimsun and lectures (theory and hands on experience) are taking place in a computer room.

The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.

Lecture notes

The lecture notes and additional handouts will be provided before the lectures.

Literature

Additional literature recommendations will be provided at the lectures.

Prerequisites / notice

Students need to know some basic road transport concepts. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.

Competencies

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<thead>
<tr>
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<th>Methods-specific Competencies</th>
<th>Social Competencies</th>
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Materials and Constructions

W 4 credits 2G G. Habert, M. Posani

Abstract

Building materials with a special focus on regenerative materials: earth, bio-based and reuse.

Looking at material sourcing, properties and performance, as well as how they are integrated in the buildings (building envelope and detailing).

Choice of material is done out of sustainability concern.

Comfort, moisture transfer and building physics with hygroscopic materials.

Objective

Special focus on regenerative materials: earth, bio-based and reuse

The students will acquire knowledge in the following fields:
- Fundamentals of material performance
- Introduction to durability problems of building facades
- Materials for the building envelope:
  - Overview of structural materials and systems: concrete, steel, stone, earth, wood and bamboo
  - Insulating materials (bio-based vs conventional)
- Assessment of materials and components behaviour and performance
- Degradation risks connected to insulation and post-insulation
- Aspects of sustainability and durability

Content

Special focus on comfort, moisture transfer and building physics with hygroscopic materials will be done.

Introduction

Sustainable cement and concrete
Earth construction
Stone
Steel
Bamboo
Timber construction
Building physics and conventional insulation
Bio-based insulation and degradation risks with insulation
Hygrothermal properties of building materials and dynamic numerical simulations
Efficiency and sustainability of modern window glazing

Course will have general lectures
+ hands on lab @home experiments
+ group project for implementation of regenerative materials.
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection

Competencies

Objectives
- The goal of the course is to introduce students to Structural Design. The course fosters the development of a design thinking that emerges from the coexistence of a number of design parameters and performance criteria related to force flow, construction technologies, material use, and spatial qualities.
- After a successful completion of the course, students will be able to:
  1. Critically evaluate structural design concepts based on their impact and implications beyond the sole structural performance
  2. Identify the most relevant design parameters and performance criteria for a given design task and select adequate tools to effectively integrate them as part of the design process
  3. Develop structural systems in compliance with structural, spatial, and environmental design aspects simultaneously

Content
- The goal of the course is to introduce students to Structural Design. The course fosters the development of a design thinking that emerges from the coexistence of a number of design parameters and performance criteria related to force flow, construction technologies, material use, and spatial qualities. Students will learn about diverse tools that allow for controlling such a complex blend of parameters and criteria at the interface between different disciplines such as structural engineering and architecture. These tools will include physical models, graphical methods, and digital tools. After a series of lectures and workshops, students will work on a design exercise that represents the core of the entire course. The design exercise is an opportunity to deal with an open-ended task that does not admit a univocal answer. In fact, besides structural performance, design options will be discussed and evaluated through a set of criteria including spatial qualities, constructability, and environmental footprint.

Numerical Hydraulics

Abstract
- In this course Numerical Hydraulics the basics of numerical modelling of flows are presented. All methods discussed are applied practically in exercises. This is done using programs in MATLAB which partially are programmed by the students themselves. Further, some generally available softwares such as BASEMENT for non-steady shallow water flows are used.

Objective
- The goal of the course is to develop the understanding of the students for numerical simulation of flows to an extent that they can later use commercial software in a responsible and critical way.

Content
- The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their applicability is discussed. Using the example of non-steady state pipe flow numerical methods such as the method of characteristics and finite difference methods are introduced. The finite volume method as well as the method of characteristics are used for the solution of the shallow water equations. Special aspects such as wave propagation and turbulence modelling are also treated.

BIM, Parametric Modeling and Digital Construction for Civil Engineers

Abstract
- Practice-oriented introduction to BIM working methods for civil engineers. Advantageous applications compared to 2D/3D, especially for digital construction and parametric modelling.

Objective
- In this course students will see what the BIM method entails for a civil engineer and learn how to create a parametric model yourself incl. associated steel, precast concrete, in-situ concrete, reinforcement and masonry parts based on a practical example. Students will also learn how to automatically create formwork plans, parts lists and data for digital prefabrication and construction sites. They will thus acquire the necessary basis for their future work as engineers and how their work interacts with draughtsmen, designers and master builders in a digital working environment.

Content
- Parametric modelling of steel, precast concrete, in-situ concrete, reinforcements and masonry
- Parametric modelling of connections and joints
- Defining and evaluating concreting stages
- Semi-automatic creation of formwork plans according to sia standards
- Automatic export of all necessary models and data for BIM2Field
- Insight into BIM2Field applications "Stake out from model" and "Lay reinforcement based on model".

Lecture notes
- Available eLearning content
- PowerPoint slides
<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>Basic knowledge of construction detailing in steel and concrete, as taught in the BSc courses for steel and concrete structures, is of advantage.</th>
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<td>Competencies</td>
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### 101-0129-00L Non Destructive Evaluation & Rehabilitation of Existing Structures

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<tr>
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<th><strong>2G</strong></th>
<th>E. Chatzi, B. Herrera Gómez, G. Kocur</th>
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<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Introduction to non destructive evaluation tools and quantitative structural analyses and verifications for condition assessment of existing structures and subsequent decisions on their rehabilitation.</td>
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<td><strong>Objective</strong></td>
<td>The goal is for students to familiarize themselves with the handling of assessment and rehabilitation of existing structures from the perspective of a consulting engineer, following a systematic approach as described in current codes and to further learn how to use new non destructive evaluation technologies.</td>
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<td><strong>Content</strong></td>
<td>This course is organized in two main pillars. The first pillar describes the technologies that are available for non destructive evaluation of structures and delves into description of the principle of operation of such methods (e.g. wave propagation, acoustic emission analysis, tomography). The second pillar, overviews the current implementation of condition assessment processes in codes and standards, Complementary to the topic of structural evaluation, the topic of interventions, rehabilitation and retrofitting of existing structures for different construction materials is next addressed.</td>
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<td><strong>Lecture notes</strong></td>
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<td>Techniques and Technologies</td>
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<td>Negotiation</td>
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<td>Critical Thinking</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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### 101-0328-00L Granular Mechanics

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<th><strong>W</strong></th>
<th>4 credits</th>
<th><strong>4G</strong></th>
<th>J. Gaume</th>
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<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This course aims to provide a basic understanding of the mechanics and rheology of granular matter. It includes fundamental concepts as well as recent progress in research with main focus on related engineering and natural hazards applications. Small experiments are performed in class to illustrate important processes and state-of-the-art numerical modeling tools are introduced and used.</td>
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<td><strong>Objective</strong></td>
<td>Granular materials have the ability to sustain stresses like a solid of flow like a fluid depending on the applied solicitation and boundary conditions. This course targets civil, geotechnical and mechanical engineering students, who are interested in discovering the fascinating and sometimes surprising world of granular media, the second most used material in industry and in learning novel modeling approaches. After this class, the students should know how to describe inter-particle interactions at the grain scale, the statics of granular materials, the transition towards fluid states through classical frictional plastic laws and the rheology of granular flows. Furthermore, the students should know the basics of the Discrete Element Method (DEM), its advantage and limitations and should be able to use a commercial software for different types of application.</td>
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<td><strong>Content</strong></td>
<td>This course covers grain-scale interactions, statics and rheology of granular materials based on a mix between classical lectures, on-board developments, presentation of small experiments, analytical and numerical exercises. We present the domains of application of granular mechanics through examples taken from the industry or research. In addition, the Discrete Element Method (DEM) together with state-of-the-art contact models will be presented and used to simulate standard tests such as the granular column collapse, shear flows but also more complex industrial or geophysical problems. Calibration of model parameters based on laboratory experiments will be discussed. The course will not cover aspects related to granular gasses and kinetic theory.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Lecture slides and lecture notes will be provided on Moodle.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>Book:</td>
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<td></td>
<td>1. Granular Media: Between Fluid and Solid by Bruno Andreotti, Olivier Pouliquen, and Yoël Forterre</td>
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<td>2. Particulate Discrete Element Modelling: A Geomechanics Perspective by Catherine O’Sullivan</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Basic knowledge of physics, mechanics and soil mechanics is required.</td>
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In the fall semester 2024 we will focus on applying artificial intelligence (AI) and extended reality (XR) to the circular design workflow and...
Content

Students will receive an introduction to circular principles by experts from the building industry and visit of (de-)construction sites where circular construction is exemplified. They will explore how to use digital technologies such as LiDAR scanning, photogrammetry, scan-to-BIM, computer vision, computational design, digital fabrication, blockchain technology and learn about the design implications using reclaimed building materials. This course is meant as an overview/introduction of many digital technologies that could be useful for circularity and gives the tools to students to further study the technologies they are most interested in on their own. Creativity in writing, filmmaking, design, construction, etc. is expected from the students. This course will give the tools to students to learn more on LCA if they wish to deepen their knowledge further.

Lecture notes

Language: English
Courses are on Tuesday afternoons in Kunsthalle or a room at ETH, but also require out-of-the-semester work and significant homework and site visits outside of class hours.

Literature

Prerequisites / notice
Interest in Digitalisation and Construction. Flexibility: This is a hands-on course, where students explore digital technologies and opportunities/challenges of reuse. Flexibility (e.g. adapting to unforeseen circumstances), responsibility (e.g. arriving on time for safety briefing), and spontaneity (e.g. finding innovative solutions) is expected from the students to adapt to the contingencies from demolition and construction sites with reused materials. The course is mandatory for MIBS students. If you are a first year MIBS student, please do not apply, you are automatically accepted. All other students from other departments should apply. Please only register for the course if you really intend to participate on all course dates (see course catalog). Please only register for the course if you are willing to send us a letter of motivation and really intend to participate; otherwise, you will deprive someone else of a place. All non-MIBS students who register go onto a waiting list until 11.09.2024 and up to 25 of them will be selected by the lecturer.

To register:
1. Enroll before 05.09.2024.
2. Send a short letter of motivation (max. 300 words) and a 1-page CV to cea-course@bi.baug.ethz.ch by 05.09.2024.

Collaborators: Kunsthalle Zürich, ETH AI Center, Design++

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Customer Orientation assessed
Leadership and Responsibility assessed
Self-presentation and Social Influence assessed
Sensitivity to Diversity assessed
Negotiation assessed

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

Master’s Thesis

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<td>Supervisors</td>
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</tbody>
</table>

Only students who fulfill the following criteria are allowed to begin with their master thesis:

a. successful completion of the bachelor programme;
b. fulfilling of any additional requirements necessary to gain admission to the master programme.

Abstract
The Master Programme concludes with the Master Thesis, which has to be done in one of the chosen specialisations and has to be completed within 18 weeks. The Master Thesis is supervised by a professor and shall attest the students ability to work independently and to produce scientifically structured work.

Objective
To work independently and to produce a scientifically structured work.

Content
The topics of the Master Thesis are published by the professors. The Topic can be set also in consultation between the student and the professor.

Master’s Thesis (ONLY for Programme Regulations 2006)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0010-00L</td>
<td>Master’s Thesis ▶️ Only for Civil Engineering MSc, Programme Regulations 2006.</td>
<td>O</td>
<td>24</td>
<td>51D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Only students who fulfill the following criteria are allowed to begin with their master thesis:

a. successful completion of the bachelor programme;
b. fulfilling of any additional requirements necessary to
The Master Programme concludes with the Master Thesis, which has to be done in one of the chosen Majors and has to be completed within 16 weeks. The Master Thesis is supervised by a professor and shall attest the students’ ability to work independently and to produce scientifically structured work.

**Electives**

The entire course programs of ETH Zurich and the University of Zurich are open to the students to individual selection.

**Recommended Electives of Master Programme**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>363-1047-00L</td>
<td>Urban Systems and Transportation</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Köthenbürger, G. Loumeau</td>
</tr>
<tr>
<td>Abstract</td>
<td>The main objective of this course is to provide students with some basic tools to analyze the fundamental economic forces at play in urban systems (i.e., agglomeration and congestion forces), and the role of transport networks in shaping the structure of these systems. Why do urban areas grow or decline? How do transport networks affect the location of individuals and firms? Does the location of a firm determine its productivity? Can transport infrastructure investments reduce economic disparities? These are some of the questions that students should be able to answer after completing the course. It focuses on the formation and development of urban areas, and how transport infrastructure investments can affect the location, size, and composition of such systems.</td>
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<tr>
<td>Objective</td>
<td>The course is organized in three parts. The first part focuses on urban and regional economics. It covers the fundamentals of urban systems, the role of transport networks in shaping their structure, and how transport infrastructure investments can affect location, size, and composition of such systems. The second part explores the planning and pricing of transport networks, focusing on the development of transport networks and the demographic effects of transport networks. The third part integrates the previous two parts and analyzes the interaction between urban systems and transportation. Thereby, the main focus is on understanding economic mechanisms that can lead to changes in the distribution of economic activity. Finally, we broaden the scope of the course and explore related topics. There will be a particular emphasis on the relation between urban systems and fiscal federalism as well as urban environmental policies. Both aspects are important determinants of contemporary developments of urban systems, and as such, deserve our attention.</td>
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<tr>
<td>Content</td>
<td>The course is organized in four parts. It starts with the key observation that economic activity (both in terms of population density and productivity) is unevenly distributed in space. For instance, the share of the population living in urban centers is increasing globally, from 16% in 1900 and 50% in 2000 to about 68% by the year 2050. The goal of the first part is to understand the economic forces at play behind these trends, looking at the effects within and across urban areas. I will also discuss how natural or man-made geographical characteristics (e.g., rivers, mountains, borders, etc.) affect the development of such urban systems. In the second part, I discuss the planning and pricing of transport networks, moving from simple local models to more complex transport models at a global scale. The key aspects include: the first and second best road pricing, the public provision of transport networks, and the demographic effects of transport networks. In the third part, I combine the previous two parts and analyze the interaction between urban systems and transportation. Thereby, the main focus is on understanding economic mechanisms that can lead to changes in the distribution of economic activity. Finally, we broaden the scope of the course and explore related topics. There will be a particular emphasis on the relation between urban systems and fiscal federalism as well as urban environmental policies. Both aspects are important determinants of contemporary developments of urban systems, and as such, deserve our attention.</td>
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<td>Lecture notes</td>
<td>Course slides will be made available to students prior to each class.</td>
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<tr>
<td>Literature</td>
<td>Course slides will be made available to students.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
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<td></td>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<td>Social Competencies</td>
<td>Communication</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>fostered</td>
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<td>Critical Thinking</td>
<td>fostered</td>
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**Course Catalogue of ETH Zurich**

- **Urban Design III**
  - **Number:** 052-0707-00L
  - **Abstract:** Students are introduced to a narrative of ‘Urban Stories’ through a series of three tools driven by social, governance, and environmental transformations in today’s urbanization processes. Each lecture explores one city's spatial and organizational ingenuity born out of a particular place's realities, allowing students to transfer these inventions into a catalog of conceptual tools.
  - **Objective:** How can students of architecture become active agents of change? What does it take to go beyond a building's scale, making design-relevant decisions to the city rather than a single client? How can we design cities with a lack of land, tax base, risk, and resilience, understanding that Zurich is the exception and these other cities are the rule? How can we discover, set rather than follow trends and understand existing urban phenomena activating them in a design process? The lecture series produces a growing catalog of operational urban tools across the globe, considering Governance, Social, and Environmental realities. Instead of limited binary comparing of cities, we are building a catalog of change, analyzing what design solutions cities have been developing informally incrementally over time, why, and how. We look at the people, institutions, culture behind the design and make concepts beyond these tools visible. Students get first-hand information from cities where the chair as a Team has research, worked, or constructed projects over the last year, allowing competent, practical insight about the people and topics that make these places unique. Students will be able to use and expand an alternative repertoire of experiences and evidence-based design tools, go to the conceptual core of them, and understand how and to what extent they can be relevant in other places. Urban Stories is the basic practice of architecture and urban design. It introduces a repertoire of urban design tools to the students to use, test, and start their designs.
  - **Type:** W
  - **ECTS:** 2
  - **Hours:** 2V
  - **Lecturer:** F. T. Salva Rocha Franco
How did cities develop into the cities we live in now? Urban plans, instruments, visions, political decisions, economic reasonings, cultural inputs, and social organization have been used to operate in urban settlements in specific moments of change. We have chosen cities that exemplify how these instruments have been implemented and how they have shaped urban environments. We transcribe these instruments into urban operational tools that we have recognized and collected within existing tested cases in contemporary cities across the globe.

This lecture series will introduce urban knowledge and the way it has introduced urban models and operational modes within different concrete realities, therefore shaping cities. The lecture series translates urban knowledge into operational tools, extracted from cities where they have been tested and become exemplary samples, most relevant for understanding how the urban landscape has taken shape. The tools are clustered in twelve thematic clusters and three tool scales for better comparability and cross-reflection.

The Tool case studies are compiled into a global urbanization toolbox, which we use as typological models to read the city and critically reflect upon it. The presented contents are meant to serve as inspiration for positioning in future professional life and provide instruments for future design decisions.

In an interview with a local designer, we measure our insights against the most pressing design topics in cities today, including inclusion, affordable housing, provision of public spaces, and infrastructure for all.

<table>
<thead>
<tr>
<th>Title</th>
<th>Code</th>
<th>Credits</th>
<th>Semester</th>
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</thead>
<tbody>
<tr>
<td>101-0186-01L</td>
<td>BIM, Parametric Modeling and Digital Construction for Civil Engineers</td>
<td>2</td>
<td>Autumn Semester 2024</td>
</tr>
</tbody>
</table>

Abstract
Practice-oriented introduction to BIM working methods for civil engineers. Advantageous applications compared to 2D/3D, especially for digital construction and parametric modelling.

Objective
In this course students will see what the BIM method entails for a civil engineer and learn how to create a parametric model yourself included associated steel, precast concrete, in-situ concrete, reinforcement and masonry parts based on a practical example. Students will also learn how to automatically create formwork plans, parts lists and data for digital prefabrication and construction sites. They will thus acquire the necessary basis for their future work as engineers and how their work interacts with draughtsmen, designers and master builders in a digital working environment.

Content
- Parametric modeling of steel, precast concrete, in-situ concrete, reinforcement and masonry
- Parametric modelling of connections and joints
- Defining and evaluating concreting stages
- Semi-automatic creation of formwork plans according to size standards
- Automatic export of all necessary models and data for BIM2Field
- Insight into BIM2Field applications "Stake out from model" and "Lay reinforcement based on model".

Lecture notes
Available eLearning material, and three tool scales for better comparability and cross-reflection.

Prerequisites / notice
Basic knowledge of construction detailing in steel and concrete, as taught in the BSc courses for steel and concrete structures, is of advantage.

Competencies
- Method-specific Competencies
  - Media and Digital Technologies
  - Cooperation and Teamwork

<table>
<thead>
<tr>
<th>Competency</th>
<th>W</th>
<th>2K</th>
<th>P. Urech, M. Vollmer</th>
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</thead>
<tbody>
<tr>
<td>052-0715-24L</td>
<td>Topology</td>
<td>2</td>
<td>Autumn Semester 2024</td>
</tr>
</tbody>
</table>

Abstract
The elective course "Topology" in the Autumn Semester 2023 builds on a long standing specialization in the spatial exploration of the landscape. We will embark the participants on a terrain that we shape through our own thoughts and actions, adopting different perceptual perspectives, supported by examples from art, literature, technology and history.

Objective
This elective course gives architecture students the opportunity to further develop their perception of space through a site-specific approach in the field of landscape architecture. The students will learn to use 3D point cloud technology and other spatial sensing technologies in order to analyze complex urban landscape and develop new ways of editing and representing these intertwined spaces.

Content
Students will document and analyze a case-study site to reveal its topological potentials and sensory qualities. This understanding will be fostered by contributions from its entire lifecycle, visible in the physical environment, and non-physical aspects. This imaginary city exists along with its potentials and problems and with the conflicts that have evolved. Knowledge and understanding, along with a critical observation of the actions and policies, are necessary to understand the diversity and instability present in the contemporary city and understand how urban form evolved to its current state.

Lecture notes
Literature will be provided during the course.

Prerequisites / notice
- The course is limited to 20 students (based on available computer stations)
- Students will work in groups of 2
- The lectures will be held in English, assistance in English and German
- The enrolment will be prioritized by the time of inscription and balanced between departments.
<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
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<tr>
<td>Problem-solving</td>
<td>fostered</td>
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<td>Project Management</td>
<td>fostered</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
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<tr>
<td>Cooperation and Teamwork</td>
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<td>Leadership and Responsibility</td>
<td>fostered</td>
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<td>Sensitivity to Diversity</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
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<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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</tbody>
</table>

**Science in Perspective**

*see Science in Perspective: Language Courses ETH/UZH*

*see Science in Perspective: Type A: Enhancement of Reflection Capability*

*Recommended Science in Perspective (Type B) for D-BAUG*

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**Civil Engineering Master - Key for Type**

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
</tr>
</thead>
<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</tbody>
</table>

**Key for Hours**

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
# Biochemistry – Chemical Biology Bachelor

## Core Courses First Year Examination

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0011-02L</td>
<td>General Chemistry (Inorganic Chemistry) I</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>A. Togni</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>Introduction to the chemistry of ionic equilibria: Acids and bases, redox reactions, formation of coordination complexes and precipitation reactions</td>
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<td><strong>Objective</strong></td>
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<td></td>
<td>Understanding and describing ionic equilibria from both a qualitative and a quantitative perspective</td>
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<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>Chemical equilibrium and equilibrium constants, mono- and polyprotic acids and bases in aqueous solution, calculation of equilibrium concentrations, acidity functions, Lewis acids, acids in non-aqueous solvents, redox reactions and equilibration, Galvanic cells, electrode potentials, Nernst equation, coordination chemistry, stepwise formation of metal complexes, solubility</td>
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<td></td>
<td><strong>Lecture notes</strong></td>
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<td></td>
<td>Copies of the course slides as well as other documents will be provided as pdf files via the moodle platform.</td>
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<tr>
<td>529-0011-03L</td>
<td>General Chemistry (Organic Chemistry) I</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>P. Chen</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>Introduction to Organic Chemistry. Classical structure theory, stereochemistry, chemical bonds and bonding, symmetry, nomenclature, organic thermochemistry, conformational analysis, basics of chemical reactions.</td>
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<td><strong>Objective</strong></td>
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<td></td>
<td>Introduction to the structures of organic compounds as well as the structural and energetic basis of organic chemistry.</td>
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<td><strong>Content</strong></td>
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<td>Introduction to the history of organic chemistry, introduction to nomenclature, learning of classical structures and stereochemistry: isomerism, Fischer projections, CIP rules, point groups, molecular symmetry and chirality, topicity, chemical bonding: Lewis bonding model and resonance theory in organic chemistry, description of linear and cyclic conjugated molecules, aromaticity, Huckel rules, organic thermochemistry, learning of organic chemistry reactions, intramolecular interactions.</td>
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<td><strong>Lecture notes</strong></td>
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<td>Unterlagen werden als PDF über die ILIAS-Plattform zur Verfügung gestellt</td>
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<td>Subject-specific Competencies</td>
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<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Self-presentation and Social Influence</td>
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<td>Self-direction and Self-management</td>
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<td>551-0125-00L</td>
<td>Fundamentals of Biology I: From Molecules to the Cell</td>
<td>O</td>
<td>6 credits</td>
<td>5G</td>
<td>J. Vorholt-Zambelli, N. Ban,</td>
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The lecture provides an introduction to the basics of biochemistry and molecular biology as well as evolutionary principles. The focus is on bacteria and archaea under consideration of universal concepts.

Introduction to biochemistry, molecular biology and evolutionary principles

The lecture introduces biochemistry as an interdisciplinary science. Links to physics and chemistry will manifest as biological processes that operate within the laws of thermodynamics and are rooted in elements, molecules and chemical reactions. The transition from geochemistry to biochemistry is discussed and considered in relation to the origin of life. Evolutionary principles are introduced and resulting processes are used as a guiding principle. Unifying concepts in biology are presented, including the structure and function of cellular macromolecules and the ways in which hereditary information is encoded, decoded and replicated. Central principles of universal energy conversion are looked at, starting from redox processes and focusing on bacteria and archaea. Finally, biological processes are put into an ecosystems perspective.

The lecture is divided into different sections:
1. Geochemical perspectives on Earth and introduction to evolution
2. Building blocks of life
3. Macromolecules: Proteins
4. Membranes and transport across the plasma membrane
5. Universal mechanisms of inheritance, transcription and translation
6. Reaction Kinetics, binding equilibria and enzymatic catalysis
7. Essentials of Catabolism
8. Essentials of Anabolism
9. Metabolism and biogeochemical cycling of elements

The newly conceived lecture is supported by scripts. The lecture contains elements of "Brock Biology of Microorganisms", Madigan et al. 15th edition, Pearson und "Biochemistry" (Stryer), Berg et al. 9th edition, Macmillan international.

Concepts and Theories fostered

Techniques and Technologies fostered

Analytical Competencies fostered

Problem-solving fostered

Critical Thinking fostered

Self-awareness and Self-reflection fostered

401-0271-00L Mathematical Foundations I: Analysis A 5 credits O 3V+2U L. Lewark

Abstract Introduction to calculus in one dimension. Building simple models and analysing them mathematically.

Objective Functions of one variable: the notion of a function, of the derivative, the idea of a differential equation, complex numbers, Taylor polynomials and Taylor series. The integral of a function of one variable.

Content Further reading suggestions will be indicated during the lecture.

Literature
- L. Papula: Mathematik für Ingenieure und Naturwissenschaftler (3 Bände), Vieweg
- R. Sperb/M. Akveld: Analysis I (vdf)

Competencies

Subject-specific Competencies Concepts and Theories assessed

Methods and Technologies assessed

Analytical Competencies assessed

Problem-solving fostered

Critical Thinking fostered

Integrity and Work Ethics fostered

Second and Third Year Core Courses

Examination Blocks

Examination Block I

Inorganic Chemistry I

Discussion of syntheses, structures, and general reactivity of coordination compounds of the transition metals (as well as the lanthanides and actinides). Introduction of methods of characterization and physicochemical properties of coordination compounds.

Lecture notes

A (commented) collection of slides and a script will be made available via Moodle.

Literature

**Objective**


**Content**

- Physikalische Chemie I

**Literature**


**Prerequisites / notice**

Voraussetzung: Mathematik I und II, Allgemeine Chemie I und II, Physikalische Chemie I

**Examination Block II**

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<tr>
<td>529-0221-00L</td>
<td>Organic Chemistry I</td>
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<td>3</td>
<td>2V+1U</td>
<td>H. Wennemers</td>
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This course will build upon the basic knowledge of structure and reactivity of organic molecules gained in AC/OCI and AC/OCII. The module aims to provide a wide understanding of the occurrence, synthesis, properties, and reactivity of carbonyl compounds.

**Objective**

The goal of this course is the acquisition of a basic repertoire of synthetic methods including important reactions of aldehydes, ketones, carboxylic acids, and carboxylic acid derivatives. Particular emphasis is placed on the understanding of reaction mechanisms and the correlation between structure and reactivity. A deeper understanding of the concepts presented during the lecture is reached by solving the problems handed out each day and discussed once a week later in the exercise class.
Lecture notes
- The lecture slides, problem sets, and additional documents are provided online. Link: https://wennemers.ethz.ch/education.html

Literature

402-0043-00L

Abstract
Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics of point-like and ridged bodies, periodic motion and mechanical waves.

Objective
The concepts and tools in physics, as well as the methods of an experimental science are taught. The student should learn to identify, communicate and solve physical problems in his/her own field of science.

Content
Mechanics (motion, Newton’s laws, work and energy, conservation of momentum, rotation, gravitation, fluids) Periodic Motion and Waves (periodic motion, mechanical waves, acoustics).

Lecture notes
The lecture follows the book “Physics” by Paul A. Tipler.

Literature
Paul A. Tipler and Gene P. Mosca, Physics (for Scientists and Engineers), W. H. Freeman and Company

Competencies
- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
  - fostered

Method-specific Competencies
- Problem-solving
  - fostered

Personal Competencies
- Critical Thinking
  - fostered

529-0051-00L

Abstract
Introduction into the most important spectroscopical methods and their applications to gain structural information.

Objective
Knowledge about the necessary theoretical background of spectroscopical methods and their practical applications

Content
Application oriented basics of organic and inorganic instrumental analysis and of the empirical employment of structure elucidation methods:
- Mass spectrometry: Ionization methods, mass separation, iso-tope signals, rules of fragmentation, rearrangements.
- NMR spectroscopy: Experimental basics, chemical shift, spin-spin coupling.
- IR spectroscopy: Revisiting topics like harmonic oscillator, normal vibrations, coupled oscillating systems (in accordance to the basics of the related lecture in physical chemistry); sample preparation, acquisition techniques, law of Lambert and Beer, interpretation of IR spectra; Raman spectroscopy.

Lecture notes
Script will be for the production price

Literature
- M. Hesse, H. Meier, B. Zeeh, Spektroskopische Methoden in der organischen Chemie, 5. überarbeitete Auflage, Thieme, Stuttgart, 1995


Prerequisites / notice
Exercises are integrated in the lectures. In addition, attendance in the lecture 529-0289-00 "Instrumental analysis of organic compounds" (4th semester) is recommended.

Exam Block III

Number
551-0307-00L

Title
Molecular and Structural Biology I: Protein Structure and Function

Type
O
ECTS
3
Hours
2V

Lecturers
R. Glockshuber, K. Locher, E. Weber-Ban

Abstract
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

Objective
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

Lecture notes
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.

Literature
Basics:
- Creighton, T.E., Proteins, Freeman, (1993)

Current topics: References will be given during the lectures.

529-0731-00L

Title
Nucleic Acids and Carbohydrates

Note for BSc Biology students: Only one of the two concept courses 529-0731-00 Nucleic Acids and Carbohydrates (autumn semester) or 529-0732-00 Protein and Lipids (spring semester) can be counted for the Bachelor's degree.

Type
O
ECTS
6

Lecturers
K. Lang, M. Frei, P. A. Kast, H. Wennemers

Abstract
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNA; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Objective
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNA; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Content
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNA; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Lecture notes
No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).
Mainly based on original literature, a detailed list will be distributed during the lecture.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

#### Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed

#### Personal Competencies
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

#### Methods and Technologies
- Concepts and Theories: assessed
- Problem-solving: assessed

#### Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed

#### Personal Competencies
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

#### Literature

- Relevant research articles and review papers will be available in the course material.

### Prerequisites / Notice

This is an advanced organic chemistry course. Prior knowledge of organic synthesis, reactions, and mechanisms is required. Familiarity with biochemistry and biology is recommended.

### Laboratory Courses

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<tr>
<td>529-0124-00L</td>
<td>BCB I: General Chemistry</td>
<td>O</td>
<td>6</td>
<td>41P</td>
<td>M. Bezdek, D. Dirin, A. Yakimov</td>
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</table>

Latest online enrolment is 18.09.2023.

Information about the practical course will be given on the first day.

The general chemistry practical course aims at preparing the students for the work in modern chemistry laboratory. The students are trained to behave safely in the laboratory and use chemicals, chemistry glassware, and related equipment to perform and analyze the equilibrium in basic chemical reactions.

The students are expected to gain practical experience with as well as establish understanding of the following concepts and phenomena:

- Safe behavior and safety regulations in chemistry laboratory;
- Best practices in common techniques (purification, recrystallization, distillation, etc.);
- Analysis of measured values (measuring error, average value, error analysis);
- Acid-base-equilibria (strengths of acids and bases, pH- and pKa-values, titrations, buffer systems);
- Precipitation equilibria (gravimetry, potentiometry, conductivity measurements);
- Oxidation state and redox reactions (redox-titrations, galvanic elements);
- Metal complexes (syntheses of complexes, ligand exchange reactions, complexometric titration);
- Qualitative analysis (cation and anion separation, determination of cations and anions).

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 243 of 2653
In the general chemistry practical course students are introduced to the work in chemistry laboratory. During the course they become familiar with common chemistry glassware and related equipment as well as learn basic experimental procedures, such as distillation, recrystallization, purification, digestion etc. Upon the measurements of pH, conductivity, and potential in the course of reactions, students establish the understanding of the chemical equilibrium concept.

Students work with various classes of inorganic compounds and types of chemical reactions, e.g. acid-base, redox, precipitation. They also obtain first experience with the synthesis of metal complexes as well as learn basics of qualitative analysis of an unknown substance.

**Literature**

Moodle Lernplattform

**Prerequisites / notice**

Compulsory: online enrolment latest one week after start of the semester

By enrolling in the laboratory course, students confirm to study all safety information thoroughly and to follow instructions.

**Competencies**

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**Abstract**

Laboratory course in Organic Chemistry for students of “Biochemistry - Chemical Biology”

**Objective**

Introduction into basic techniques used in the organic laboratory. Understanding organic reactions through experiments.

**Content**

**Part I:** Basic operations such as the isolation, purification, and characterization of organic compounds: distillation, extraction, chromatography, crystallization, IR (UV/1H-NMR)-spectroscopy for the identification of the constitution of organic compounds.

**Part II:** Organic reactions: preparative chemistry. From simple, one-step to multi-step syntheses. The syntheses include classic Organic Chemistry as well as methods widely used in a Chemical Biology context.

**Lecture notes**

see [https://bode.ethz.ch/education/bcb-iii/bcb-iii-lab-course.html](https://bode.ethz.ch/education/bcb-iii/bcb-iii-lab-course.html)

**Literature**


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<th>Method-specific Competencies</th>
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<td></td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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</table>

**Block Courses**

Registration for Block courses is mandatory. Please register under https://www.mybioportal.uzh.ch. Registration period: from DATUM

Please note the ETH admission criteria for the admission of ETH students to ETH block courses on the block course registration website under “allocation”.

**Block Courses in the 1st Quarter of the Semester**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>551-1129-00L</td>
<td>Understanding and Engineering Microbial Metabolism</td>
<td>W</td>
<td>6 credits</td>
<td>7P</td>
<td>J. Vorholt-Zambelli</td>
</tr>
</tbody>
</table>

**Abstract**

The focus of this laboratory course is on current research topics related to metabolic engineering and the general understanding of metabolism, particularly in relation to one carbon metabolism. Projects will be carried out in small teams.

**Objective**

The course aims at introducing technologies to investigate bacterial metabolism and key principles of metabolic engineering. The main focus of this block course is on practical work and will familiarize participants with complementary approaches, in particular genetic, biochemical and analytical techniques including metabolomics. Results will be presented by students in scientific presentations. Another goal is to learn how to write a scientific report.
The course and will include topics such as pathway elucidation & engineering and related ongoing research projects in the lab. Experimental work applied during the course will comprise methods such as cloning work & transformation, growth determination, enzyme activity assays, liquid-chromatography mass-spectrometry and dynamic labeling experiments.

The course will include topics such as pathway elucidation & engineering and related ongoing research projects in the lab. Experimental work applied during the course will comprise methods such as cloning work & transformation, growth determination, enzyme activity assays, liquid-chromatography mass-spectrometry and dynamic labeling experiments.

Lecture notes
None

Literature
Will be provided at the beginning of the course.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Techniques and Technologies</td>
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</table>

551-1421-00L The Mechanisms of Natural Transformation in Competent Gram-Negative Bacteria

Number of participants limited to 5.
The enrolment is done by the D-BIOL study administration.

Abstract
Students will carry out defined research projects related to the current research topics of the Hospenthal group. The topics will include protein expression of pilins and/or other competence proteins from Gram-negative bacteria, protein purification using affinity chromatography, crystallisation experiments and analysis of assembled pili by electron microscopy.

Objective
The course should enable students to understand concepts of protein expression, purification and the characterisation of biomolecular interactions. In addition, students will learn some basic principles of X-ray crystallography and electron microscopy.

Content
The students will be tutored in their experimental work by an experienced doctoral student. The course will also include a short lecture delivered by M. Hospenthal, providing the theoretical background for the experimental work. Throughout the course, students will receive exercises that further help to explain the theory of the practical work, as well as literature research tasks.

Participation in the following Hospenthal lab projects will be possible:
- Purification, biophysical characterisation and structure determination of pilins
- Purification, biophysical characterisation and structure determination of proteins and protein complexes involved in natural transformation.

Experimental work on this project involves:
- Cloning and mutagenesis
- Recombinant or endogenous protein production in E. coli or Legionella
- Protein purification by affinity chromatography (other chromatographic purification techniques will also be discussed)
- Protein crystallisation and crystal optimisation
- Visualisation of bacterial pili by electron microscopy (negative stain or cryo electron microscopy)
- DNA binding experiments
- Enzymatic activity measurements
- In silico structural analyses using PyMOL and Chimera

Literature
Any required reading of literature will be discussed at the beginning of the course.

Prerequisites / notice
There are no special requirements for this course.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
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551-0345-00L Mechanisms of Bacterial Pathogenesis

Number of participants limited to 15.
The enrolment is done by the D-BIOL study administration.

Abstract
Research laboratory class in small groups. Research projects on current topics in cellular microbiology and bacterial pathogenesis are assigned to each student.

Objective
Introduction to a current topic in cellular microbiology, molecular genetics of a bacterial pathogen or its interaction with the host's microbiome. Experimental work in the research lab and introduction to the current lab techniques. This includes contributions to the analysis of animal experiment. You will work with the current research literature in bacterial pathogenesis and write a research protocol. Requirement for obtaining the credit points: oral presentation of the research project, a short written exam and evaluation of the research protocol.

Content
Research projects on the model pathogen Salmonella.

Lecture notes
none.

Literature
Literature will be selected with reference to the assigned research project.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 245 of 2653
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

551-0351-00L Membrane Biology

W 6 credits 7P V. Korkhov, U. Kutay, S. C. Zeeman

Number of participants limited to 12.
The enrolment is done by the D-BIOL study administration.

Abstract
The course will introduce the students to the key concepts in membrane biology and will allow them to be involved in laboratory projects related to that broad field. The course will consist of lectures, literature discussions, and practical laboratory work in small groups. Results of the practical projects will be presented during the poster session at the end of the course.

Objective
The aim of the course is to expose the students to a wide range of modern research areas encompassed by the field of membrane biology.

Content
Students will be engaged in research projects aimed at understanding the biological membranes at the molecular, organelar and cellular levels. Students will design and perform experiments, evaluate experimental results, analyze the current scientific literature and understand the relevance of their work in the context of the current state of the membrane biology field.

Lecture notes
No script

Literature
The recommended literature, including reviews and primary research articles, will be provided during the course.

Prerequisites / notice
The course will be taught in English. All general lectures will be held at ETH Hoenggerberg. Students will be divided into small groups to carry out experiments at ETH or at the Paul Scherrer Institute. Travel to the Paul Scherrer Institute will be by public transportation.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

551-0359-00L Plant Biochemistry

W 6 credits 7P S. C. Zeeman, B. Pfister

Number of participants limited to 11.
The enrolment is done by the D-BIOL study administration.

Abstract
In this block course, students actively participate in ongoing research projects in plant metabolism and plant cell biology, supervised by PhD students and postdoctoral fellows in small groups. The research background is discussed in Journal Clubs. At the end of the course, students present their projects and results in an interactive poster session.

Objective
Students are able to independently apply and record current molecular biology methods on plants, critically evaluate and communicate the results, understand the larger context of their research project and develop ideas for further experiments.

Content
Projects are newly designed each year and announced a few days before the course starts. Possible projects include the cell biology of starch granule formation (using fluorescence and electron microscopy and protein-protein interaction studies) or RNA metabolism in chloroplasts (using import assays and RNA detection).

Lecture notes
No script

Literature
Descriptions of the possible projects including individual reading suggestions will be handed out beforehand.
### Single Molecule Biophysics Studies of the Microtubule Cytoskeleton

**Abstract**
This laboratory course has a focus on current research topics in our laboratory related to microtubule nucleation and dynamics and its investigation using in vitro reconstitutions and single molecule biophysics. Projects will be conducted in small groups.

**Objective**
The course aims to introduce technologies to investigate cytoskeletal processes and regulation using in vitro reconstitutions and single molecule biophysics methods. The main focus of this block course is on practical work and will familiarize participants with complementary approaches, in particular protein purification and biophysical techniques including single molecule fluorescence imaging using Total Internal Reflection Fluorescence Microscopy (TIRFM) and subsequent image analysis methods. Results will be presented by students in scientific presentations. Another goal is to learn how to write a scientific report.

**Content**
The course will include topics such as microtubule polymerization dynamics and related ongoing research projects in the lab. Experimental work applied during the course will comprise methods such as cloning work & transformation, protein purification, single molecule fluorescence imaging using Total Internal Reflection Fluorescence Microscopy (TIRFM), and single molecule image analysis.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: fostered

#### Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: assessed

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### Genetic Code Expansion for Studying Posttranslational Modifications

**Abstract**
In this block course we will prepare proteins bearing site-specifically installed post-translational modifications using genetic code expansion. The impact of the post-translational modifications on enzymatic activity and protein-protein interactions will be studied.

**Objective**
Students will learn basic techniques for genetic code expansion. They will learn how to synthesize non-canonical amino acids (ncAAs), manipulate plasmids through cloning techniques to introduce an amber codon at a user defined site in a gene of interest, express and purify recombinant proteins bearing site-specific ncAAs using state-of-the-art chromatographic techniques, characterize the target protein using mass spectrometry and analyze the properties of the target protein regarding enzymatic activity and protein-protein interactions using biophysical techniques.

After the course, participants should be able to apply the gained skills in future chemical and molecular biology lab courses and projects. Individual reports describing the experiments and obtained results must be prepared by the end of the course. At the end of the course, each team (consisting of two participants each) will present their results in an oral presentation.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories: fostered
- Techniques and Technologies: fostered

#### Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: fostered
- Project Management: fostered

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered
Adaptability and Flexibility

Research project on bacteria that produce bioactive natural products (e.g., Streptomycetes, Cyanobacteria, uncultivated bacteria). The participants will work in teams of two, will first synthesize different ncAAs mimicking PTMs, such as acylated lysine derivatives (e.g., acetylisylines, butyrylisylines etc.). These ncAAs will be incorporated into target proteins using orthogonal aminoacyl tRNA synthetase / tRNA pairs, which direct the site-specific incorporation in response to an in frame introduced amber stop codon (amber suppression). Therefore, the participants will introduce the amber stop codon at different positions in the gene of interest using standard molecular cloning techniques. After recombinant expression of the target protein, the participants will isolate the ncAA-bearing target proteins using different chromatography techniques using a FPLC system. After characterization of the PTM-bearing protein using mass spectrometry, the participants will study the impact of the PTM on enzymatic activity and protein-protein interactions using biophysical techniques.

Block Courses in the 3rd Quarter of the Semester

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0739-01L</td>
<td>Biological Chemistry B: New Enzymes from Directed Evolution Experiments</td>
<td>W</td>
<td>6 credits</td>
<td>7P</td>
<td>P. A. Kast, M. Levasseur</td>
</tr>
</tbody>
</table>

**Number of participants limited to 12.**

*The enrolment is done by the D-BIOL study administration.*

**Abstract**

During this block course, the participants will study the impact of different post-translational modifications (PTMs) on protein function using genetic code expansion. The participants will work in teams of two, will first synthesize different ncAAs mimicking PTMs, such as acylated lysine derivatives (e.g., acetylisylines, butyrylisylines etc.). These ncAAs will be incorporated into target proteins using orthogonal aminoacyl tRNA synthetase / tRNA pairs, which direct the site-specific incorporation in response to an in frame introduced amber stop codon (amber suppression). Therefore, the participants will introduce the amber stop codon at different positions in the gene of interest using standard molecular cloning techniques. After recombinant expression of the target protein, the participants will isolate the ncAA-bearing target proteins using different chromatography techniques using a FPLC system. After characterization of the PTM-bearing protein using mass spectrometry, the participants will study the impact of the PTM on enzymatic activity and protein-protein interactions using biophysical techniques.

**Objective**

All technologies used for the experiments will be explained to the students in theory and in practice with the goal that they will be able to independently apply them for the course project and in future research endeavors. After the course, an individual report about the results obtained has to be prepared.

**Literature**

A script will be distributed to the participants on the first day of the course. General literature to "Directed Evolution" and chorismate mutases, e.g.:


Further literature will be indicated in the distributed script.

**Prerequisites / notice**

This laboratory block course is designed for 3 weeks, 3.5 days. Students should have basic practical knowledge in organic synthesis, molecular cloning, protein expression and purification (participants must have attended the practical course BCB-IV prior to this block course). The maximum number of participants is currently limited to 8. Interested applicants may contact Dr. M. Fottner for further information. Commitment for attendance of entire course is necessary. The course cannot be interrupted by individual absences once started.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>551-1147-00L</td>
<td>Bioactive Natural Products from Bacteria</td>
<td>W</td>
<td>6 credits</td>
<td>7P</td>
<td>J. Piel</td>
</tr>
</tbody>
</table>

*Number of participants limited to 8.*

*The enrolment is done by the D-BIOL study administration.*

**Abstract**

During this block course, the participants will study the impact of different post-translational modifications (PTMs) on protein function using genetic code expansion. The participants will work in teams of two, will first synthesize different ncAAs mimicking PTMs, such as acylated lysine derivatives (e.g., acetylisylines, butyrylisylines etc.). These ncAAs will be incorporated into target proteins using orthogonal aminoacyl tRNA synthetase / tRNA pairs, which direct the site-specific incorporation in response to an in frame introduced amber stop codon (amber suppression). Therefore, the participants will introduce the amber stop codon at different positions in the gene of interest using standard molecular cloning techniques. After recombinant expression of the target protein, the participants will isolate the ncAA-bearing target proteins using different chromatography techniques using a FPLC system. After characterization of the PTM-bearing protein using mass spectrometry, the participants will study the impact of the PTM on enzymatic activity and protein-protein interactions using biophysical techniques.

**Objective**

Introduction to relevant subjects of the secondary metabolism of bacteria. Training in practical work in a research laboratory. Scientific writing in form of a research report.

**Content**

Research project on bacteria that produce bioactive natural products (e.g., Streptomycetes, Cyanobacteria, uncultivated bacteria). The techniques used will depend on the project, e.g. PCR, cloning, natural product analysis, precursor feeding studies, enzyme expression and analysis.
The course is divided between lectures and practical work in the lab. The lectures will introduce the general topic of amyloids and in particular:

- Part I: Molecular interactions, concepts of polymer physics, spectroscopic methods
- Part II: Polymer types in biology - proteins, DNA/RNA

Students will learn concepts and methods for analyzing complex ‘omics’ datasets and applying them in individual projects. To facilitate learning, the course includes lectures on functional genomics, metagenomics and microbiology, along with practical sessions on scientific programming to analyze and visualize biological data. Additionally, students will learn how to plan, execute, report on, and present a scientific project.

Prerequisites / notice
Participants should bring their own laptop computer. Basic knowledge in [R], Python and/or UNIX is required.

Competencies

- Subject-specific Competencies:
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies:
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management
- Social Competencies:
  - Communication
  - Cooperation and Teamwork
  - Leadership and Responsibility
  - Self-presentation and Social Influence
- Personal Competencies:
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

Literature

- Jacob N. Israelachvili “Intermolecular and Surface Forces” Elsevier Third edition 2011
- M. Rubinstein and R.H. Colby “Polymer Physics” Oxford Press 2003; Große Auswahl an Fachbüchern und Forschungsartikeln

Block Courses in the 4th Quarter of the Semester

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0053-00L</td>
<td>Polymer Physics Methods for Unstructured Biomolecules</td>
<td>W</td>
<td>6</td>
<td>7G</td>
<td>M. Yulikov, L. Galazzo, G. Jeschke</td>
</tr>
<tr>
<td>529-0019-00L</td>
<td>Characterization of the Aggregation Landscape of Peptide Amyloids and their Chemical Templating</td>
<td>W</td>
<td>6</td>
<td>7P</td>
<td>R. Riek, J. Greenwald</td>
</tr>
</tbody>
</table>

Enrollment limited to 6.

Short peptide amyloids are models for their more complex protein counterparts in the study of disease-related and functional aggregation as well as being interesting in their own right as molecules that may have played a role in the origin of life. This block course will allow the students to study novel peptides in order to characterize their aggregation landscape and also to assess the ability of short peptide amyloids to template their own chemical synthesis.

The course is divided between lectures practical work in the lab. The lectures will introduce the general topic of amyloids and in particular their potential role in the origin of molecular complexity, as well as cover the theory and the practice behind the tools that are used to characterize peptide amyloids. The practical work in the lab will allow the students to gain hands-on experience working on a novel peptide that has yet to be characterized. Since the course consists of genuine research we also hope that new discoveries will be made that will provide insights into the role that amyloids may have played in the origin of life.

A script will be distributed to the participants on the first day of the course.

Further literature will be indicated in the distributed script.

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Assessed

Subject-specific Competencies
- Assessed

Method-specific Competencies
- Assessed

Social Competencies
- Assessed

Personal Competencies
- Assessed

Prerequisites / notice
- The course will be taught in English.

Objective
- The students will obtain an overview about the diversity of current RNA-research. They will learn to design experiments and use techniques necessary to analyze different aspects of RNA biology. Through lectures and literature seminars, they will learn about the burning questions of RNA research and discuss approaches to address these questions experimentally. In practical lab projects the students will work in one of the participating laboratories. Finally, they will learn how to present and discuss their data in an appropriate manner. Student assessment is graded semester performance based on individual performance in the laboratory, the written exam and the poster presentation.

Literature
- Documentation and recommended literature will be provided at the beginning and during the course.
- Literature
- Lecture notes

Abstract
- Introduction to the diversity of current RNA-research at all levels from structural biology to systems biology using mainly model systems like S. cerevisiae (yeast), mammalian cells.

Method-specific Competencies
- Analytical Competencies
  - assessed
- Decision-making
  - fostered
- Media and Digital Technologies
  - fostered
- Problem-solving
  - assessed

Social Competencies
- Communication
  - assessed
- Cooperation and Teamwork
  - assessed
- Leadership and Responsibility
  - fostered

Personal Competencies
- Adaptability and Flexibility
  - assessed
- Creative Thinking
  - fostered
- Critical Thinking
  - assessed
- Self-direction and Self-management
  - fostered

551-1417-00L In Vivo Cryo-EM Analysis of Dynein Motor Proteins

Number of participants limited to 5.

The enrolment is done by the D-BIOL study administration.

Abstract
- Motor proteins convert chemical energy into mechanical motion. In this block course, we study dynein motor proteins in cilia. Dynein causes conformational change upon ATP hydrolysis and finally generate cilary bending motion. Participants will analyze cryo-EM data of cilia and visualize in vivo 3D structure of dynein to learn how motor proteins function in the cell.

Objective
- The goal of this course is to familiar with structural biology techniques of cryo-electron tomography and single particle cryo-EM studies on motor proteins. The main focus is 3D image analysis of cryo-EM datasets acquired by highest-end microscopes. Participants will learn structure-function relationship at various scales: how the conformational change of motor proteins causes mechanical force and generates cellular motility.

Content
- Motor proteins, such as dynein, myosin and kinesin, hydrolyze ATP to ADP and phosphate to convert chemical energy to mechanical motion. Their function is essential for intracellular transport, muscle contraction and other cellular motility as well as cell division. Motor proteins have been major targets of biophysical studies. There exist questions from atomic to tissue levels – how ATP hydrolysis causes conformational change of motor proteins; how their motion is regulated by calcium, phosphorylation and other factors; how motions of multiple motor proteins are coordinated to generate cellular motility. Structural biology has been playing central roles to answer these questions. X-ray crystallography and single particle cryo-EM address structural analysis at atomic resolution and try to reveal molecular mechanism of conformational change. Cryo-electron tomography analyze localization and 3D structure of motor proteins in the cell to explain how motions of molecular motors happen in the context of cellular environment and are integrated into cellular motion.

In this course, we study dyneins in cilia. Cilia are force-generating organelles, made by nine microtubules and thousands of dyneins. Dynein hydrolyzes ATP and undergoes conformational change, generating linear motion with respect to the microtubule. As a whole system, cilia integrate motions of these dyneins and orchestrate beating motion. To explain cilary motion at molecular level, we need to know dynein conformational change in the cellular context. Cryo-electron tomography is recently developed technique to study molecular structures in vivo and therefore a suitable method to study dynein in cilia. Recently spatial resolution of these cryo-EM techniques was dramatically improved, driven by development of new types of detectors and electron optics.

The participants of this course will learn a program to analyze cryo-electron tomography and single particle cryo-EM data, acquired by highest-end electron microscopes and detectors in ETH and other places, and reconstruct 3D structure (tomogram) of cilia from various organisms (from green algae to human). They will further learn a program to study molecular structures from these tomograms (called subtomogram averaging) and apply it to reconstruct high-resolution 3D structure of dyneins, microtubules and regulatory proteins. This practical course is therefore mainly computational, but we will also provide students a chance of cilia preparation from green algae, cryo-EM data collection using an electron microscope in PSI and site-visit of highest-end electron microscope facility in ETH.

Lecture notes
- Scripts will be distributed during the course.

Literature
- An overview is given in the following review articles. Further literature will be indicated during the course.

Block Courses in the 1st Half of the Semester

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0810-01L</td>
<td>Laboratory Course Organic Chemistry II</td>
<td>W</td>
<td>12</td>
<td>14P</td>
<td>C. Thilgen</td>
</tr>
</tbody>
</table>

Abstract
- An organic-synthetic sub-project of the current research of a group from the Laboratory of Organic Chemistry is carried out under the guidance of doctoral students.

Objective
- Motor proteins convert chemical energy into mechanical motion. In this block course, we study dynein motor proteins in cilia. Dynein causes conformational change upon ATP hydrolysis and finally generate cilary bending motion. Participants will analyze cryo-EM data of cilia and visualize in vivo 3D structure of dynein to learn how motor proteins function in the cell.

Content
- Assessed

Lecture notes
- No course notes.

Literature
- No set textbooks. Literature will be indicated or provided by the supervising tutors.
Prerequisites / notice
Course prerequisites: Accomplished laboratory course Organic Chemistry I (529-0229-00 or 529-0016-00) and passed session exams Organic Chemistry I (529-0221-00 or 529-1011-00) / Organic Chemistry II (529-0222-00 or 529-1012-00). The number of participants per course is limited to 4.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

►► Block Courses in the 2nd Half of the Semester

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0810-01L</td>
<td>Laboratory Course Organic Chemistry II</td>
<td>W</td>
<td>12 credits</td>
<td>14P</td>
<td>C. Thilgen</td>
</tr>
</tbody>
</table>
- Admittance is limited and depends on the availability of hosting research labs.
- Interested students are asked to contact Prof. C. Thilgen (thilgen@org.chem.ethz.ch) before the end of the preceding semester for further details.
- In case of admittance, the actual enrolment needs to be done via the D-BIOL study administration.

Abstract
An organic-synthetic sub-project of the current research of a group from the Laboratory of Organic Chemistry is carried out under the guidance of doctoral students.

Objective
Learn to plan and carry out challenging multistep syntheses making use of modern methods; reach a deeper understanding of organic reactions through experimental work; develop an organic-synthetic research project; take accurate notes, write a publication style report, and present the obtained results in a seminar.

Content
An organic-synthetic sub-project of the current research of a group from the Laboratory of Organic Chemistry is carried out under the guidance of doctoral students.

Lecture notes
No course notes.

Literature
No set textbooks. Literature will be indicated or provided by the supervising tutors.

Prerequisites / notice
Course prerequisites: Accomplished laboratory course Organic Chemistry I (529-0229-00 or 529-0016-00) and passed session exams Organic Chemistry I (529-0221-00 or 529-1011-00) / Organic Chemistry II (529-0222-00 or 529-1012-00). The number of participants per course is limited to 4.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
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Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
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Integrity and Work Ethics fostered
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► Electives

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<tr>
<td>535-0230-00L</td>
<td>Medicinal Chemistry I</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>J. Hall</td>
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</table>

Abstract
The lectures give an overview of selected drugs and the molecular mechanisms underlying their therapeutic effects in disease. The historical and modern-day methods by which these drugs were discovered and developed are described. Structure-function relationships and the biophysical rules underlying ligand-target interactions will be discussed and illustrated with examples.

Objective
Basic understanding of therapeutic agents with respect to molecular, pharmacological and pharmaceutical properties.

Content
Molecular mechanisms of action of drugs. Structure function and biophysical basis of ligand-target interactions

Lecture notes
Will be provided in parts before each individual lecture.

Literature
Inorganic Chemistry III: Organometallic Chemistry and Homogeneous Catalysis

Abstract
Fundamental aspects of the organometallic chemistry of the transition elements. Mechanistic homogeneous catalysis including oxidative additions, reductive eliminations and insertion reactions. Catalytic hydrogenation, carboxylation, C-C bond-forming and related reactions.

Objective
Towards an understanding of the fundamental coordination-chemical and mechanistic aspects of transition-metal chemistry relevant to homogeneous catalysis.

Content
Fundamental aspects of the organometallic chemistry of the transition elements. Mechanistic homogeneous catalysis including oxidative additions, reductive eliminations and insertion reactions. Catalytic hydrogenation, carboxylation, C-C bond-forming and related reactions.

551-0319-00L Cellular Biochemistry (Part I)

Abstract
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.
Content
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes. Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Lecture notes
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Prerequisites / notice
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Self-direction and Self-management</td>
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551-1299-00L Bioinformatics

Abstract
Students will study bioinformatic concepts in the areas of metagenomics, genomics, transcriptomics, proteomics, biological networks and biostatistics. Through integrated lectures, practical hands-on exercises and project work, students will also be trained in analytical and programming skills to meet the emerging increase in data-driven knowledge generation in biology in the 21st century.

Objective
Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

Prerequisites / notice
Course participants have already acquired basic programming skills in UNIX, Python and R. Students bring their own computer with keyboard, internet access (browser) and software to connect to the ETH network via VPN.

Competencies

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529-0231-00L Organic Chemistry III: Introduction to Asymmetric Synthesis

Abstract
Methods of Asymmetric Synthesis

Objective
Understanding of the basic principles of diastereoselective synthesis

Content
Conformational analysis: acyclic and cyclic systems; Diastereoselective sigmatropic rearrangements; Diastereoselective Carbonyl addition reactions: Cram- and Felkin-Anh models, carbonyl Lewis acid interactions, chelate controlled reactions; chemistry of enolates, selective formation; asymmetric enolate alkylation; aldol reactions, allyl- and crotyl-metal chemistry; cyclisations, Baldwin rules; Diastereoselective olefin functionalization: hydroboration, dihydroxylation, epoxidation.

Literature

Evans’ Problems in Organic Chemistry App

Competencies

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Science in Perspective

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-
## Language Courses

*see Science in Perspective: Language Courses ETH/UZH*

<table>
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<tr>
<th>Key for Type</th>
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<tr>
<td>W</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<td>Dr</td>
<td>Suitable for doctorate</td>
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<td>O</td>
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<td>W+</td>
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### Key for Hours

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<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

### ECTS

- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.

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## Core Subjects

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>529-0733-02L</td>
<td>Chemical Biology and Synthetic Biochemistry</td>
<td>O</td>
<td>6</td>
<td>3G</td>
<td>K. Lang, M. Fottner</td>
</tr>
</tbody>
</table>

### Abstract
Overview of modern chemical biology and synthetic biochemistry techniques, focussed on protein modification and labeling and on methods to endow proteins with novel functionalities.

### Objective
A) Recall different possibilities for modifying proteins in vitro and in vivo and their applications in a biological context,
B) Understand the chemical and biochemical consequences of modifications and assess the different reaction possibilities in the context of in vivo - in vitro,
C) Critically analyze and assess current chemical biology articles
D) Question the approaches learned and apply them to new biological problems.

### Content
- Principles of protein labeling and protein modification (fluorescent proteins, enzyme-mediated labeling, bioorthogonal chemistries)
- Directed evolution and protein engineering
- Chemical biology of ubiquitin and targeted protein degradation

### Lecture notes
A script will not be handed out. Handouts to the lecture will be provided through moodle.

### Literature
Citations from the original literature relevant to the individual lectures will be assigned during the lectures.

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<tr>
<th>Number</th>
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<td>529-0240-00L</td>
<td>Chemical Biology - Peptides</td>
<td>O</td>
<td>6</td>
<td>3G</td>
<td>H. Wennemers</td>
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</table>

### Abstract
An advanced course on the synthesis, properties and function of peptides in chemistry and biology.

### Objective
Knowledge of the synthesis, properties and function of peptides in chemistry and biology.

### Content
- Advanced peptide synthesis, conformational properties, combinatorial chemistry, therapeutic peptides, peptide based materials, peptides in nanotechnology, peptides in asymmetric catalysis.

### Lecture notes
Citations from the original literature relevant to the individual lectures will be assigned weekly.

### Literature

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<table>
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<tr>
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<td>529-0241-10L</td>
<td>Selectivity in Organic Synthesis</td>
<td>O</td>
<td>6</td>
<td>3G</td>
<td>J. W. Bode</td>
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</table>

### Abstract
Fundamentals of selective organic reactions, including current and historical examples of enantioselectivity, regioselectivity, chemoselectivity. Further aspects include recent developments in catalysis, strategies and tools for selective organic synthesis.

### Objective
Understanding and explaining the origin of selectivity in organic synthesis and the application of selective organic reactions to the construction of complex organic and biological molecules.

### Content
Fundamental concepts and recent advances for the selective synthesis of complex organic molecules, including natural products, pharmaceuticals, and biological molecules. Key concepts include the development of enantioselective and regioselective catalysts, the identification of new reaction mechanisms and pathways, and technological advances for facilitating the synthesis of organic molecules. Analysis of key primarily literature including identification of trends, key precendents, and emerging topics will be emphasized.

### Lecture notes
will be provided in class and online

### Literature
ECTS

Polymerization reactions and processes. Homogeneous and heterogeneous (emulsion) kinetics of free radical polymerization. Post
Transition Metal Catalysis: From Mechanisms to
Analytical Competencies
assessed

Subject-specific Competencies
Concepts and Theories assessed

Method-specific Competencies
Analytical Competencies assessed

Media and Digital Technologies fostered

Problem-solving assessed

Project Management fostered

Social Competencies
Communication assessed

Cooperation and Teamwork fostered

Customer Orientation fostered

Leadership and Responsibility fostered

Self-presentation and Social Influence fostered

Sensitivity to Diversity fostered

Personal Competencies
Negotiation fostered

Adaptability and Flexibility assessed

Creative Thinking assessed

Critical Thinking assessed

Integrity and Work Ethics fostered

Complementary Courses

Compensatory courses can be used to compensate for core subjects that have been failed twice. The assignment of the corresponding course units to
the regulatory category “core subjects and compensatory courses” in the transcript of records is only made upon application by the student to the study administration office of the degree programme.

<table>
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<tr>
<th>Number</th>
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<td>529-0615-01L</td>
<td>Biochemical and Polymer Reaction Engineering</td>
<td>W</td>
<td>6</td>
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<td>P. Arosio, P. Fleckenstein</td>
</tr>
<tr>
<td>Objective</td>
<td>The aim of the course is to learn how to design polymerization reactors and bioreactors to produce polymers and proteins with the specific product qualities that are required by different applications in chemical, pharmaceutical and food industry. This activity includes the post-treatment of polymer latexes, the downstream processing of proteins and the analysis of their colloidal behavior.</td>
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<tr>
<td>Content</td>
<td>We will cover the fundamental processes and the operation units involved in the production of polymeric materials and proteins. In particular, the following topics are discussed: Overview on the different polymerization processes, Kinetics of free-radical polymerization and use of population balance models. Production of polymers with controlled characteristics in terms of molecular weight distribution. Kinetics and control of emulsion polymerization. Surfaceactive and colloidal stability. Aggregation kinetics and aggregate structure in conditions of diffusion and reaction limited aggregation. Modeling and design of colloid aggregation processes. Physico-chemical characterization of proteins and description of enzymatic reactions. Operation units in bioprocessing: upstream, reactor design and downstream. Industrial production of therapeutic proteins. Characterization and engineering of protein aggregation. Protein aggregation in biology and in biotechnology as functional materials.</td>
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<tr>
<td>Lecture notes</td>
<td>Scripts are available on the web page of the Arosio-group: <a href="http://www.arosiogroup.ethz.ch/education.html">http://www.arosiogroup.ethz.ch/education.html</a> Additional handout of slides will be provided during the lectures.</td>
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<td>529-0243-01L</td>
<td>Transition Metal Catalysis: From Mechanisms to Applications</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>B. Morandi</td>
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<tr>
<td>Abstract</td>
<td>Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint</td>
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<tr>
<td>Objective</td>
<td>Understanding and critical evaluation of current research in transition metal catalysis. Design of mechanistic experiments to elucidate reaction mechanisms. Synthetic relevance of transition metal catalysis. Students will also learn about writing an original research proposal during a workshop.</td>
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<tr>
<td>Content</td>
<td>Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint. Synthetic applications of these reactions. Introduction and application of tools for the elucidation of mechanisms. Selected examples of topics include: C-H activation, C-O activation, C-C activation, redox active ligands, main group redox catalysis, bimetallic catalysis.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture slides will be provided online. A Handout summarizing important concepts in organometallic and physical organic chemistry will also be provided. Useful references and handouts will also be provided during the workshop. Slides will be uploaded 1-2 days before each lecture on <a href="http://morandi.ethz.ch/education.html">http://morandi.ethz.ch/education.html</a></td>
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<tr>
<td>Literature</td>
<td>Primary literature and review articles will be cited during the course.</td>
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<td>The following textbooks can provide useful support for the course:</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Required level: Courses in organic and physical chemistry (kinetics in particular) of the first and second year as well as ACI and III</td>
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Electives

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>535-0030-00L</td>
<td>Pharmaceutical Immunology II &amp; Therapeutic Proteins</td>
<td>W</td>
<td>3</td>
<td>3G</td>
<td>C. Halin Winter, D. Neri</td>
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<tr>
<td>Prerequisites: Either 535-0830-00L Pharmaceutical Immunology I or 551-0317-00L Immunology I must have been taken.</td>
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Abstract
In this course, various topics related to the development, GMP production and application of therapeutic proteins will be discussed. Furthermore, students will expand their training in pharmaceutical immunology and will be introduced to the basic concepts of pharmaceutical product quality management.

Objective
Students know and understand:
- basic mechanisms and regulation of the immune response
- the pathogenic mechanisms of the most important immune-mediated disorders
- the concepts of vaccination and cancer immunotherapy
- the most frequently used expression systems for the production of therapeutic proteins
- the use of protein engineering tools for modifying different features of therapeutic proteins
- the mechanism of action of selected therapeutic proteins and their application
- basic concepts in the GMP production of therapeutic proteins

Content
The course consists of two parts:

1. In the first part, students will complete their training in Pharmaceutical Immunology. This part particularly focuses on the pathogenic mechanisms of immune-mediated diseases, vaccination and cancer immunotherapy. Deepened knowledge of immunology will be relevant for understanding the mechanism of action of many therapeutic proteins, as well as for understanding one major concern related to the use of protein-based drugs, namely, immunogenicity.

2. The second part focuses on topics related to the development and application of therapeutic proteins, such as protein expression, protein engineering, reducing immunogenicity, and GMP production of therapeutic proteins. Furthermore, selected examples of approved therapeutic proteins will be discussed.

Literature
- Janeway's Immunobiology, by Kenneth Murphy (9th or 10th Edition)
- Lecture Handouts
- Paper References provided in the Scripts
- EMEA Dossier for Humira

Prerequisites / notice
Prerequisites: Either 535-0830-00L Pharmaceutical Immunology I or 551-0317-00L Immunology I

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
Method-specific Competencies
- Analytical Competencies
- Problem-solving
Social Competencies
- Communication
Personal Competencies
- Critical Thinking

535-0230-00L Medicinal Chemistry I

Abstract
The lectures give an overview of selected drugs and the molecular mechanisms underlying their therapeutic effects in disease. The historical and modern-day methods by which these drugs were discovered and developed are described. Structure-function relationships and the biophysical rules underlying ligand-target interactions will be discussed and illustrated with examples.

Objective
Basic understanding of therapeutic agents with respect to molecular, pharmacological and pharmaceutical properties.

Content
Molecular mechanisms of action of drugs. Structure function and biophysical basis of ligand-target interactions

Lecture notes
Will be provided in parts before each individual lecture.

Literature

Prerequisites / notice
Requirements: Knowledge of physical and organic chemistry, biochemistry and biology.

Competencies
- Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Method-specific Competencies
- Project Management
- Social Competencies
- Leadership and Responsibility
- Personal Competencies
- Self-awareness and Self-reflection

551-0313-00L Microbiology (Part I)

Abstract
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Objective
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacteriology, cell structure, genetics, metabolism, symbiosis and pathogenesis.

Content
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Lecture notes
Updated handouts will be provided during the class.

Literature
Current literature references will be provided during the lectures.

Prerequisites / notice
English
The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

529-0041-00L Modern Mass Spectrometry, Hyphenated Methods, and Chemometrics

Abstract
Modern mass spectrometry, hyphenated analytical methods, speciation, chemometrics.

Objective
Comprehensive knowledge about the analytical methods introduced in this course and their practical applications.

Content
Hyphenation of separation with identification methods such as GC-MS, LC-MS, GC-IR, LC-IR, LC-NMR etc.; importance of speciation.
Modern mass spectrometry: time-of-flight, orbitrap and ion cyclotron resonance mass spectrometry, ICP-MS. Soft ionization methods, desorption methods, spray methods. Mass spectrometry imaging.
Use of statistical and computer-assisted methods for processing analytical data (chemometrics).

Lecture notes
Lecture notes will be made available online.

Literature
Information about relevant literature will be available in the lecture & in the lecture notes.

Prerequisites / notice
Exercises are an integral part of the course. Prerequisites:
529-0051-00 "Analytische Chemie I (3. Semester)"
529-0058-00 "Analytische Chemie II (4. Semester)" (or equivalent)
551-1299-00L Bioinformatics

Abstract
Students will study bioinformatic concepts in the areas of metagenomics, genomics, transcriptomics, proteomics, biological networks and biostatistics. Through integrated lectures, practical hands-on exercises and project work, students will also be trained in analytical and programming skills to meet the emerging increase in data-driven knowledge generation in biology in the 21st century.

Objective
Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

Prerequisites / notice
Course participants have already acquired basic programming skills in UNIX, Python and R.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

551-0319-00L Cellular Biochemistry (Part I)

Abstract
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Content
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Lecture notes
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Literature
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

551-0309-00L Concepts in Modern Genetics

Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIC348 at UZH.
Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html

### Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

### This course focuses on the concepts of classical and modern genetics and genomics.

### The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

### Scripts and additional material will be provided during the semester.

### Introduction into structural and functional aspects of the immune system.

### Basic knowledge of the mechanisms and the regulation of an immune response.

### - Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histocompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

### Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"

### - Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020

### For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

### The lecture conveys the fundamental concepts underlying multicellularity with an emphasis on the molecular basis of multicellular biological systems and their functional integration into coherent wholes. The structural and functional specialization in multicellular organisms will be discussed by highlighting common and specific functions in fungi, plants, and animals (including humans).

### 1. Students can describe advantages and challenges associated with being multicellular and outline independent solutions that organisms have developed to cope with the challenges of complex multicellularity.

### 2. Students can explain how the internal and external structures of fungi, plants and animals function to support survival, growth, behavior, and reproduction.

### 3. Students can explain the basic pathways and mechanisms of cellular communication regulating cellular behavior (cell adhesion, metabolism, proliferation, reproduction, development).

### 4. Students can describe how a single cell develops from one cell into many, each with different specialized functions.
Content

The lecture introduces the structural and functional specialization in fungi, plants and animals, including humans. After providing an overview on the diversity of eukaryotic organisms, the lecture will discuss how fungi, plants, animals and humans have evolved structures and strategies to cope with the challenges of multicellularity. The molecular basis underlying communication, coordination and differentiation will be conveyed and complemented by key aspects of reproduction, metabolism development, and regeneration. Topics include form and function of fungi and plants, human anatomy and physiology, metabolism, cell signaling, adhesion, stem cells, regeneration, reproduction, and development.

Literature

Campbell “Biology”, 11th Edition

Prerequisites / notice

Some lecture are held in English.

Competencies

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</table>

Abstract

The course will introduce students to a selected set of laboratory techniques that are foundational to modern biological research.

Objective

For each of the techniques covered in the course, the students will be able to explain:

a) the physical, chemical and biological principles underlying the technique,
b) the requirements for the sample,
c) the type of raw data collected by the technique,
d) the assumptions and auxiliary information used in the interpretation of the data and
e) how these data can be used to answer a given biological question.

By the end of the course the students will be able to select the appropriate experimental technique to answer a given biological problem and will be able to discuss the advantages and limitations of individual techniques as well as how different techniques can be combined to gain a more complete understanding of a given biological questions.

Content

The course will be based on a combination of lectures, self-study elements and exercises.

The focus will be on the following experimental techniques:

- DNA sequencing
- chromatography
- mass-spectrometry
- UV/Vis and fluorescence spectrometry
- light microscopy
- electron microscopy
- X-ray crystallography
- NMR spectroscopy

Lecture notes

The course is supported by a Moodle page that gives access to all supporting materials necessary for the course.

Competencies

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Abstract

Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Objective

Introduction to classical (atomistic) computer simulation of (bio)molecular systems, development of skills to carry out and interpret these simulations.

Content

Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Lecture notes

The powerpoint slides of the lectures will be made available weekly on the website in pdf format (on the day preceding each lecture).

Prerequisites / notice

Since the exercises on the computer do convey and test essentially different skills than those being conveyed during the lectures and tested at the oral exam, the results of the exercises are taken into account when evaluating the results of the exam (learning component, possible bonus of up to 0.25 points on the exam mark).

For more information about the lecture: www.csms.ethz.ch/education/CSBMS
Subject-specific Competencies

Individual development of strategies for the optimal application of chemical, biochemical, and physico-chemical methods in analytical processes of macromolecules and proteins.

Prerequisites:
- 529-0051-00 "Analytical Chemistry I (3. Semester)"
- 529-0058-00 "Analytical Chemistry II (4. Semester)"

Competencies

Objectives

Abilities to create solutions for particular analytical problems.

Content

Lecture notes

Prerequisites / notice

Copies of problem sets and solutions will be distributed free of charge.

<table>
<thead>
<tr>
<th>Competencies</th>
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Analytical Strategy

W 6 credits 3G R. Zenobi, S. Giannoukos, D. Günther

529-0043-01L

Abstract

Problem-oriented development of analytical strategies and solutions.

Objective

Ability to create solutions for particular analytical problems.

Content

Individual development of strategies for the optimal application of chemical, biochemical, and physico-chemical methods in analytical chemistry solving predefined problems. Experts from industry and administration present particular problems in their field of activity.

Principles of sampling.

Design and application of microanalytical systems.

Lecture notes

Prerequisites:

Copies of problem sets and solutions will be distributed free of charge.

Comptencies

Objectives

Abilities to create solutions for particular analytical problems.

Content

Lecture notes

Prerequisites / notice

Copies of problem sets and solutions will be distributed free of charge.

<table>
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Biochemical and Polymer Reaction Engineering

W 6 credits 3G P. Arosio, P. Fleckenstein

529-0615-01L

Abstract


Objective

The aim of the course is to learn how to design polymerization reactors and bioreactors to produce polymers and proteins with the specific product qualities that are required by different applications in chemical, pharmaceutical and food industry. This activity includes the post-treatment of polymer latexes, the downstream processing of proteins and the analysis of their colloidal behavior.

Content

We will cover the fundamental processes and the operation units involved in the production of polymeric materials and proteins. In particular, the following topics are discussed: Overview on the different polymerization processes. Kinetics of free-radical polymerization and use of population balance models. Production of polymers with controlled characteristics in terms of molecular weight distribution. Kinetics and control of emulsion polymerization. Surfactants and stable colloidal stability. Aggregation kinetics and aggregate structure in conditions of diffusion and reaction limited aggregation. Modeling and design of colloid aggregation processes. Physico-chemical characterization of proteins and description of enzymatic reactions. Operation units in bioprocessing: upstream, reactor design and downstream. Industrial production of therapeutic proteins. Characterization and engineering of protein aggregation. Protein aggregation in biology and in biotechnology as functional materials.

Lecture notes

Additional handout of slides will be provided during the lectures.

Literature


Cell Biophysics

W 6 credits 4G T. Zambelli

227-0939-00L

Abstract

Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.

Objective

Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars of thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding experimental results from the literature.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.
Content
- Basics of theory of probability
- Boltzmann's law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Protein motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns

Theory and corresponding exercises are merged together during the classes.

Lecture notes
No lecture notes because the two proposed textbooks are more than exhaustive!

I am willingly available Mondays 17.00 o'clock - 18.00 in my office GLC F12.2 for whatever discussion about the lessons and the exercises.

!!! I am using OneNote. All lectures will be broadcast via ZOOM, while corresponding videos of the previous years (lectures and exercises) are available in Moodle !!!

Literature

As further deepening:

Prerequisites / notice
Participants need a good command of
- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

529-0231-00L Organic Chemistry III: Introduction to Asymmetric Synthesis

Abstract
Methods of Asymmetric Synthesis

Objective
Understanding the basic principles of diastereoselective synthesis

Content
- Conformational analysis: acyclic and cyclic systems; Diastereoselective sigmatropic rearrangements; Diastereoselective Carbonyl addition reactions: Cram- and Felkin-Anh models, carbonyl Lewis acid interactions, chelate controlled reactions; chemistry of enolates, selective formation; asymmetric enolate alkylation; aldol reactions, allyl- and crotyl-metal chemistry; cyclisations, Baldwin rules; Diastereoselective olefin functionalization: hydroboration, dihydroxylation, epoxidation.

Literature

Evans' Problems in Organic Chemistry App

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 262 of 2635
1) The students will be able to recognize different polymer types and associate them with their chemical structure and properties (i.e. conventional chain growth polymerization, living chain growth polymerization, step growth polymerization, polymeric architectures).

2) The students will become familiar with various synthetic methods to produce polymers of different architectures and topologies.

3) The students will be exposed to different characterization methods (e.g. size exclusion chromatography, mass-spectrometry, nuclear magnetic resonance) that are necessary to confirm the successful synthesis and structure of a polymer.

4) The students will understand the mechanism of selected polymerization methodologies.

5) The students will be introduced to state-of-the-art polymer synthesis and recent literature examples will be critically discussed.

The course teaches the basics and terminology of polymer synthesis. To synthesize various polymeric materials, different polymerization techniques are required. This course will introduce representative polymerization methodologies and will discuss how they operate in order to yield materials with enhanced polymeric characteristics.

Lecture slides with references to further literature will be available on Moodle.

Organic Synthesis: Methods and Strategies

Abstract

The complex relation between structural analysis, methods leading to desired transformations, and insight into reaction mechanisms is exemplified. Relations between retrosynthetic analysis of target structures, synthetic methods and their combination in a synthetic strategy.

Objective

Extension and deepening of the knowledge in organic synthesis and the principles of structure and reactivity.

Content


Prerequisites / notice

OC I-IV
Inorganic Chemistry III: Organometallic Chemistry and Homogeneous Catalysis

- Fundamentals of the organometallic chemistry of the transition elements.
- Mechanistic homogeneous catalysis including oxidative additions, reductive eliminations and insertion reactions.
- Catalytic hydrogenation, carbonylation, C-C bond-forming and related reactions.

Abstract

This course covers aspects of the organometallic chemistry of the transition elements. Mechanistic homogeneous catalysis including oxidative additions, reductive eliminations and insertion reactions. Catalytic hydrogenation, carbonylation, C-C bond-forming and related reactions.

Objective

Towards an understanding of the fundamental coordination-chemical and mechanistic aspects of transition-metal chemistry relevant to homogeneous catalysis.

Prerequisites / notice

Basic knowledge of cell and molecular biology.

RNA Biology Lecture Series II: Non-Coding RNAs: Biology and Therapeutics

- RNA biology related to the functions of non-coding RNAs as well as their use as drugs to treat diseases.
- ncRNA-mediated genome regulation; epigenetic programming of genome remodelling in ciliates; telomerase and telomeres; tRNA biology.

Abstract

This course covers aspects of RNA biology related to the posttranscriptional level. These include RNA transcription, processing, alternative splicing, editing, export and translation.

Objective

The students should get familiar with the wide array of roles, which non-coding RNAs play in cellular functions.

Prerequisites / notice

Basic knowledge of cell and molecular biology.

Transition Metal Catalysis: From Mechanisms to Applications

- Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint.
- Synthetic applications of these reactions. Introduction and application of tools for the elucidation of mechanisms. Selected examples of topics include: C-H activation, C-O activation, C-C activation, reductively active ligands, main group reduct catalysis, bimetallic catalysis.

Abstract

Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint. Synthetic applications of these reactions. Introduction and application of tools for the elucidation of mechanisms. Selected examples of topics include: C-H activation, C-O activation, C-C activation, reductively active ligands, main group reduct catalysis, bimetallic catalysis.

Objective

Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint. Synthetic applications of these reactions. Introduction and application of tools for the elucidation of mechanisms. Selected examples of topics include: C-H activation, C-O activation, C-C activation, reductively active ligands, main group reduct catalysis, bimetallic catalysis.

Literature

- Slides will be uploaded 1-2 days before each lecture on http://morandi.ethz.ch/education.html
- Handout summarizing important concepts in organometallic and physical chemistry will also be provided. Useful references and handouts will also be provided during the workshop.

The following textbooks can provide useful support for the course:

### Semester Theses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0260-00L</td>
<td>Research Project I</td>
<td>O</td>
<td>16</td>
<td>34A</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

**Abstract**
In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student.

**Objective**
Students are accustomed to scientific work and they get to know one specific research field.

**Content**
This laboratory project is organised during the spring vacation before the sixth semester. The participant can choose his topic from the list of projects suggested. Main emphasis during this research work is to get experience in using different engineering tools and evaluation and the interpretation of the results. Those are presented as a scientific report.

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0265-00L</td>
<td>Research Project II</td>
<td>O</td>
<td>16</td>
<td>34A</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

**Abstract**
In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student.

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Students are accustomed to scientific work and they get to know one specific research field.

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This laboratory project is organised during the spring vacation before the sixth semester. The participant can choose his topic from the list of projects suggested. Main emphasis during this research work is to get experience in using different engineering tools and evaluation and the interpretation of the results. Those are presented as a scientific report.

### Science in Perspective

- see Science in Perspective: Language Courses ETH/UZH
- see Science in Perspective: Type A: Enhancement of Reflection Capability

**Recommended Science in Perspective (Type B) for D-CHAB**

### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0080-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>32</td>
<td>69D</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

**Abstract**
In the Master's thesis students prove their ability to independent, structured and scientific working. The Master's thesis is usually carried out in a core or optional subject area as chosen by the student.

**Duration of the Master's Thesis**
26 weeks.

**Objective**
In the Master's Thesis students prove their ability to independent, structured and scientific working.

**Biochemistry - Chemical Biology Master - Key for Type**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<tr>
<td>O+</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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</table>

**Biochemistry - Chemical Biology Master - Key for Hours**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

**ECTS**
European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.

Data: 15.06.2024 12:39
## Complementary Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1791-00L</td>
<td>Introductory Course in Neuroscience I (University of Zurich)</td>
<td>Z Dr</td>
<td>2 credits</td>
<td>2V</td>
<td>W. Knecht, University lecturers</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
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<tr>
<td></td>
<td>The course gives an introduction to human and comparative neuroanatomy, molecular, cellular and systems neuroscience.</td>
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<td><strong>Objective</strong></td>
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<td></td>
<td>The course gives an introduction to the development and anatomical structure of nervous systems. Furthermore, it discusses the basics of cellular neurophysiology and neuropharmacology. Finally, the nervous system is described on a system level.</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>1) Human Neuroanatomy I&amp;II</td>
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<td></td>
<td>2) Comparative Neuroanatomy</td>
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<td>3) Building a central nervous system I,II</td>
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<td>4) Synapses I,II</td>
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<td>5) Glia and more</td>
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<td>6) Excitability</td>
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<td>7) Circuits underlying Emotion</td>
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<td>8) Visual System</td>
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<td></td>
<td>9) Auditory &amp; Vestibular System</td>
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<td></td>
<td>10) Somatosensory and Motor Systems</td>
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<td></td>
<td>11) Learning in artificial and biological neural networks</td>
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<td></td>
<td><strong>Prerequisites / notice</strong></td>
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<td>For doctoral students of the Neuroscience Center Zurich (ZNZ).</td>
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<tr>
<td>151-0927-00L</td>
<td>Rate-Controlled Separations in Fine Chemistry</td>
<td>Z Dr</td>
<td>6 credits</td>
<td>3V+1U</td>
<td>M. Mazzotti, V. Becattini, N. Casas, F. Kiefer</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.</td>
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<td><strong>Objective</strong></td>
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<td>The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>The class covers separation techniques that are central in the purification and downstream processing of chemicals and biopharmaceuticals. Examples from both areas illustrate the utility of the methods: 1) Adsorption and chromatography; 2) Membrane processes; 3) Crystallization and precipitation.</td>
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<tr>
<td></td>
<td><strong>Lecture notes</strong></td>
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<tr>
<td></td>
<td>Handouts during the class</td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<tr>
<td></td>
<td>Recommendations for text books will be covered in the class</td>
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<tr>
<td>401-0649-00L</td>
<td>Applied Statistical Regression</td>
<td>Z Dr</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>M. Dettling</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning &quot;good practice&quot; that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.</td>
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<td></td>
<td><strong>Objective</strong></td>
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<td></td>
<td>The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<td>The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.</td>
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<td>The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.</td>
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<tr>
<td></td>
<td><strong>Lecture notes</strong></td>
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<td>A script will be available</td>
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</tbody>
</table>
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Methods-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>assessed</td>
<td>assessed</td>
<td>Communication</td>
<td>fostered</td>
</tr>
<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
<td>assessed</td>
<td>Customer Orientation</td>
<td>fostered</td>
</tr>
<tr>
<td>Analytical Competencies</td>
<td>assessed</td>
<td>Decision-making</td>
<td>Leadership and Responsibility</td>
<td>fostered</td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>assessed</td>
<td>Problem-solving</td>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
</tr>
<tr>
<td>Project Management</td>
<td>assessed</td>
<td></td>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
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<td></td>
<td>Negotiation</td>
<td>fostered</td>
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<td></td>
<td>Adaptable and Flexibility</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td></td>
<td></td>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<td></td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<td></td>
<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Students are able to describe selected chemicals, biological and molecular processes that occur in cells spontaneously or after physical or chemical exposure and resulting in a tumor. They are able to list important cancer-inducing agents and explain the respective mechanism of action. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies.</td>
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</tbody>
</table>
Abstract

Seminars by invited speakers covering selected microbiology themes.

Objective

Discussion of selected microbiology themes presented by invited speakers.

Content

Statistical Consulting

The Statistical Consulting service is open for all members of ETH, including students, and partly also to other persons.

Method-specific Competencies

Advice for analyzing data by statistical methods.

Personal Competencies

None

Prerequisites / notice

Students and researchers can get advice for analyzing scientific data, often for a thesis.

Contact: beratung@stat.math.ethz.ch. Tel. 044 632 2223. See also http://stat.ethz.ch/consulting

Requirements: Knowledge of the basic concepts of statistics is desirable.

Abstract

Current Topics in Molecular and Cellular Neurobiology

Does not take place this semester.

Objective

The course introduces you to recent developments in the fields of cellular and molecular neurobiology. It also supports you to develop your skills in critically reading the scientific literature. You should be able to grasp what the authors wanted to learn i.e. their goals, why the authors chose the experimental approach they used, the strengths and weaknesses of the experiments and the data presented, and how the work fits into the wider literature in the field. You will present one paper yourself, which provides you with practice in public speaking. You are expected to take part in the discussion and to ask questions. To prepare for this you should read all the papers beforehand (they will be announced a week in advance of the presentation).

Lecture notes

None

Prerequisites / notice

You must attend at least 80% of the journal clubs, and give a presentation of your own. At the end of the semester there will be a 30 minute oral exam on the material presented during the seminar. The grade will be based on the exam (45%), your presentation (45%), and a contribution based on your active participation in discussion of other presentations (10%).

Abstract

Zürich Ecology and Evolution Interaction Seminar

Interaction seminar. Student-led presentations, guests and discussions on current themes in ecology, evolution and population biology.

Objective

Students gain competences in presenting their work orally, leading discussions about current topics in ecology and evolution, interacting with colleagues from various subdisciplines, and engaging in critical dialogue about ongoing research projects.

Lecture notes

None

Prerequisites / notice

For information, location and details: https://pe.ethz.ch/education/zis.html

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Decision-making

Problem-solving

Social Competencies

Communication

Leadership and Responsibility

Self-presentation and Social Influence

Personal Competencies

Critical Thinking

Self-awareness and Self-reflection

Abstract

This monthly meeting is a platform for Zurich-based immunology research groups to present and discuss their ongoing research projects. At each meeting three PhD students or Postdocs from the participating research groups present an ongoing research project in a 30 min seminar followed by a plenary discussion.
Participants will be able to:

5S  Presentation and discussion of current research results in the field of Microbiology and Infection Immunology

Agriculture, food and waste management should use less resources to accept the planetary boundaries. The focus of the seminar is:

1 credit  Creative Thinking
A. D. Gossert, S. F. Bender, S. C. Zeeman

2 credits  Precise and transparent presentation of research findings in relation to the current literature, critical discussion of experimental data and their interpretation, development and presentation of future research aims.

2S  assessed

S. C. Zeeman

Sustainable Plant Systems (Seminar)

Agriculture, food and waste management should use less resources to accept the planetary boundaries. The focus of the seminar is:

1) Agroecological systems. Can we transform the impact of agricultural in Switzerland and beyond?
2) Food system transformation. How can local sustainable food systems be built and scaled through policy strategies, food environments and consumer habits.

Objectives

1) Research in agroecological systems. Can we transform the impact of agricultural in Switzerland and beyond?
2) Food system transformation. How can local sustainable food systems be built and scaled through policy strategies, food environments and consumer habits.

The seminar will have (a) two face-to-face sessions, (b) self-organized group work phase with case studies that will be analyzed by student groups and results be presented, (c) participants will publish a report in the ETHZ-PSC Science and Policy Blog on their findings.

Case studies (CS) will include:

CS 1: How can Swiss farmers move to zero environmental impact?
CS 2: What influence do the consumers in developed (importing) countries have on sustainability of (mainly) small-holder farming in the developing (sourcing) countries?
CS 3: Sensor based fertilization techniques at the filed for sustainability?
CS 4: The blessing and curse of nitrogen – transferring knowledge from Science to Society to create more awareness.

Competencies

Subject-specific Competencies
Concepts and Theories  assessed

Method-specific Competencies
Analytical Competencies  assessed
Decision-making  assessed
Problem-solving  assessed

Social Competencies
Communication  fostered
Cooperation and Teamwork  fostered
Self-presentation and Social Influence  fostered

Personal Competencies
Creative Thinking  fostered
Critical Thinking  assessed
Self-awareness and Self-reflection  fostered
Self-direction and Self-management  fostered

Plant Biology Colloquium (Autumn Semester)

This compulsory course is only once. It may be taken in autumn as course 551-0120-00 "Plant Biology Colloquium (Autumn Semester)" or in spring as course 551-0120-01 "Plant Biology Colloquium (Spring Semester)".

Objectives

Current topics in Molecular Plant Biology presented by internal and external speakers from accademia.
Getting insight into actual areas and challenges of Molecular Plant Biology.

Competencies

Subject-specific Competencies
Concepts and Theories  assessed
Techniques and Technologies  assessed

Method-specific Competencies
Analytical Competencies  fostered
Media and Digital Technologies  fostered

Personal Competencies
Creative Thinking  assessed
Critical Thinking  assessed
Self-direction and Self-management  fostered

NMR Methods for Studies of Biological Macromolecules

Prerequisites: Basic knowledge in biological NMR spectroscopy.

Objectives

In this seminar series, topics relevant to solution state NMR with biological macromolecules are treated. Each semester a different aspect of biomolecular NMR is discussed in depth. The course is tailored to advanced students (PhD students and postdocs) who have experience with applications of NMR spectroscopy. Each participant presents a selected topic in form of a seminar.

The students will actively participate in the course which is held in the form of a seminar. Individual students will prepare particular topics of the course based on literature references and present the material in form of a seminar to their fellow students. In short, the students learn to actively participate in discussions and to prepare a presentation of a scientific topic which was mostly unknown to them before.
Current Topics in Molecular Health Sciences  
**Z** 0 credits  2S  I. Zanini, further lecturers

**Abstract**
This course is a seminar series on current research topics within the Institute of Molecular Health Sciences.

**Objective**
The course introduces the participants to recent developments in the fields of molecular health sciences.

**Prerequisites / notice**
Approval of the responsible lecturer necessary for participation.

Lecture Series: Space Research and Exploration  
**Z** Dr 1 credit  2V  S. P. Quanz

**Abstract**
Lecture Series about selected topics of space research and exploration consisting of individual talks given by different leading experts from academia and industry.

**Objective**
Attending students will:
- experience the interdisciplinarity of space research and exploration spanning physics, engineering, geosciences, biology and more
- get familiar with the Swiss space research and industry landscape
- enhance their communication skills by broadening their research horizon
- have the opportunity for direct learning by posing questions to experts

**Content**
The field of space research and exploration is intrinsically interdisciplinary. Cutting edge space activities are dominated by an interplay between the scientifically desirable and the technologically possible. The 'Lecture Series: Space Research and Exploration' aims to shed light on key questions engaged by leading scientists and engineers today. It consists of weekly lectures, given by different speakers with vast experience in their respective field (e.g., Human Spaceflight, System Engineering of Spacecraft, Space Life Sciences, Space-based astrophysics). Subsequent to the talk, the student will have the opportunity to deepen their understanding by asking questions to the presenter in a moderated Q&A.

Confirmed speakers will be announced by the start of the semester (see lecture from last year for previous speakers).

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
  - Analytical Competencies
  - Media and Digital Technologies
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Sensitivity to Diversity
  - Adaptability and Flexibility
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-direction and Self-management

- Method-specific Competencies
  - Project Management
  - Communication

- Social Competencies
  - Cooperation and Teamwork
  - Customer Orientation
  - Sensitivity to Diversity

- Personal Competencies
  - Creativity
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

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**Biology (General Courses) - Key for Type**

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<th>Key for Type</th>
<th>W+</th>
<th>W</th>
<th>Dr</th>
<th>E-</th>
<th>O</th>
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<td>Suitable for doctorate</td>
<td>Recommended, not eligible for credits</td>
<td>Compulsory</td>
<td>Courses outside the curriculum</td>
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**Key for Hours**

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<td>seminar</td>
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<td>independent project</td>
<td>diploma thesis</td>
<td>revision course / private study</td>
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**ECTS**
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.

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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 270 of 2653
### Subject-specific Competencies

The lecture provides an introduction to the basics of biochemistry and molecular biology as well as evolutionary principles. The focus is on bacteria and archaea under consideration of universal concepts.

### Analytical Competencies

The lecture introduces biochemistry as an interdisciplinary science. Links to physics and chemistry will manifest as biological processes that operate within the laws of thermodynamics and are rooted in elements, molecules and chemical reactions. The transition from geochemistry to biochemistry is discussed and considered in relation to the origin of life. Evolutionary principles are introduced and resulting processes are used as a guiding principle. Unifying concepts in biology are presented, including the structure and function of cellular macromolecules and the ways in which hereditary information is encoded, decoded and replicated. Central principles of universal energy conversion are looked at, starting from redox processes and focusing on bacteria and archaea. Finally, biological processes are put into an ecosystems perspective.

The lecture is divided into different sections:

1. Geochanical perspectives on Earth and introduction to evolution
2. Building blocks of life
3. Macromolecules: Proteins
4. Membranes and transport across the plasma membrane
5. Universal mechanisms of inheritance, transcription and translation
6. Reaction Kinetics, binding equilibria and enzymatic catalysis
7. Essentials of Catabolism
8. Essentials of Anabolism
9. Metabolism and biogeochemical cycling of elements

### Literature

The lecture is supported by scripts. The newly conceived lecture is supported by scripts. The lecture contains elements of "Brock Biology of Microorganisms", Madigan et al. 15th edition, Pearson und "Biochemistry" (Stryer), Berg et al. 9th edition, Macmillan international.

### Competencies

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<tr>
<th>Competencies</th>
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<th>Hours</th>
<th>Lecturers</th>
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<td>Critical Thinking</td>
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<td>Self-awareness and Self-reflection</td>
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### Literature

**General Chemistry (for Biol./Pharm.Sc.)**

- **Abstract**: The lecture deals with a number of basic chemistry concepts. These include (amongst others) chemical reactions, energy transfer during chemical reactions, properties of ionic and covalent bonds, Lewis structures, properties of solutions, kinetics, thermodynamics, acid-base equilibria, electrochemistry and properties of metal complexes.

- **Objective**: The course is designed to provide an understanding of the basic principles and concepts of general and inorganic chemistry.


**Weiterführende Literatur:**


### Competencies

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</table>

### Literature

**Organic Chemistry I (for Biol./Pharm.Sc./HST)**

- **Abstract**: Fundamentals of Organic Chemistry: molecular structure, Bonding and functional groups; nomenclature; resonance and aromaticity; stereochemistry; conformation; bond strength; organic acids and bases; basic reaction thermodynamics and kinetics; reactive intermediates: carbanions, carbene ions and radicals.

- **Objective**: Understanding the basic concepts and definitions of organic chemistry. Knowledge of the functional groups and classes of compounds that are important in biological systems. Foundations for the understanding of the relationship between structure and reactivity.


- **Lecture notes**: Lecture notes are available (pdf file). Exercises, answer keys and other handouts can be downloaded from the Moodle course "Organic Chemistry f" of the current semester (https://moodle-app2.let.ethz.ch).
Literature


Prerequisites / notice

The course consists of lectures (36 hours) and problem-solving lessons (20 hours, groups of ca. 25 people). In addition, online exercises are available in the e-learning environment Moodle (Course OC I).

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Method-specific Competencies
Analytical Competencies assessed
Social Competencies
Communication fostered
Sensitivity to Diversity fostered
Personal Competencies
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

First Year Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0073-00L</td>
<td>Physics I</td>
<td>O</td>
<td>3</td>
<td>2V+2U</td>
<td>T. M. Ihn</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics and elements of quantum mechanics</td>
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<tr>
<td>Objective</td>
<td>Students know and understand the basic ideas of the scientific description of nature. They understand the fundamental concepts and laws of mechanics and they are able to apply them in practical problems. They know the concepts of quantization and quantum numbers.</td>
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</tbody>
</table>
| Content      | 1. Description of Motion  
2. The laws of Newton  
3. Work and energy  
4. Collision problems  
5. Wave properties of particles  
6. The atomic structure of matter |
| Lecture notes| T. Ihn: Physics for Students in Biology and Pharmaceutical Sciences (unpublished lecture notes) |
| Competencies | Subject-specific Competencies
Concepts and Theories assessed |
Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed |
Social Competencies
Cooperation and Teamwork fostered
Sensitivity to Diversity fostered |
Personal Competencies
Critical Thinking assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered |
| 401-0291-00L | Mathematics I         | O    | 6    | 4V+2U   | E. W. Farkas |
| Abstract     | Mathematics I/II is an introduction to one- and multidimensional calculus and linear algebra emphasizing on applications. |
| Objective    | Students understand mathematics as a language for modeling and as a tool for solving practical problems in natural sciences. Students can analyze models, describe solutions qualitatively or calculate them explicitly if need be. They can solve examples as well as their practical applications manually and using computer algebra systems. |
## Eindimensionale diskrete Entwicklungen ##
- linear, exponentiell, begrenzt, logistisch
- Fixpunkte, diskrete Veränderungsraten
- Folgen und Grenzwerte

## Funktionen in einer Variablen ##
- Reproduktion, Fixpunkte
- Periodizität
- Stetigkeit

## Differentialrechnung (I) ##
- Veränderungsrate-geschwindigkeit
- Differentialquotient und Ableitungsfunktion
- Anwendungen der Ableitungsfunktion

## Integralrechnung (I) ##
- Stammfunktionen
- Integrationstechniken

## Gewöhnliche Differentialgleichungen (I) ##
- Qualitative Beschreibung an Beispielen: Beschränkt, Logistisch, Gompertz
- Stationäre Lösungen
- Lineare DGL 1. Ordnung
- Trennung der Variablen

## Lineare Algebra ##
- Erste Arithmetische Aspekte
- Matrizenrechnung
- Eigenwerte / -vektoren
- Quadratische LGS und Determinante

Lecture notes
In Ergänzung zu den Vorlesungskapiteln der Lehrveranstaltungen fassen wir wichtige Sachverhalte, Formeln und weitere Ausführungen jeweils in einem Vademecum zusammen.

Dabei gilt:
* Die Skripte ersetzen nicht die Vorlesung und/oder die Übungen!
* Ohne den Besuch der Lehrveranstaltungen verlieren die Ausführungen ihren Mehrwert.
* Details entwickeln wir in den Vorlesungen und den Übungen, um die hier bestehenden Lücken zu schliessen.
* Prüfungsrelevant ist, was wir in der Vorlesung und in den Übungen behandeln.

Literature
Siehe auch Lernmaterial > Literatur

**Th. Wihler**
Mathematik für Naturwissenschaften, 2 Bände: Einführung in die Analysis, Einführung in die Lineare Algebra; Haupt-Verlag Bern, UTB.

**H. H. Storrer**
Einführung in die mathematische Behandlung der Naturwissenschaften I; Birkhäuser. Via ETHZ-Bibliothek:
https://link.springer.com/book/10.1007/978-3-0348-8598-0

**Ch. Blatter**
Lineare Algebra; VDF und als Skript in der PolyBox

**A. Caspar, N. Hungerbühler**
Mathematische Modellierung in den Life Sciences, Springer. Via ETH-Bibliothek:

Prerequisites / notice
+ Die Übungsaufgaben (Handaufgaben, Khan-Aufgaben, Multiple-Choice) sind ein wichtiger Bestandteil der Lehrveranstaltung.
+ Es wird erwartet, dass Sie mindestens 9 von 13 der wöchentlichen Serien bearbeiten und zur Korrektur einreichen.
+ Der Prüfungsstoff ist eine Auswahl von Themen aus Vorlesung und Übungen. Für eine erfolgreiche Prüfung ist die konzentrierte Bearbeitung der Aufgaben unerlässlich.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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### First Year Laboratory Courses

<table>
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<tr>
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<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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Laboratory Course General Chemistry (for Biology and Pharmacy)

**Abstract**
Introduction to the practical work in a chemistry laboratory. The most important manipulations and techniques are treated, as well as the most fundamental chemical reaction types.

**Objective**
- Knowledge of the basic chemical laboratory methods
- Basic knowledge of the scientific approach in experimenting
- Observation and interpretation of chemical processes
- Keeping of a reliable laboratory journal
- Simple chemical working techniques/methods
- Separation techniques
- Physical measurements: mass, volume, pH
- Ionic solids (salts)
- Acid/base chemistry, buffers
- Redox reactions
- Metal complexes
- Titration methods and quantitative spectrometry
- Introduction to qualitative analysis

**Content**
- Simple chemical working techniques/methods
- Separation techniques
- Physical measurements: mass, volume, pH
- Ionic solids (salts)
- Acid/base chemistry, buffers
- Redox reactions
- Metal complexes
- Titration methods and quantitative spectrometry
- Introduction to qualitative analysis

**Lecture notes**
Course manual in German (is handed out to the students at the begin of the lessons)
Language: German, English upon request

**Literature**
- Wiley

**Prerequisites / notice**
This practical course causes costs for materials and chemicals. The costs are charged to the students at the end of semester.

By enrolling in this lab course, students confirm that they will thoroughly study and follow all safety information and instructions and that they have an accident insurance valid for Switzerland for the entire duration of the semester.

**Competencies**

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<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>fostered</th>
<th>Analytical Competencies</th>
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<th>Decision-making</th>
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<th>Problem-solving</th>
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**Second Year Courses**

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<th>Lecturers</th>
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</thead>
</table>

**Abstract**
The lecture conveys the fundamental concepts underlying multicellularity with an emphasis on the molecular basis of multicellular biological systems and their functional integration into coherent wholes. The structural and functional specialization in multicellular organisms will be discussed by highlighting common and specific functions in fungi, plants, and animals (including humans).

**Objective**
1. Students can describe advantages and challenges associated with being multicellular and outline independent solutions that organisms have developed to cope with the challenges of complex multicellularity
2. Students can explain how the internal and external structures of fungi, plants and animals function to support survival, growth, behavior, and reproduction.
3. Students can explain the basic pathways and mechanisms of cellular communication regulating cellular behavior (cell adhesion, metabolism, proliferation, reproduction, development).  
4. Students can describe how a single cell develops from one cell into many, each with different specialized functions.

**Content**
The lecture introduces the structural and functional specialization in fungi, plants and animals, including humans. After providing an overview on the diversity of eukaryotic organisms, the lecture will discuss how fungi, plants, animals and humans have evolved structures and strategies to cope with the challenges of multicellularity. The molecular basis underlying communication, coordination and differentiation will be conveyed and complemented by key aspects of reproduction, metabolism development, and regeneration. Topics include form and function of fungi and plants, human anatomy and physiology, metabolism, cell signaling, adhesion, stem cells, regeneration, reproduction, and development.

**Literature**
- Alberts et al. 'Molecular Biology of the Cell' 6th edition
- Campbell ‘Biology’, 11th Edition

**Prerequisites / notice**
Some lecture are held in English.
Bioanalytics

Objective
For each of the techniques covered in the course, the students will be able to explain:

- the physical, chemical and biological principles underlying the technique,
- the requirements for the sample,
- the type of raw data collected by the technique,
- the assumptions and auxiliary information used in the interpretation of the data and
- how these data can be used to answer a given biological question.

By the end of the course the students will be able to select the appropriate experimental technique to answer a given biological problem and will be able to discuss the advantages and limitations of individual techniques as well as how different techniques can be combined to gain a more complete understanding of a given biological questions.

Content
The course will be based on a combination of lectures, self-study elements and exercises.

The focus will be on the following experimental techniques:

- DNA sequencing
- chromatography
- mass-spectrometry
- UV/Vis and fluorescence spectrometry
- light microscopy
- electron microscopy
- X-ray crystallography
- NMR spectroscopy

Foundations of Computer Science

Objective
Students learn to:

- encode a problem into a program, test the program, and correct errors.
- understand and improve existing code.
- deal with the complexity of real data.
- store data in a suitable data structure.
- query databases and understand and evaluate the corresponding database model.
- implement models from the natural sciences as a simulation.
- run random experiments and interpret the results.
- explain and apply standard algorithms and evaluate their efficiency.

Content
1. Variables, data types
2. Control structures, logic
3. Sequential data types, search- and sort algorithms, sequence analysis
4. Functions, modules, simulation and animation
5. Manage data with a relational database
6. Matrices, random experiments, cellular automata

Statistics II

Objective
This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.
Vertiefung von Statistikmethoden. Nach dem detaillierten Fundament aus Statistik I liegt nun der Fokus auf konzeptueller Breite und konkreter Problemlösungsfähigkeit mit der Statistiksoftware R.

**Objective**


**529-0015-00L**  **Physical Chemistry**  
O 3 credits 2V+1U  G. Jeschke, D. Klose

**Abstract**

Thermodynamic foundations of phase equilibria, intermolecular interactions, and molecular self-assembly; kinetics of chemical reactions and transport processes

**Objective**

This course teaches physical-chemical foundations of important processes in living cells and organisms as well as of working techniques in biochemistry and molecular biology. Students learn:

1. Evaluation of chemical equilibria based on chemical potential
2. Interpretation of phase diagrams
3. Which interactions between molecules are important in living cells
4. Why molecules self-organize into aggregates
5. Which physical-chemical basics determine behavior of biomembranes
6. What determines the rate of chemical reactions, in particular also of enzymatically catalyzed reactions
7. What determines the transport rate of matter and heat

**Content**

Chemical potential, prediction of the direction of processes, phase equilibria, phase rule, phase diagrams of pure substances, colligative properties, osmosis, dialysis, surface tension, intermolecular interactions, hydrophobic effect, hydrophilic effect and denaturation, amphiphiles, basics of self-association, micelles, packing parameter, double layers, vesicles, membranes, elementary reactions, parallel reactions, consecutive reactions, Eyring theory, enzyme kinetics, diffusion, heat conduction, active transport

**Lecture notes**

A lecture script is provided

**Literature**

In addition to the lecture script, the following two books can be used to gain deeper understanding


Jacob Israelachvili, Intermolecular and Surface Forces, Academic Press, 1992

**Competencies**

**Subject-specific Competencies**

- Concepts and Theories  
  - fostered
- Techniques and Technologies  
  - fostered

**Method-specific Competencies**

- Analytical Competencies  
  - fostered
- Decision-making  
  - fostered
- Media and Digital Technologies  
  - fostered
- Problem-solving  
  - fostered

**Social Competencies**

- Communication  
  - fostered
- Cooperation and Teamwork  
  - fostered
- Customer Orientation  
  - fostered
- Leadership and Responsibility  
  - fostered
- Self-presentation and Social Influence  
  - fostered
- Sensitivity to Diversity  
  - fostered
- Negotiation  
  - fostered

**Personal Competencies**

- Adaptability and Flexibility  
  - fostered
- Creative Thinking  
  - fostered
- Critical Thinking  
  - fostered
- Integrity and Work Ethics  
  - fostered
- Self-awareness and Self-reflection  
  - fostered
- Self-direction and Self-management  
  - fostered

**529-0229-00L**  **Practical Course Organic Chemistry (for Students of Biology and Pharmaceutical Sciences)**  
O 8 credits 12P  C. Thiligen

Latest online enrolment is 10 days before the beginning of the semester.

Students who did not pass the first-year examinations need the lecturers’ written permission to take this course.

**Abstract**

Analytical part: basic operations for the separation of mixtures of organic compounds (recrystallization, distillation, extraction, chromatography)

Synthetic part (main part): at least 8 synthetic steps (one- or two-step syntheses).

**Objective**

Learn the basic techniques for the preparation and purification of organic compounds. Learn to take accurate notes of the experiments and to write reports. Deepen the understanding of reaction mechanisms.

**Content**

Analytical part: basic operations for the separation of mixtures of organic compounds (recrystallization, distillation, extraction, chromatography).

Synthetic part (main part): at least 8 synthesis steps (one- to two-step preparations) from the following classes of reactions: 1. nucleophilic substitution at C(sp3), 2. elimination or electrophilic addition to a C=C bond, 3. electrophilic aromatic substitution, 4. reduction of an aldehyde/ketone, 5. Grignard reaction, 6. heterocyclization with imine/enamine formation, 7. synthesis of a carboxylic acid derivative by acyl group transfer, 8. aldol, Claisen, Mannich, Michael reaction or Robinson anellation.

Introduction to database searches (Reaxys, SciFinder).

**Lecture notes**

Written documents are distributed via Moodle course.
Prerequisites / notice
The basic reactions of Organic Chemistry and their mechanisms should be known and the corresponding exam have been passed (cf. course 529-1012-00L Organic Chemistry II for Students of Biology, Pharmaceutical Sciences, and Health Sci. and Tech.). The prerequisite for passing the ETH security exam.

By enrolling in this lab course, students confirm that they have thoroughly studied all safety information and will follow all instructions.

Competencies

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<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
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<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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Number Type ECTS Hours Lecturers
701-2413-00L Evolutionary Genetics W 6 credits 4V T. Städler, A. Widmer, S. Fior, M. Fischer, J. Stapley

Abstract
The concept course 'Evolutionary Genetics' consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics (emphasis on basic concepts) and ecological genetics (more emphasis on evolutionary and ecological processes of adaptation and speciation).

Objective
The aim of the course is to provide students with a solid introduction to the fields of population genetics, quantitative genetics, and ecological genetics. The concepts and research methods developed in these fields have undergone profound transformations; they are of fundamental importance in our understanding of evolutionary processes, both past and present. Students should gain an appreciation for the concepts, methods and explanatory power of evolutionary genetics.

Content
Population genetics - Types and sources of genetic variation; randomly mating populations and the Hardy-Weinberg equilibrium; effects of inbreeding; natural selection; random genetic drift and effective population size; gene flow and hierarchical population structure; molecular population genetics: neutral theory of molecular evolution and basics of coalescent theory.

Quantitative genetics - Continuous variation; measurement of quant. characters; genes, environments and their interactions; measuring their influence; response to selection; inbreeding and crossbreeding, effects on fitness; Fisher's fundamental theorem.

Ecological Genetics - Concepts and methods for the study of genetic variation and its role in adaptation, reproductive isolation, hybridization and speciation

Lecture notes
Handouts

Literature

Methods and Technologies as well as modern methods for protein purification and microanalytics.

\[ \text{D-BIOL students are obliged to take part I and part II (next semester) as a two-semester course} \]

Abstract
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAI, current topics in protein biophysics and structural biology.

Objective
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

Lecture notes
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching. Basics:
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

Literature
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

551-0307-00L Molecular and Structural Biology I: Protein Structure and Function

W 3 credits 2V R. Glockshuber, K. Locher, E. Weber-Ban

Abstract
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAI, current topics in protein biophysics and structural biology.

Objective
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

Lecture notes
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching. Basics:
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

Literature
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

551-0309-00L Concepts in Modern Genetics

W 6 credits 4V Y. Barral, A. Hajnal, O. Voinnet, University lecturers

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html
551-0311-00L  Molecular Life of Plants  W  6 credits  4V  S. C. Zeeman, K. Bombilies, O. Vainnet

Abstract
The advanced course introduces students to plants through a concept-based discussion of developmental processes that integrates physiology and biochemistry with genetics, molecular biology, and cell biology. The course follows the life of the plant, starting with the seed, progressing through germination to the seedling and mature plant, and ending with reproduction and senescence.

Objective
The new course "Molecular Life of Plants" reflects the rapid advances that are occurring in the field of experimental plant biology as well as the changing interests of students being trained in this discipline. Contemporary plant biology courses emphasize a traditional approach to experimental plant biology by discussing discrete topics that are removed from the context of the plant life cycle. The course will take an integrative approach that focuses on developmental concepts. Whereas traditional plant physiology courses were based on research carried out on intact plants or plant organs and were often based on phenomenological observations, current research in plant biology emphasizes work at the cellular, subcellular and molecular levels.

Content
The goal of "Molecular Life of Plants" is to train students in integrative approaches to understand the function of plants in a developmental context. While the course focuses on plants, the training integrative approaches will also be useful for other organisms.

551-0313-00L  Microbiology (Part I)  W  3 credits  2V  W.-D. Hardt, L. Eberl, B. Nguyen, J. Piel, M. Pilhofer, A. Vagstad

Abstract
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Objective
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Content
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

551-0319-00L  Cellular Biochemistry (Part I)  W  3 credits  2V  U. Kutay, F. Allain, T. Kleele, I. Zemp

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.
Abstract

Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular processes requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Content

Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes. Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Lecture notes

Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Literature

Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice

To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

assessed

assessed

551-0317-00L

Immunology I

W

3 credits

2V

M. Kopf, A. Oxenius

Abstract

Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and regulation of an immune response.

Objective

Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response. Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

Content

- Vaccines, immune-therapeutic interventions
- Hypersensitivities
- Allergies
- Th1 and Th2 cells, regulatory T cells
- Cytotoxic T cells and NK cells
- Autoimmunity
- Thymus and T cell selection
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- B cells and antibodies
- Generation of diversity
- Innate and adaptive immunity, Cells and organs of the immune system
- Biostatistics
- Cellular and molecular biology
- Transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression

Lecture notes

Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"

Literature

- Kuby, Immunology, 9th edition, Freemen + Co., New York, 2020

Prerequisites / notice

For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

assessed

assessed

Method-specific Competencies

Analytical Competencies

Decision-making

Problem-solving

assessed

assessed

Project Management

assessed

Social Competencies

Communication

Cooperation and Teamwork

assessed

assessed

Personal Competencies

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Self-direction and Self-management

assessed

assessed

551-1299-00L

Bioinformatics

W

6 credits

4G

S. Sunagawa, P. Beltrao, V. Boeva, A. Kahles, C. von Mering, N. Zamboni

Abstract

Students will study bioinformatic concepts in the areas of metagenomics, genomics, transcriptomics, proteomics, biological networks and biostatistics. Through integrated lectures, practical hands-on exercises and project work, students will also be trained in analytical and programming skills to meet the emerging increase in data-driven knowledge generation in biology in the 21st century.

Objective

Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

Prerequisites / notice

Course participants have already acquired basic programming skills in UNIX, Python and R. Students bring their own computer with keyboard, internet access (browser) and software to connect to the ETH network via VPN.
### Nucleic Acids and Carbohydrates

**Note for BSc Biology students:** Only one of the two concept courses 529-0731-00 Nucleic Acids and Carbohydrates (autumn semester) or 529-0732-00 Proteins and Lipids (spring semester) can be counted for the Bachelor's degree.

**Abstract**
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

**Objective**
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

**Content**
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

**Lecture notes**
No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).

**Literature**
Mainly based on original literature, a detailed list will be distributed during the lecture

### Block Courses

**Registration for Block courses is mandatory. Please register under https://www.mybiportal.uzh.ch. Registration period: from 22.07.2024 - 09.08.2024**

Please note the ETH admission criteria for the admission of ETH students to ETH block courses on the block course registration website under "allocation".

### Block Courses in 1st Quarter of the Semester

**From 17.09.2024 to 9.10.2024**

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>551-1129-00L</td>
<td>Understanding and Engineering Microbial Metabolism</td>
<td>W</td>
<td>6</td>
<td>7P</td>
<td>J. Vorholt-Zambelli</td>
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<td><em>The enrolment is done by the D-BIOL study administration.</em></td>
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<td><em>The focus of this laboratory course is on current research topics related to metabolic engineering and the general understanding of metabolism, particularly in relation to one carbon metabolism. Projects will be carried out in small teams.</em></td>
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<td><em>The course aims at introducing technologies to investigate bacterial metabolism and key principles of metabolic engineering. The main focus of this block course is on practical work and will familiarize participants with complementary approaches, in particular genetic, biochemical and analytical techniques including metabolomics. Results will be presented by students in scientific presentations. Another goal is to learn how to write a scientific report.</em></td>
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<td><em>The course will include topics such as pathway elucidation &amp; engineering and related ongoing research projects in the lab. Experimental work applied during the course will comprise methods such as cloning work &amp; transformation, growth determination, enzyme activity assays, liquid-chromatography mass-spectrometry and dynamic labeling experiments.</em></td>
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<td>Techniques and Technologies</td>
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<td>Problem-solving</td>
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<td>Communication</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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<tr>
<td>551-1421-00L</td>
<td>The Mechanisms of Natural Transformation in Competent Gram-Negative Bacteria</td>
<td>W</td>
<td>6</td>
<td>7P</td>
<td>M. Hospenthal</td>
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<td><em>Number of participants limited to 5.</em></td>
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</table>
Concepts and Theories fostered assessed

Cell Biology of the Nucleus

Number of participants limited to 14.

The enrolment is done by the D-BIOL study administration.

Abstract

Introduction to the organizational principles of the nucleus using budding yeast, drosophila and vertebrate cells as model systems.

Objective

The aim of our course is to introduce the students to the organizational principles of the nucleus using budding yeast, drosophila and vertebrate cells as model systems. Emphasis is given to:

- Establishment of nuclear identity and nuclear-cytoplasmic communication
- Reorganization of the nucleus in aging
- Animal cells during the generation of cell diversity and neuronal differentiation

By the end of the course, based on lectures, literature reading and practical lab work, the students will be able to formulate open questions concerning the function of the nucleus. Thus, the students will know about the mechanisms and consequences of nuclear-cytoplasmic compartmentalization, DNA clustering in the nucleus and cytoplasm during cell divisions and aging.

Content

During this block-course, the students will
- learn how organelles establish and maintain identity with a focus on the nucleus
- discover the evolutionary and functional plasticity of the nucleus
- design, apply, evaluate and compare experimental strategies

Students - in groups of 2 or max. 3 - will be integrated into a research project connected to the subject of the course, within one of the participating research groups.

Lecture notes

About 1 week before course start you will be invited to express your preference for a practical lab project on the course moodle site. Optional papers linked to the projects shall support you in that choice. They can also serve as framework orientation for the practical parts of this block course.

Literature

Documentation and recommended literature (review articles) will be provided during the course.

Competencies

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<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
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<th>Decision-making</th>
<th>Problem-solving</th>
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551-0337-00L

Cell Biology of the Nucleus

W 6 credits 7P R. Kroschewski, Y. Barral, M. Jaganathan, S. Jessberger, K. Weis

The enrolment is done by the D-BIOL study administration.

Abstract

Students will carry out defined research projects related to the current research topics of the Hospenthal group. The topics will include protein expression of pilins and/or other competence proteins from Gram-negative bacteria, protein purification using affinity chromatography, crystallisation experiments and analysis of assembled pil by electron microscopy.

Objective

The course should enable students to understand concepts of protein expression, purification and the characterisation of biomolecular interactions. In addition, students will learn some basic principles of X-ray crystallography and electron microscopy.

Content

The students will be tutored in their experimental work by an experienced doctoral student. The course will also include a short lecture delivered by M. Hospenthal, providing the theoretical background for the experimental work. Throughout the course, students will receive exercises that further help to explain the theory of the practical work, as well as literature research tasks.

Participation in the following Hospenthal lab projects will be possible:

- Purification, biophysical characterisation and structure determination of pilins
- Purification, biophysical characterisation and structure determination of proteins and protein complexes involved in natural transformation.

Experimental work on this project involves:

- Cloning and mutagenesis
- Recombinant or endogenous protein production in E. coli or Legionella
- Protein purification by affinity chromatography (other chromatographic purification techniques will also be discussed)
- Protein crystallisation and crystal optimisation
- Visualisation of bacterial pil by electron microscopy (negative stain or cryo electron microscopy)
- DNA binding experiments
- Enzymatic activity measurements

In silico structural analyses using PyMOL and Chimera

Any required reading of literature will be discussed at the beginning of the course.

Literature

There are no special requirements for this course.

Comprehension

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W 7P

Autumn Semester 2024

Page 281 of 2653
### Course: Cancer Progression: Mechanisms, Targets and Therapeutic Approaches

**Number of participants limited to 15.**

*The enrolment is done by the D-BIOL study administration.*

**Abstract**

This course will consider the pathogenetic landscape of cancer and its progression to metastasis, explore how abnormalities of cellular information management cause cancer and demonstrate how the integrated application of modern profiling technologies, mouse cancer models, and human pathology provides a foundation for developing individualized cancer therapeutics.

**Objective**

Insights into and overview about the genetic and metabolic alterations that underlie different cancer types, the complex cancer cell circuitries governing tumor development, progression, and metastasis. Understanding of modern approaches used in contemporary basic and translational cancer research and sophisticated strategies to control individual cancers and combat drug resistance. The course is closely linked to ongoing research projects in the lab to provide the participants with direct insights into current experimental approaches and strategies. Student assessment is a graded performance based on individual performance in the laboratory, a written report of their data and a presentation of a recent paper published in a top ranking international peer reviewed journal that relates to cancer.

**Competencies**

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### Course: Introduction to Mass Spectrometry-Based Proteomics

**Number of participants limited to 12.**

*The enrolment is done by the D-BIOL study administration.*

**Abstract**

Protein Analysis by Mass Spectrometry

The following topics will be covered: basics of biological mass spectrometry, including instrumentation, data collection and data analysis; applications to protein identification and characterization; sample preparation methods; proteomics strategies; and quantitative analysis.

**Objective**

How to prepare a protein sample for MS analysis (trypsin digestion, C18 clean-up)

Principles of data acquisition LC-MS (QTOF and/or Ion Trap instruments)

Perform qualitative proteomic analysis (protein identification with Mascot and/or Sequest Softwares)

Perform quantitative proteomic analysis (label-free and labeled analyses)

Analyze/interpret the data to find up/down regulated proteins

**Competencies**

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<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Methods-specific Competencies</th>
<th>Personal Competencies</th>
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### Block Courses in 2nd Quarter of the Semester

*From 10.10.2024 to 1.11.2024*

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<td>W</td>
<td>6</td>
<td>7P</td>
<td>W.-D. Hardt, B. Nguyen</td>
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</table>

*The enrolment is done by the D-BIOL study administration.*

**Abstract**

Research laboratory class in small groups. Research projects on current topics in cellular microbiology and bacterial pathogenesis are assigned to each student.

**Objective**

Introduction to a current topic in cellular microbiology, molecular genetics of a bacterial pathogen or its interaction with the host's microbiome. Experimental work in the research lab and introduction to the current lab techniques. This includes contributions to the analysis of animal experiment. You will work with the current research literature in bacterial pathogenesis and write a research protocol. Requirement for obtaining the credit points: oral presentation of the research project, a short written exam and evaluation of the research protocol.

**Competencies**

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**Data:** 15.06.2024 12:39 | **Autumn Semester 2024** | **Page 282 of 2653**
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<td>The enrolment is done by the D-BIOL study administration.</td>
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**Abstract**

Introduction of the biological and ecological basics of fungi in forests. Focusing on mycorrhizal, saprobic, and pathogenic fungi and their functional relevance in the forest ecosystems. To get to know current methodological research approaches on the basis of selected examples with practical works in forest and lab as well as excursions and lectures.

**Objective**

Knowledge of the fungi of forest and its ecological significance. Knowing of current methodological research approaches. Self-reliant and deepened activities of selected topics of fungi from forests.

**Content**

Introduction of the biological and ecological basics of fungi in forests. Focusing on mycorrhizal, saprobic, and pathogenic fungi and their functional relevance in the forest ecosystems. To get to know current methodological research approaches on the basis of selected examples with practical works in forest and lab as well as excursions and lectures.

**Lecture notes**

Unterlagen zum Kurs werden abgegeben.

**Prerequisites / notice**

Der Blockkurs findet an der Eidg. Forschungsanstalt WSL in Birmensdorf statt. Der Wald vor der Haustüre des Institutes macht diesen Kurs besonders praxisnah.

Erreichbarkeit mit Tram 14 bis Triemli, danach PTT-Bus 220 oder 350 bis Birmensdorf Sternen/WSL, oder mit S9 bis Birmensdorf SBB und mit PTT-Bus eine Station in Richtung Zürich bis Birmensdorf Sternen/WSL.

**Literature**


**Prerequisites / notice**

The enrolment is done by the D-BIOL study administration.

**Number of participants limited to 12.**

**Content**

The course will introduce the students to the key concepts in membrane biology and will allow them to be involved in laboratory projects related to that broad field. The course will consist of lectures, literature discussions, and practical laboratory work in small groups. Results of the practical projects will be presented during the poster session at the end of the course.

**Objective**

The aim of the course is to expose the students to a wide range of modern research areas encompassed by the field of membrane biology. Students will be engaged in research projects aimed at understanding the biological membranes at the molecular, organellar and cellular levels. Students will design and perform experiments, evaluate experimental results, analyze the current scientific literature and understand the relevance of their work in the context of the current state of the membrane biology field.

**Lecture notes**

No script

**Prerequisites / notice**

The course will be taught in English. All general lectures will be held at ETH Hoenggerberg. Students will be divided into small groups to carry out experiments at ETH or at the Paul Scherrer Institute. Travel to the Paul Scherrer Institute will be by public transportation.

**Literature**

The recommended literature, including reviews and primary research articles, will be provided during the course.

**Prerequisites / notice**

The enrolment is done by the D-BIOL study administration.

**Number of participants limited to 7.**

**Content**

This course aims to provide students with a comprehensive overview of computational methods for sequence analysis and assist with developing skills for application of computational approaches by experimental scientists in the life sciences.

**Objective**

Methods for analyzing animal genomes are increasingly becoming important for applications in human health and biotechnology suggesting that the experience will be useful to develop relevant expertise for a broad range of functions. Students will have the opportunity to advance their knowledge in programming by focusing on algorithms for genome and gene sequence analysis. A major goal of the course will be to lead the student to an independent and empowered attitude towards computational problems. For reaching this goal the students will work on an implementation of a solution for a set real-world problem in genome and sequence analysis under guided supervision.
The course will consist of a series of lectures, assignments for implementing elementary tasks in Python, project development and discussion workshops, and 3 and a half week of practical work implementing a Python's script as a solution to a real world problem associated with sequence analysis. At the end of the course students will explain their solutions and demonstrate the functionality of their implementations, which will then be discussed and commented on by the group. It is expected that students will be able to apply the knowledge to improve on concrete problems.

### Prerequisites / notice
- It is recommended to bring your own computer with a Python installation to the course
- simple computers can be provided
- Programming basics with Python

### Competencies

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<th>Competencies</th>
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### Content

- Understanding the information in biological sequences and quantifying similarity
- Introduction to algorithms for sequence comparison and searches
- Implementation of sequence comparisons and searches in Python
- Accessing data formats associated with genome sequence analysis tasks
- Understanding the anatomy of a real world sequence analysis project
- Applying tools for sequence alignment and estimating error rates
- Ability to implement a solution to a problem in sequence analysis using Python
- Accessing genome annotation and retrieving relevant information in Pandas
- Application of Genomic intervals and arrays for sequence analysis with HTSeq

Descriptions of the possible projects including individual reading suggestions will be handed out beforehand.

### Literature

Descriptions of the possible projects including individual reading suggestions will be handed out beforehand.

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### Objective

Students are able to independently apply and record current molecular biology methods on plants, critically evaluate and communicate the results, understand the larger context of their research project and develop ideas for further experiments.

### Prerequisites / notice

- It is recommended to bring your own computer with a Python installation to the course
- simple computers can be provided
- Programming basics with Python

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### Content

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Descriptions of the possible projects including individual reading suggestions will be handed out beforehand.

### Literature

Descriptions of the possible projects including individual reading suggestions will be handed out beforehand.
The course will include topics such as microtubule polymerization dynamics and related ongoing research projects in the lab. Experimental work applied during the course will comprise methods such as cloning work & transformation, protein purification, single molecule fluorescence imaging using Total Internal Reflection Fluorescence Microscopy (TIRFM), and single molecule image analysis.

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Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

| 529-0044-00L Genetic Code Expansion for Studying Posttranslational Modifications | W 6 credits 7P | K. Lang, M. Fottner |

Abstract
In this block course we will prepare proteins bearing site-specifically installed post-translational modifications using genetic code expansion. The impact of the post-translational modifications on enzymatic activity and protein-protein interactions will be studied.

Objective
Students will learn basic techniques for genetic code expansion. They will learn how to synthesize non-canonical amino acids (ncAAs), manipulate plasmids through cloning techniques to introduce an amber codon at a user-defined site in a gene of interest, express and purify recombinant proteins bearing site-specific ncAAs using state-of-the-art chromatographic techniques, characterize the target protein using mass spectrometry and analyze the properties of the target protein regarding enzymatic activity and protein-protein interactions using biophysical techniques.

Content
During this block course, the participants will study the impact of different post-translational modifications (PTMs) on protein function using genetic code expansion. The participants will work in teams of two, will first synthesize different ncAAs mimicking PTMs, such as acetylated lysine, butryllysine etc.). These ncAAs will be incorporated into target proteins using orthogonal aminoacyl tRNA synthetase / tRNA pairs, which direct the site-specific incorporation in response to an in-frame introduced amber stop codon (amber suppression). Therefore, the participants will introduce the amber stop codon at different positions in the gene of interest using standard molecular cloning techniques. After recombinant expression of the target protein, the participants will isolate the ncAA-bearing target proteins using different chromatography techniques using a FPLC system. After characterization of the PTM-bearing protein using mass spectrometry, the participants will study the impact of the PTM on enzymatic activity and protein-protein interactions using biophysical techniques.

Lecture notes
All the required theoretical and experimental informations can be found in the provided script. Details will be discussed in class. Relevant research papers will be recommended for reading during the seminars.

Prerequisites / notice
This laboratory block course is designed for 3 weeks, 3.5 days. Students should have basic practical knowledge in organic synthesis, molecular cloning, protein expression and purification (participants must have attended the practical course BCB-IV prior to this block course). The maximum number of participants is currently limited to 8. Interested applicants may contact Dr. M. Fottner for further information. Commitment for attendance of entire course is necessary. The course cannot be interrupted by individual absences once started.

Block Courses in 3rd Quarter of the Semester
From 5.11.2024 to 27.11.2024

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<td>W</td>
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<td>7P</td>
<td>P. A. Kast, M. Levasseur</td>
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</table>

The enrolment is done by the D-BIOL study administration.

Abstract
During the block course in the fall semester, we will carry out biological-chemical enzyme evolution experiments using molecular genetic mutation technologies and in vivo selection in recombinant bacterial strains. The class with its very dense program consists of the practical course itself and an integrated series of seminar/lecture sessions.

Objective
All technologies used for the experiments will be explained to the students in theory and in practice with the goal that they will be able to independently apply them for the course project and in future research endeavors. After the course, an individual report about the results obtained has to be prepared.

Content
The class deals with a specifically designed and genuine research project. We intend to carry out biological-chemical enzyme evolution experiments using molecular genetic mutation technologies and in vivo selection in recombinant bacterial strains. By working in parallel, teams of 2 participants each will generate a variety of different variants of a chorismate mutase. Individual enzyme catalysts will be purified and subsequently characterized using several different spectroscopic methods. The detailed chemical-physical analyses include determination of the enzymes’ kinetic parameters, their molecular mass, and the integrity of the protein structure. The results obtained from the individual evolution experiments will be compared and discussed at the end of the class in a final seminar. We expect that during this lab course we will not only generate novel enzymes, but also gain new mechanistic insights into the investigated catalysts.

Lecture notes
A script will be distributed to the participants on the first day of the course.
Introduction to the physiological and biochemical action of insulin signaling and its role in the fasted/feeding response and in obesity and diabetes.

Further literature will be indicated in the distributed script.

Prerequisites / notice
This laboratory course will involve experiments that require a tight schedule and, particularly in the second half, very long (!) working days. The maximum number of participants for the laboratory class is limited, but surplus applicants may contact P. Kast directly to have their names added to a waiting list. A valid registration is considered a commitment for attendance of the entire course, as involved material orders and experimental preparations are necessary and, once the class has started, the flow of the experiments must not be interrupted by individual absences. In case of an emergency, please immediately notify P. Kast. For more information see http://www.kast.ethz.ch/teaching.html, from where you can also download a flyer.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Self-presentation and Social Influence fostered
Personal Competencies
Adaptability and Flexibility assessed
Critical Thinking fostered
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed

Literature
Document and recommended literature (review articles and selected primary literature) will be provided during the course.

Methods in Cellular Biochemistry
W 6 credits 7P I. Zemp, T. Kleele, V. Korkhov, U. Kutay, T. Michaels, M. Peter

Insulin Signaling
W 6 credits 7P M. Stoffel

Experimental Food Microbiology for Biologists
W 6 credits 7P M. Schuppler, A. Harms, M. Loessner

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 286 of 2653
Abstract
Teaching of basic experimental knowledge for detection and identification of microorganisms in food. Practical experiments were accompanied by theoretical introductions. Students become acquainted with classical and state-of-the-art molecular techniques for the rapid detection of foodborne pathogens and experiments in dependence on current research topics of the Laboratory of Food Microbiology.

Objective

Fachliche Lernziele
- Die Studierenden setzen im Studium erworbenes und im Rahmen der Lehrveranstaltung neu erarbeitetes Wissen ein, um zu beurteilen, welche Mikroorganismen in welchen Lebensmitteln relevant sind.
- Die Studierenden können entscheiden, welche Verfahren zum Nachweis welcher Mikroorganismen geeignet sind.

Überfachliche Lernziele
- Die Studierenden evaluieren und bewerten ihre Ergebnisse vor dem Hintergrund der verwendeten Methoden.
- Die Studierenden dokumentieren ihre Tätigkeiten in einem Laborjournal in übersichtlicher Form und diskutieren die erhaltenen Ergebnisse kritisch.
- Die Studierenden präsentieren die erhaltenen Ergebnisse in mündlicher Form verständlich und nachvollziehbar.

Content
Teaching of basic experimental knowledge for detection and identification of foodborne pathogens by applying state-of-the-art techniques as well as modern molecular techniques for the rapid identification of relevant foodborne pathogens.

Lecture notes
Handouts were provided at the start of the course.

Literature
- Krämer: "Lebensmittel-Mikrobiologie" (Ulmer; UTB)
- Süssmuth et al.: "Mikrobiologisch-Biochemisches Praktikum" (Thieme)

Prerequisites / notice
Important information!
During the course we will work with the food-borne pathogen Listeria monocytogenes. Listeria monocytogenes represents a particular threat to pregnant women. Due to biosafety reasons participation is not allowed in case of pregnancy.

Competencies

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Method-specific Competencies
Analytical Competencies
Social Competencies
Communication
Personal Competencies
Critical Thinking

551-1119-00L Microbial Community Genomics

Number of participants limited to 10.
Prerequisites: Participants should bring their own laptop computer. Basic knowledge in [R], Python and/or UNIX is required.
The enrolment is done by the D-BIOL study administration.

Abstract
We provide training in the use of computational methods to address molecular, genetic, ecological and/or evolutionary questions by analyzing DNA sequencing data from microbial communities. The course includes lectures, tutorials, and the development of a research project at the intersection between microbiology and bioinformatics.

Objective
Students will learn concepts and methods for analyzing complex 'omics' datasets and applying them in individual projects. To facilitate learning, the course includes lectures on functional genomics, metagenomics and microbiology, along with practical sessions on scientific programming to analyze and visualize biological data. Additionally, students will learn how to plan, execute, report on, and present a scientific project.

Prerequisites / notice
Participants should bring their own laptop computer. Basic knowledge in [R], Python and/or UNIX is required.

Competencies

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management
Social Competencies
Communication
Leadership and Responsibility
Self-presentation and Social Influence
Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

551-1147-00L Bioactive Natural Products from Bacteria

Number of participants limited to 8.
The enrolment is done by the D-BIOL study administration.

Abstract
Lab course. In small groups projects of relevance to current research questions in the field of bacterial natural product biosynthesis are addressed.

Objective
Introduction to relevant subjects of the secondary metabolism of bacteria. Training in practical work in a research laboratory. Scientific writing in form of a research report.

Content
Research project on bacteria that produce bioactive natural products (e.g., Streptomycetes, Cyanobacteria, uncultivated bacteria). The techniques used will depend on the project, e.g., PCR, cloning, natural product analysis, precursor feeding studies, enzyme expression and analysis.

Lecture notes
none.
Introduction to Ecology

**Objective**

Studierende vertiefen ihr Wissen zu ökologischen Themen konkret anhand von:

- Vorlesungen zu Grundlagen der Ökologie
- Planen und Durchführen von Experimenten (z.B. Verhaltensökologie mit Insekten)
- Literaturdiskussionen
- Besprechung der Möglichkeiten zum Einsatz von Ökologie im theoretischen und praktischen Unterricht

**Content**

- Einleitung: evolutionäre Hintergrund der Ökologie / Ökologie in Forschung und Praxis
- Umweltbedingungen & Ressourcen: Abiotische Umweltbedingungen & Verfügbarkeit von Ressourcen / Klima & Biome der Erde
- Individuen & Populationen: Geburt, Tod & Wanderungen / Interspezifische Konkurrenz / Prädation, Weidegang & Parasiten / Molekular & evolutionäre Ökologie
- Lebensgemeinschaften und Ökosysteme: Von Populationen zu Lebensgemeinschaften / Muster des Artenreichtums / Energie- & Stofffluss durch Ökosysteme
- Angewandte Aspekte der Ökologie: Globale biogeochemische Kreisläufe & ihre Veränderung durch den Menschen / Naturschutzbiologie / Ökologie des Menschen: Bevölkerungswachstum, Krankheiten & Nahrungsversorgung

**Lecture notes**

Kursunterlagen werden via Moodle verfügbar sein.

**Literature**


**Competencies**

- Subject-specific Competencies: Concepts and Theories, Techniques and Technologies
- Method-specific Competencies: Analytical Competencies, Communication
- Personal Competencies: Critical Thinking, Cooperation and Teamwork
- Social Competencies: Self-awareness and Self-reflection, Self-direction and Self-management

**Polymer Physics Methods for Unstructured Biomolecules**

**Objective**

Establishing a link between known phenomena, concepts and spectroscopic techniques in polymer physics on the one hand and the study of unstructured biological macromolecules on the other. Attention is paid to the relationship between molecular interactions in biopolymers and their tendency to form molecular condensates, such as membraneless organelles.

**Content**

- Part I: Molecular interactions, concepts of polymer physics, spectroscopic methods; Part II: Polymer types in biology - proteins, DNA/RNA, polysaccharides, lipids; Part III: Molecular modeling and determination of conformational ensembles.

**Lecture notes**

Script for part I of the course in HS2024; slides for all three parts

**Literature**


**Competencies**

- Subject-specific Competencies: Concepts and Theories, Techniques and Technologies
- Method-specific Competencies: Decision-making, Problem-solving

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 288 of 2653
This course aims at the understanding of the cellular and molecular mechanisms underlying tissue repair processes in response to different insults. The focus will be on repair of the skin and the liver. In addition, we will highlight the parallels and differences between tissue repair and cancer. To learn modern technologies in Molecular and Cellular Biology as well as Histology and to use these techniques to study questions related to mechanisms underlying tissue repair and cancer.

**Lecture notes**
Hand-outs will be distributed.

**Literature**

No text book for ferns

**Prerequisites / notice**
Students have to present a poster on a special topic.

**Competencies**

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**551-1309-00L RNA-Biology**

*Number of participants limited to 12.
The enrolment is done by the D-BIOL study administration.*

**Abstract**
Introduction to the diversity of current RNA-research at all levels from structural biology to systems biology using mainly model systems like S. cerevisiae (yeast), mammalian cells.

**Objective**
The students will get an overview about the diversity of current RNA-research. They will learn to design experiments and use techniques necessary to analyze different aspects of RNA biology. Through lectures and literature seminars, they will get an overview of the burning questions of RNA research and discuss approaches to address these questions experimentally. In practical lab projects the students will work in one of the participating laboratories. Finally, they will learn how to present and discuss their data in an appropriate manner. Student assessment is a graded semester performance based on individual performance in the laboratory, the written exam and the poster presentation.

**Literature**
Documentation and recommended literature will be provided at the beginning and during the course.

**Prerequisites / notice**
The course will be taught in English.

**Competencies**

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<th>Media and Digital Technologies</th>
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**551-1511-00L Parallels Between Tissue Repair and Cancer**

*Number of participants limited to 20.
The enrolment is done by the D-BIOL study administration.*

**Abstract**
This course aims at the understanding of the cellular and molecular mechanisms underlying tissue repair processes in response to different insults. The focus will be on repair of the skin and the liver. In addition, we will highlight the parallels and differences between tissue repair and cancer.

**Objective**
To learn the cellular and molecular principles underlying tissue repair processes, in particular in the skin and in the liver, and the parallels and differences to cancer. To learn modern technologies in Moleculer and Cellular Biology as well as Histology and to use these technologies to study questions related to mechanisms underlying tissue repair and cancer.

**Content**
This course aims at the understanding of the cellular and molecular mechanisms underlying tissue repair processes in response to different insults. The focus will be on repair of the skin and the liver. In addition, we will highlight the parallels and differences between tissue repair and cancer. Experimental approaches include biochemical studies, molecular and cellular studies using cultured cell lines and primary cells, as well as analysis of murine and human tissues.

The course combines practical work with lectures, discussions, project preparations and presentations.

**Lecture notes**
siehe Lernmaterialien

**551-1403-00L Imaging Bacterial Cells in a Native State by Electron Cryotomography**

*Number of participants limited to 15.
The enrolment is done by the D-BIOL study administration.*

**Abstract**
The goal is to acquire the techniques to image bacteria by electron cryotomography, resolving their structure in a native state, in 3D, and to macromolecular resolution. In a small group, students will perform wet lab experiments, data collection with state-of-the-art equipment, data processing and analyses. The key method and its application in bacterial cell biology will be introduced by lectures.

**Objective**
Students will acquire the skills to cultivate bacteria, plunge-freeze samples for cryotomography, collect data using an electron cryomicroscope, process raw data, analyze tomograms, perform subtomogram averaging, model structures of interest, and generate movies for visualization, https://www.mbiol.ethz.ch/groups/pilhofer_group/

**551-1417-00L In Vivo Cryo-EM Analysis of Dynein Motor Proteins**

*Number of participants limited to 5.
The enrolment is done by the D-BIOL study administration.*

**Abstract**
Motor proteins convert chemical energy into mechanical motion. In this block course, we study dynein motor proteins in cilia. Dynein causes conformational change upon ATP hydrolysis and finally generate ciliary bending motion. Participants will analyze cryo-EM data of cilia and visualize in vivo 3D structure of dynein to learn how motor proteins function in the cell.

**Objective**
The goal of this course is to be familiar with structural biology techniques of cryo-electron tomography and single particle cryo-EM studies on motor proteins. The main focus is 3D image analysis of cryo-EM datasets acquired by highest-end microscopes. Participants will learn structure-function relationship at various scales: how the conformational change of motor proteins causes mechanical force and generates cellular motility.
Motor proteins, such as dynein, myosin and kinesin, hydrolyze ATP to ADP and phosphate to convert chemical energy to mechanical motion. Their function is essential for intracellular transport, muscle contraction and other cellular mobility as well as cell division. Motor proteins have been major targets of biophysical studies. There exist questions from atomic to tissue levels – how ATP hydrolysis causes conformational change of motor proteins; how their motion is regulated by calcium, phosphorylation and other factors; how motions of multiple motor proteins are coordinated to generate cellular motility. Structural biology has been playing central roles to answer these questions. X-ray crystallography and single particle cryo-EM address structural analysis at atomic resolution and try to reveal molecular mechanism of conformational change. Cryo-electron tomography analyze localization and 3D structure of motor proteins in the cell to explain how motions of molecular motors happen in the context of cellular environment and are integrated into cellular motion.

In this course, we study dyneins in cilia. Cilia are force-generating organelles, made by microtubules and thousands of dyneins. Dynein hydrolyzes ATP and undergoes conformational change, generating linear motion with respect to the microtubule. As a whole system, cilia integrate motions of these dyneins and orchestrate beating motion. To explain ciliary motion at molecular level, we need to know dynein conformational change in the cellular context. Cryo-electron tomography is recently developed technique to study molecular structures in vivo and therefore a suitable method to study dynein in cilia. Recently spatial resolution of these cryo-EM techniques was dramatically improved, driven by development of new types of detectors and electron optics.

The participants of this course will learn a program to analyze cryo-electron tomography and single particle cryo-EM data, acquired by highest-end electron microscopes and detectors in ETH and other places, and reconstruct 3D structure (tomogram) of cilia from various organisms (from green algae to human). They will further learn a program to study molecular structures from these tomograms (called subtomogram averaging) and apply it to reconstruct high-resolution 3D structure of dyneins, microtubules and regulatory proteins. This practical course is therefore mainly computational, but we will also provide students a chance of cilia preparation from green algae, cryo-EM data collection using an electron microscope in PSI and site-visit of highest-end electron microscope facility in ETH.

Prerequisites / administration.

The course can only be booked via the Biology Office of administration.

The enrolment is done by the D-BIOL study administration.


Number of participants limited to 6.

Characterization of the Aggregation Landscape of Peptide Amyloids and their Chemical Templating

The course can only be booked by the Biological Office of Student Affairs.

This course combines Limnology (the study of inland waters in its broad sense) with ecological and evolutionary concepts. It deals with aquatic ecosystems in Switzerland and the most important identification traits.

During the experimental part of this course you will learn the principles of doing research to observe interrelations in aquatic ecosystems. This course contains a lecture part, an experimental part, two determination courses (aquatic invertebrates and algae) as well as excursions.

During the block course, each student will learn how to handle aggregation-prone peptides, characterize their aggregation state and structure as well as assay their ability to template their own chemical synthesis.

This course is divided between lectures practical work in the lab. The lectures will introduce the general topic of amyloids and in particular their potential role in the origin of molecular complexity, as well as cover the theory and the practice behind the tools that are used to characterize peptide amyloids. The practical work in the lab will allow the students to gain hands-on experience working on a novel peptide that has yet to be characterized. Since the course consists of genuine research we also hope that new discoveries will be made that will provide insights into the role that amyloids may have in the origin of life.

The maximal participating number of biology students is 16.

Further literature will be indicated in the distributed script.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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Further literature will be indicated in the distributed script.

From 17.09.2024 to 01.11.2024

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<th>Number</th>
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<th>Lecturers</th>
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</table>

- **Abstract**: This course combines Limnology (the study of inland waters in its broad sense) with ecological and evolutionary concepts. It deals with aquatic ecosystems in Switzerland and the most important identification traits.

- **Objective**: The participants of this course will learn a program to analyze cryo-electron tomography and single particle cryo-EM data, acquired by highest-end electron microscopes and detectors in ETH and other places, and reconstruct 3D structure (tomogram) of cilia from various organisms (from green algae to human). They will further learn a program to study molecular structures from these tomograms (called subtomogram averaging) and apply it to reconstruct high-resolution 3D structure of dyneins, microtubules and regulatory proteins. This practical course is therefore mainly computational, but we will also provide students a chance of cilia preparation from green algae, cryo-EM data collection using an electron microscope in PSI and site-visit of highest-end electron microscope facility in ETH.

- **Content**: The course contains a lecture part, an experimental part, two determination courses (aquatic invertebrates and algae) and field excursions.

- **Lecture notes**: A script will be distributed to the participants on the first day of the course.


Further literature will be indicated in the distributed script.
Competencies

Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies

- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management assessed

Social Competencies

- Communication assessed
- Cooperation and Teamwork assessed
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered

Personal Competencies

- Negotiation assessed
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

529-0810-01L Laboratory Course Organic Chemistry II W 12 credits 14P C. Thilgen

- Admittance is limited and depends on the availability of hosting research labs.
- Interested students are asked to contact Prof. C. Thilgen (thilgen@org.chem.ethz.ch) before the end of the preceding semester for further details.
- In case of admittance, the actual enrolment needs to be done via the D-BIOL study administration.

Abstract

An organic-synthetic sub-project of the current research of a group from the Laboratory of Organic Chemistry is carried out under the guidance of doctoral students.

Objective

Learn to plan and carry out challenging multistep syntheses making use of modern methods; reach a deeper understanding of organic reactions through experimental work; develop an organic-synthetic research project; take accurate notes, write a publication style report, and present the obtained results in a seminar.

Content

An organic-synthetic sub-project of the current research of a group from the Laboratory of Organic Chemistry is carried out under the guidance of doctoral students.

Lecture notes

No course notes.

Literature

No set textbooks. Literature will be indicated or provided by the supervising tutors.

Prerequisites / notice

Course prerequisites: Accomplished laboratory course Organic Chemistry I (529-0229-00 or 529-0016-00) and passed session exams Organic Chemistry I (529-0221-00 or 529-1011-00) / Organic Chemistry II (529-0222-00 or 529-1012-00). The number of participants per course is limited to 4.

Competencies

Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies

- Analytical Competencies assessed
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

Social Competencies

- Communication fostered
- Cooperation and Teamwork fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered

Personal Competencies

- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

Block Courses in the 2nd Half of the Semester

From 05.11.2024 to 20.12.2024

<table>
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<tr>
<th>Number</th>
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<td>Laboratory Course Organic Chemistry II</td>
<td>W</td>
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<td>14P</td>
<td>C. Thilgen</td>
</tr>
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</table>

- Admittance is limited and depends on the availability of hosting research labs.
- Interested students are asked to contact Prof. C. Thilgen (thilgen@org.chem.ethz.ch) before the end of the preceding semester for further details.
- In case of admittance, the actual enrolment needs to be done via the D-BIOL study administration.

Abstract

An organic-synthetic sub-project of the current research of a group from the Laboratory of Organic Chemistry is carried out under the guidance of doctoral students.

Objective

Learn to plan and carry out challenging multistep syntheses making use of modern methods; reach a deeper understanding of organic reactions through experimental work; develop an organic-synthetic research project; take accurate notes, write a publication style report, and present the obtained results in a seminar.

Content

An organic-synthetic sub-project of the current research of a group from the Laboratory of Organic Chemistry is carried out under the guidance of doctoral students.

Lecture notes

No course notes.

Autumn Semester 2024
No set textbooks. Literature will be indicated or provided by the supervising tutors.

Course prerequisites: Accomplished laboratory course Organic Chemistry I (529-0229-00 or 529-0016-00) and passed session exams Organic Chemistry I (529-0221-00 or 529-1011-00) / Organic Chemistry II (529-0222-00 or 529-1012-00). The number of participants per course is limited to 4.

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Block Courses during the Semester Break

<table>
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<tr>
<th>Number</th>
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<td>Genomic and Genetic Methods in Cell and Developmental Biology</td>
<td>W</td>
<td>6 credits</td>
<td>7P</td>
<td>A. Wutz, M. Kopf, T. Schroeder</td>
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Abstract
This course aims to provide students with a comprehensive overview of mammalian developmental biology and stem cell systems both on the theoretical as well as the experimental level. Centering the course on genetic and genomic methods engages the students in contemporary research and prepares for future studies in the course of semester and master projects.

Objective
- Understanding mammalian development
- Introduction to stem cells systems
- Working with cultured cells
- Translational aspects of mammalian cell biology

Content
The course will consist of a series of lectures, assay assignments, project development and discussion workshops, and 2 and a half weeks of lab work with different mammalian cell systems embedded in real life research projects. At the end of the course students will take an exam consisting of questions on the topic of the lectures and workshops. It is expected that students will be able to apply the knowledge to concrete problems.

Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Problem-solving: assessed
  - Project Management: fostered

- Social Competencies
  - Communication: assessed

- Personal Competencies
  - Adaptability and Flexibility: assessed
  - Creative Thinking: fostered
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: assessed
  - Self-direction and Self-management: fostered

Science in Perspective

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-BIOL

Language Courses

see Science in Perspective: Language Courses ETH/UZH

Biology Bachelor - Key for Type

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<td>Recommended, not eligible for credits</td>
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European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Biology Teaching Diploma
Detailed information on the programme at: www.didaktischeausbildung.ethz.ch

Educational Science

Course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC". Please note that the course unit number will change from autumn semester 2024 onwards. This change has no influence on the course units and achievements completed so far and will be recognized for the respective degree.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>871-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects W</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>R. Schumacher</td>
</tr>
<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<tr>
<td></td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.</td>
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<tr>
<td>Objective</td>
<td>- Get to know cognitively activating instructions in MINT subjects</td>
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<tr>
<td></td>
<td>- Get information about recent literature on learning and instruction</td>
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</tr>
<tr>
<td>Prerequisites</td>
<td>Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.</td>
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see Educational Science Teaching Diploma

<table>
<thead>
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<tr>
<td>871-0242-07L</td>
<td>Human Intelligence W</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>E. Stern</td>
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<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<tr>
<td></td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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<tr>
<td>Abstract</td>
<td>The focus will be on the book &quot;Intelligenz: Grosse Unterschiede und ihre Folgen&quot; by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.</td>
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<tr>
<td>Objective</td>
<td>- Understanding of research methods used in the empirical human sciences</td>
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<td></td>
<td>- Getting to know intelligence tests</td>
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<tr>
<td></td>
<td>- Understanding findings relevant for education</td>
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<tr>
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<th>Hours</th>
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<tbody>
<tr>
<td>871-0229-00L</td>
<td>Using Outdoor Education W</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>R. Schumacher, P. Faller</td>
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<td>Enrolment only possible with matriculation in Teaching Diploma Biology and Geography.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>In this seminar, future teachers will be trained to prepare and conduct excursions to out-of-school learning venues. For this purpose, excursions are offered at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf.</td>
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<tr>
<td>Objective</td>
<td>Future teachers will learn to prepare and conduct excursions to out-of-school learning venues.</td>
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</tr>
<tr>
<td>Content</td>
<td>Excursions at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf:</td>
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<td></td>
<td>- Dendrochronology: What annual rings tell</td>
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<td></td>
<td>- Photosynthesis/Climate change: The tracks in the forest</td>
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<td></td>
<td>- Forest Soil: The soil in the focus of the climate</td>
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Subject Didactics in Biology

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>551-0961-00L</td>
<td>Mentored Work Subject Didactics Biology A O</td>
<td>O</td>
<td>2</td>
<td>4A</td>
<td>P. Faller, H. Stocker</td>
</tr>
<tr>
<td></td>
<td>The Subject Didactics as well as possible branch-specific requirements must be fulfilled prior to commencing the mentored paper.</td>
<td></td>
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<tr>
<td>Abstract</td>
<td>In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures. Under supervision, they compile tuition materials enabling effective learning and/or analyse and reflect on certain topics from a subject-based and pedagogical perspective.</td>
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<tr>
<td>Objective</td>
<td>The objectives for the students are</td>
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<td></td>
<td>- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics, pedagogical, and potentially social perspective.</td>
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<tr>
<td>Content</td>
<td>Thematische Schwerpunkte</td>
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<tr>
<td></td>
<td>Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.</td>
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<td></td>
<td>Lernformen</td>
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<tr>
<td>Lecture notes</td>
<td>Eine kurze Anleitung zur mentorierten Arbeit in Fachdidaktik wird zur Verfügung gestellt.</td>
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</tr>
<tr>
<td>Literature</td>
<td>Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.</td>
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</tr>
<tr>
<td>Prerequisites</td>
<td>Beginn nach Absprache jederzeit möglich, jedoch erst nach Abschluss der Fachdidaktik I und II und nach Erfüllung allfälliger fachwissenschaftlicher Auflagen.</td>
<td></td>
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<tr>
<td></td>
<td>Die Arbeit sollte vor Beginn des Unterrichtspraktikums abgeschlossen werden.</td>
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</tbody>
</table>

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<th>Number</th>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>551-0962-00L</td>
<td>Mentored Work Subject Didactics Biology B O</td>
<td>O</td>
<td>2</td>
<td>4A</td>
<td>P. Faller, H. Stocker</td>
</tr>
<tr>
<td></td>
<td>The Subject Didactics as well as possible branch-specific</td>
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</tbody>
</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 294 of 2653
requirements must be fulfilled prior to commencing the mentored paper.

**Abstract**
In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures. Under supervision, they compile tuition materials enabling effective learning and/or analyse and reflect on certain topics from a subject-based and pedagogical perspective.

**Objective**
The objectives for the students are

- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics, pedagogical, and potentially social perspective.

- to prove that they can independently compile a tuition sequence and develop it to deployment.

**Content**
Thematic Schwerpunkte
Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.

Lernformen

**Lecture notes**
Eine kurze Anleitung zur mentorierten Arbeit in Fachdidaktik wird zur Verfügung gestellt.

**Literature**
Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.

**Prerequisites / notice**
Beginn nach Absprache jederzeit möglich, jedoch erst nach Abschluss der Fachdidaktik I und II und nach Erfüllung allfälliger fachwissenschaftlicher Auflagen.

Die Arbeit sollte vor Beginn des Unterrichtspraktikums abgeschlossen werden.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0971-00L</td>
<td>Subject Didactics Biology I - Simultaneous enrolment in Introductory Internship Biology</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>P. Faller</td>
</tr>
</tbody>
</table>

**Number**

8 credits

- Basic conditions for tuition (MAR - recognition of Matura certificates - curricula, standards), selection of topics and reduction of the complexity of topics.
- Application of teaching methods and techniques from educational science in biology classes.
- Planning and preparation of lessons.

**Objective**
Students can discuss and put into practice in their teaching work the conditions and objectives set out in the regulations governing the school-leaving examination (Matura), the framework curriculum and the conditions and objectives specified by their school.

- They are in a position to select learning objectives and formulate these on the basis of the target level model. They can plan and prepare lessons and can also develop appropriate learning assignments.
- Students can reconstruct specialist contents in didactic terms and develop teaching modules suitable for the different levels from these on the basis of the subject structure and learner requirements.
- They can reduce the complexity of subject-based specialist contents and present them in such a way that they are comprehensible and meaningful for learners.
- They can select appropriate media for their work (e.g. school books) and use these. They can employ appropriate experiments.
- The students can use different forms of examination for monitoring performance.
- Students are in a position to implement and discuss the concepts of biology teaching and learning on the basis of specific topics covered in school biology.

**Content**

**Lecture notes**
Wird laufend in der Vorlesung abgegeben.

**Prerequisites / notice**
Studierende müssen LE zusammen mit dem Einführungspraktikum - LE 551-0968-00L - belegen.

**Professional Training**
Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>551-0968-00L</td>
<td>Introductory Internship Biology - Simultaneous enrolment in Biology Didactics I - course 551-0971-00L - is compulsory.</td>
<td>O</td>
<td>3</td>
<td>6P</td>
<td>P. Faller</td>
</tr>
</tbody>
</table>

**Abstract**
During the introductory teaching practice, the students sit in on five lessons given by the teacher responsible for their teaching practice, and teach five lessons themselves. The students are given observation and reflection assignments by the teacher responsible for their teaching practice.

**Objective**
Right at the start of their training, students acquire initial experience with the observation of teaching, the establishment of concepts for teaching and the implementation of teaching. This early confrontation with the complexity of everything that teaching involves helps students decide whether they wish to and, indeed, ought to, continue with the training. It forms a basis for the subsequent pedagogical and subject-didactics training.

**Content**

**Literature**
Wird von der Praktikumslehrperson bestimmt.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0966-00L</td>
<td>Teaching Internship Biology - Simultaneous enrolment in Subject Didactics I</td>
<td>O</td>
<td>8</td>
<td>17P</td>
<td>P. Faller</td>
</tr>
</tbody>
</table>

**Abstract**
The teaching practice takes in 50 lessons: 30 are taught by the students, and the students sit in on 20 lessons. The teaching practice lasts 4-6 weeks. It gives students the opportunity to implement the contents of their specialist-subject, educational science and subject-didactics training in the classroom. Students also conduct work assignments in parallel to their teaching practice.
- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics in their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They acquire the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils’ work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

**Content**

**Literature**
Wird von der Praktikumslehrperson bestimmt.

**Prerequisites / notice**
Findet in der Regel am Schluss der Ausbildung, vor Ablage der Prüfungslektionen statt.

#### 551-0969-01L Examination Lesson I Biology

**Abstract**
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

**Objective**
- On the basis of a specified topic, the candidate shows that they are in a position
- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle
- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

**Content**
Die Studierenden erfahren das Lektionsthema in der Regel 10 Tage vor dem Prüfungstermin. Von der zuständigen Lehrperson erhalten sie Informationen über den Wissensstand der zu unterrichtenden Klasse und können sie vor dem Prüfungstermin besuchen.
Sie erstellen eine Vorbereitung gemäss Anleitung und reichen diese 48 Stunden vor dem Prüfungstermin den beiden Prüfungsexperten ein.

Die gehaltene Lektion wird kriteriernbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/ der Kandidatin über die gehaltene Lektion im Rahmen eines kurzen Kolloquiums.

**Lecture notes**
Nach Abschluss der übrigen Ausbildung.

**Prerequisites / notice**

#### 551-0969-02L Examination Lesson II Biology

**Abstract**
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

**Objective**
On the basis of a specified topic, the candidate shows that they are in a position
- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle
- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

**Content**
Die Studierenden erfahren das Lektionsthema in der Regel 10 Tage vor dem Prüfungstermin. Von der zuständigen Lehrperson erhalten sie Informationen über den Wissensstand der zu unterrichtenden Klasse und können sie vor dem Prüfungstermin besuchen.
Sie erstellen eine Vorbereitung gemäss Anleitung und reichen diese 48 Stunden vor dem Prüfungstermin den beiden Prüfungsexperten ein.

Die gehaltene Lektion wird kriteriernbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/ der Kandidatin über die gehaltene Lektion im Rahmen eines kurzen Kolloquiums.

**Lecture notes**
Nach Abschluss der übrigen Ausbildung.

**Prerequisites / notice**

#### 551-0913-00L Professional Exercises in Biology

**Abstract**
Students conduct a series of "classical" biological school experiments and therefore gain practice and experience in this area.

**Objective**
Implementation of Subject Didactics I and II with the focus on conducting biological experiments in schools. This includes finding, testing and further developing suitable protocols for different subject areas of school biology. Working out how to didactically embed the experiments in lessons.

Students can perform, off the cuff, 12 school experiments (which they have tested themselves), from the different subject areas, and conduct these correctly in technical terms. They can incorporate these experiments in their tuition in a didactically meaningful manner.

**Content**
2. Die Studierenden führen alle ausgearbeiteten Experimente selber durch.

**Lecture notes**
Hand out of course material.

**Prerequisites / notice**
Der Teil biologische Experimente findet im Rahmen von 7 Halbtagen statt.


**Number**
551-0976-00L

**Title**
Innovative Biology Teaching at High School

**Abstract**
An adequate treatment of current topics of biological research in high schools is a central challenge for future teachers. In this module, students either develop learning materials that aim to prepare new content in a way that is suitable for pupils, or they focus on testing activating forms of learning in real lessons.
Objective

Students learn to
- engage with current biological research and its relevance to society
- carefully select content for high school
- make meaningful and correct didactic reductions
- compose activating and motivating learning arrangements
- put prepared lessons into practice
- reflect on their role as a teacher.

Content

Students can choose from three options:

Seminar paper;
Writing a textbook chapter on a current topic in biological research (focus on content).

Subject didactics practicum:
Planning and implementation of biology lessons with special consideration of activating forms of learning (focus on didactics).

Innovative lesson:
Planning of a specific lesson with new content and testing it in a real-life context (focus on content and didactics).

Prerequisites / notice

The results will be presented and discussed in a seminar.

The module "Innovative Biology Teaching at High School" is an integral part of the Specialized Biology Course with an Educational Focus. Before taking this module, at least one of the two lectures should have been completed.

The Specialized Biology Course with an Educational Focus can be acknowledged, in agreement with the advisor of the respective elective major, as one of the two obligatory research projects. In such a case, additional 3 CP must be obtained in another course.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Media and Digital Technologies</td>
<td>Communication</td>
<td>Creative Thinking</td>
</tr>
<tr>
<td>fostered</td>
<td>fostered</td>
<td>fostered</td>
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<tr>
<td>Problem-solving</td>
<td>Project Management</td>
<td>Cooperation and Teamwork</td>
<td>Self-direction and Self-management</td>
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<tr>
<td>Self-presentation and Social Influence</td>
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<td>Leadership and Responsibility</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
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<td>Self-presentation and Social Influence</td>
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<tr>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
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</table>

Literature

Teaching materials are available online on Moodle.

Content

After successful completion of the module, students should be able
- to retrieve in-depth knowledge of biology with a special focus on evolution and to impart this to others.
- to analyse controversial topics and to give factual explanations for these.
- to prepare teaching units suitably tailored to the recipients, with complex learning matter on a high professional level.

The Specialized Biology Course with an Educational Focus consists of three modules (4 CP each). In the fall semester, the focus of the lecture is on evolution. The lecture of the spring semester deals with biological concepts. The sequence of assignment is free. In addition, the module "Innovative Biology Teaching at High School" has to be completed.

In case of overbooking of the course, students enrolled in the Teaching Diploma in Biology will have priority.

Competencies

<table>
<thead>
<tr>
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</table>

551-0973-00L Specialized Biology Course with an Educational Focus: Evolution

Abstract

Specialist aspects of biology with a focus on evolution are covered from the angle of imparting these to pupils, their historical development, and their significance for the subject, the individual and society.

Objective

After successful completion of the module, students should be able
- to retrieve in-depth knowledge of biology with a special focus on evolution and to impart this to others.
- to analyse controversial topics and to give factual explanations for these.
- to prepare teaching units suitably tailored to the recipients, with complex learning matter on a high professional level.

Content

Selected biological topics, with a special focus on evolution, are dealt with under consideration of the special needs of persons involved in teaching.

The module comprises lectures, a book club, and a project assignment.

Prerequisites / notice

The Specialized Biology Course with an Educational Focus consists of three modules (4 CP each). In the fall semester, the focus of the lecture is on evolution. The lecture of the spring semester deals with biological concepts. The sequence of assignment is free. In addition, the module "Innovative Biology Teaching at High School" has to be completed.

Performance is assessed during the course of the entire module. Active participation in the course is required.

The Specialized Biology Course with an Educational Focus can be acknowledged, in agreement with the advisor of the respective elective major, as one of the two obligatory research projects. In such a case, additional 3 CP must be obtained in another course.

In case of overbooking of the course, students enrolled in the Teaching Diploma in Biology will have priority.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Media and Digital Technologies</td>
<td>Communication</td>
<td>Creative Thinking</td>
</tr>
<tr>
<td>fostered</td>
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</tr>
<tr>
<td>Problem-solving</td>
<td>Project Management</td>
<td>Cooperation and Teamwork</td>
<td>Self-direction and Self-management</td>
</tr>
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<td>fostered</td>
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<tr>
<td>Self-presentation and Social Influence</td>
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<td>Leadership and Responsibility</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
<td>Self-presentation and Social Influence</td>
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<tr>
<td>Sensitivity to Diversity</td>
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</tbody>
</table>

Compulsory Elective Courses

Further course offerings from the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

Number | Title | Type | ECTS | Hours | Lecturers |
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>701-0015-00L</td>
<td>Transdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement</td>
<td>W</td>
<td>2 credits</td>
<td>1S</td>
<td>B. Vienni Baptista, C. E. Pohl, M. Stauffacher</td>
</tr>
</tbody>
</table>

Abstract

This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants' research projects more societally relevant.

Data: 15.06.2024 12:39
Autumn Semester 2024
Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, or how to secure broader impact of research. They learn to critically reflect their own research project in its societal context and on their role as scientists.

The seminar covers the following topics:
1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants' research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.

Literature will be made available to the participants. The following open access article builds a core element of the course:


Further, this collection of tools will be used:

https://naturalsciences.ch/topics/co-producing_knowledge
https://www.shapeidtoolkit.eu

Participation in the course requires participants to be working on their own research project.

During the lecture we will work with Moodle. We ask that all students register themselves on this platform before the lecture.

A detailed course schedule will be made available at the beginning of the semester. During the lecture, we will work with Moodle. We ask that all students register themselves on this platform before the lecture.

We recommend that students have (a) three-years BSc education of a technical university; (b) successfully completed Bachelor introductory course to environmental policy (Entwicklungen nationaler Umweltpolitik or equivalent); and (c) familiarity with key issues in environmental policy and some fundamental knowledge of one social science or humanities discipline (political science, economics, sociology, history, psychology, philosophy)
In this seminar, future teachers will be trained to prepare and conduct excursions to out-of-school learning venues. For this purpose, excursions are offered at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf.

Excursions at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf:
- Photosynthesis/Climate change: The tracks in the forest
- Dendrochronology: What annual rings tell
- Forest Soil: The soil in the focus of the climate

The course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined.

The course is open to all ETH students and visiting students from other universities. Participation does not require previous coursework in the social sciences or environmental policy. This course will take place on campus (ETH Main Building, HG F.3). There will be no live-streaming, and the course is NOT in hybrid (on-campus plus online) format. However, the lecture will be recorded and the recordings will be made available via the Moodle platform for this course a few days after the respective lecture for students who are unable to attend in person. All electronic correspondence will take place via the ETH mystudies system and Moodle, so please make sure you are properly registered there with a functioning email address/account.

Credits and Exam
After passing a written test at the end of the course (requirement; grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test). Visiting students (e.g., from the University of Zurich, exchange students) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory. Students who obtain a grade of < 4.0 for the test will have a second chance (see table below). Students who did not participate in the test on 18 December 2023 will not have access to the repeat test unless they submit compelling and documented (e.g. medical, other exam in parallel at ETH) reasons for why they were unable to participate in the first test. It covers all contents of the lectures and the reading assignments. Visiting students (e.g., from the University of Zurich or other universities) are subject to the same conditions. Registration for the course in the mystudies system of ETH is compulsory. No separate registration for the exam is required, registration for the course as such covers everything. The exam will take place on campus, either in the F3 lecture hall or in a computer room. That is, you must be present in person at ETH Zurich on the exam date/time.

Course Units for Additional Admission Requirements
The courses below are only available for students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0151-00L</td>
<td>Human Physiology I</td>
<td>E-</td>
<td>5</td>
<td>4V</td>
<td>W. Langhans, M. Willecke, to be announced</td>
</tr>
</tbody>
</table>

Abstract
Dieser Kurs vermittelt die Grundlagen der Physiologie und Anatomie des menschlichen Körpers
The lecture introduces the structural and functional specialization in fungi and plants. After providing an overview on the diversity of eukaryotic organisms, the lecture will discuss how fungi and plants have evolved structures and strategies to cope with the challenges of multicellularity. The molecular basis underlying communication, coordination and differentiation will be conveyed and complemented by key aspects of reproduction, metabolism and development, and regeneration. Topics include form and function of fungi and plants, metabolism, cell signaling, adhesion, stem cells, regeneration, reproduction, and development.

Content

- «Kern-Konzepte» in der Physiologie
- Struktur und Funktion
- Energettransfer, -speicherung und -nutzung
- Informationsfluss, -speicherung und -nutzung
- Homöostase
- Evolution
- Allgemeine Endokrinologie und endokrines System
- Allgemeine Neurophysiologie und Neuroanatomie
- Die chemischen Sinne, Geschmack und Geruch
- Ernährung und Verdauung
- Leber und Stoffwechsel
- Energiehomöostase
- Flüssigkeitshomöostase und Niere
- Reproduktion, Entwicklung und Altern

Humanphysiologie II (FS)

- Sinnesphysiologie
- Muskelsphysiologie
- Neurionale Kontrolle von Haltung und Bewegung
- Höhere zentralnervöse Hirnfunktionen
- Atmung und Lunge
- Herz und Kreislauf
- Blut
- Immunologie
- Thermoregulation/Fieber
- Stress

Lecture notes

Online-Material wird im Laufe des Kurses zur Verfügung gestellt.

Literature

Wird im Kurs bekannt gegeben.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Analytical Competencies</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>E- 2 credits</td>
<td>2V M. Schuppler, M. La Fortezza, M. Pilhofer, S. Robinson</td>
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</table>

752-4001-00L  

Microbiology

Some parts of the lecture will be taught in English. Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Objective

- Teaching of basic knowledge in microbiology.

Content


Lecture notes

Wird von den jeweiligen Dozenten ausgegeben.

Literature

Die Behandlung der Themen erfolgt auf der Basis des Lehrbuchs Brock, Biology of Microorganisms.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>E- 4 credits</td>
<td>3G S. C. Zeeman, M. Künzler, O. Y. Martin</td>
<td></td>
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</tr>
</tbody>
</table>

551-0127-01L  

Plants and Fungi

The lecture conveys the fundamental concepts underlying multicellularity with an emphasis on the molecular basis of multicellular biological systems and their functional integration into coherent wholes. The structural and functional specialization in multicellular organisms will be discussed by highlighting common and specific functions in fungi and plant.s

Objective

1. Students can describe advantages and challenges associated with being multicellular and outline independent solutions that organisms have developed to cope with the challenges of complex multicellularity.

2. Students can explain how the internal and external structures of fungi and plants function to support survival, growth, behavior, and reproduction.

3. Students can explain the basic pathways and mechanisms of cellular communication regulating cellular behavior (cell adhesion, metabolism, proliferation, reproduction, development).

4. Students can describe how a single cell develops from one cell into many, each with different specialized functions.

Content

The lecture introduces the structural and functional specialization in fungi and plants. After providing an overview on the diversity of eukaryotic organisms, the lecture will discuss how fungi and plants have evolved structures and strategies to cope with the challenges of multicellularity. The molecular basis underlying communication, coordination and differentiation will be conveyed and complemented by key aspects of reproduction, metabolism and development, and regeneration. Topics include form and function of fungi and plants, metabolism, cell signaling, adhesion, stem cells, regeneration, reproduction, and development.

Literature

Campbell "Biologie", 11th Edition

Prerequisites / notice

Some lecture are held in English.
551-0370-00L  Introduction to Ecology  W  6 credits  7P  O. Y. Martin

Number of participants limited to 15. The enrolment is done by the D-BIOL study administration.

ATTENTION: Students of the biology teaching diploma, please contact Dr. O. Martin until 01.08.2024.

Abstract

Objective
Studierende verlieren ihr Wissen zu ökologischen Themen konkret anhand von:
- Vorlesungen zu Grundlagen der Ökologie
- Planen und Durchführen von Experimenten (z.B. Verhaltensökologie mit Insekten)
- Literaturdiskussionen
- Einblicke in aktuelle ökologische Forschungsarbeiten im Raum Zürich (z.B. Gastvorträge, Laborbesuche)
- Besprechung der Möglichkeiten zum Einsatz von Ökologie im theoretischen und praktischen Unterricht
- Exkursionen & Führungen

Content
> Einleitung: evolutionäre Hintergrund der Ökologie / Ökologie in Forschung und Praxis


Literature

Competencies
Subject-specific Competencies
Concepts and Theories  fostered
Techniques and Technologies  fostered

Method-specific Competencies
Analytical Competencies  fostered

Social Competencies
Cooperation and Teamwork  fostered

Personal Competencies
Creative Thinking  fostered
Critical Thinking  fostered
Self-awareness and Self-reflection  fostered
Self-direction and Self-management  fostered

- Einleitung: evolutionäre Hintergrund der Ökologie / Ökologie in Forschung und Praxis
- Umweltbedingungen & Ressourcen: Abiotische Umweltbedingungen & Verfügbarkeit von Ressourcen / Klima & Biome der Erde
- Individuen & Populationen: Geburt, Tod & Wanderungen / Interspezifische Konkurrenz / Prädation, Weidegang & Parasiten / Molekulare & evolutionäre Ökologie
- Lebensgemeinschaften und Ökosysteme: Von Populationen zu Lebensgemeinschaften / Muster des Artenreichtums / Energie- & Stofffluss durch Ökosysteme
- Angewandte Aspekte der Ökologie: Globale biogeochemische Kreisläufe & ihre Veränderung durch den Menschen / Naturschutzbiologie / Ökologie des Menschen: Bevölkerungswachstum, Krankheiten & Nahrungsversorgung

Lecture notes
Kursunterlagen werden via Moodle verfügbar sein.

Special students and auditors need special permission from the lecturers.

Biology Teaching Diploma - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</table>

Key for Hours

<table>
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<tr>
<th>Key</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Biology Master

Master Studies (Programme Regulations 2023)

Majors

Major in Biochemistry

Compulsory Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0319-00L</td>
<td>Cellular Biochemistry (Part I)</td>
<td>O</td>
<td>3</td>
<td>2V</td>
<td>U. Kutay, F. Allain, T. Kleele, I. Zemp</td>
</tr>
</tbody>
</table>

**Abstract**

Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

**Objective**

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

**Content**

Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

**Lecture notes**

Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials, (alicia.smith@bbc.biol.ethz.ch)

**Literature**

Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

**Prerequisites / notice**

To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

**Competencies**

Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Compulsory Master Course

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1303-00L</td>
<td>Current Research Topics in Cellular Biochemistry</td>
<td>O</td>
<td>4</td>
<td>2S</td>
<td>T. Kleele, V. Korkhov, G. Neurohr, V. Panse, M. Peter, A. E. Smith, F. van Drogen</td>
</tr>
</tbody>
</table>

**Abstract**

During this Masters level seminar style course, students will explore current research topics in cellular biochemistry focused on the structure, function and regulation of selected cell components, and the consequences of dysregulation for pathologies.

**Objective**

Students will work with experts toward a critical analysis of cutting-edge research in the domain of cellular biochemistry, with emphasis on normal cellular processes and the consequences of their dysregulation. At the end of the course, students will be able to evaluate, critically discuss and write about scientific articles in the research area of cellular biochemistry, and they will identify open testable research questions.

**Content**

Guided by an expert in the field, students will engage in classical round-table style discussions of current literature with frontal presentations. Guided by a faculty expert, students develop domain knowledge of the research area associated with a primary paper, and alternate as discussion leaders to present the research topic. By the end of the semester, students will formulate their ideas about open testable research questions that extend from the published work.

**Literature**

The literature will be provided during the course.

**Prerequisites / notice**

The course will be taught in English.

**Competencies**

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Elective Compulsory Concept Courses

See D-BIOL Master Studies Guide

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0307-00L</td>
<td>Molecular and Structural Biology I: Protein Structure and Function</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>R. Glockshuber, K. Locher, E. Weber-Ban</td>
</tr>
</tbody>
</table>

**Abstract**

Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biochemistry and structural biology.

**Objective**

Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalyticals.

**Lecture notes**

Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.
Current topics: References will be given during the lectures.

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**Concepts in Modern Genetics**

**Information for UZH students:**

Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.

**Please mind the ETH enrolment deadlines for UZH students:**


**Abstract**

Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Objective**

This course focuses on the concepts of classical and modern genetics and genomics.

**Content**

The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Lecture notes**

Scripts and additional material will be provided during the semester.

**Competencies**

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

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**Elective Compulsory Master Courses**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1153-00L</td>
<td>Systems Biology of Metabolism</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>U. Sauer, N. Zamboni</td>
</tr>
</tbody>
</table>

**Abstract**

Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.

**Objective**

Develop a deeper understanding of how relevant biological problems can be solved, thereby providing advanced insights to key experimental and computational methods in systems biology.

**Content**

The course will be given as a mixture of lectures, studies of original research and guided discussions that focus on current research topics. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation networks in populations and single cells. Key methods to be covered are various modeling approaches, metabolic flux analyses, metabolomics and other omics.

**Lecture notes**

Script and original publications will be supplied during the course.

**Prerequisites / notice**

The course extends many of the generally introduced concepts and methods of the Concept Course in Systems Biology. It requires a good knowledge of biochemistry and basics of mathematics and chemistry.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0007-00L</td>
<td>Computational Systems Biology</td>
<td>W</td>
<td>6</td>
<td>3V+2U</td>
<td>J. Stelling</td>
</tr>
</tbody>
</table>

**Abstract**

Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

**Objective**

The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

**Content**

Biological systems have witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

**Lecture notes**

http://www.csb.ethz.ch/education/lectures.html

**Literature**


Abstract
This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

Objective
The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

Content
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

Lecture notes
A script will be available.

Literature
Faraway (2005): Linear Models with R
Faraway (2006): Extending the Linear Model with R
Draper & Smith (1998): Applied Regression Analysis
Fox (2008): Applied Regression Analysis and GLMs
Montgomery et al. (2006): Introduction to Linear Regression Analysis

Prerequisites / notice
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management fostered
Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered
Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Modern Mass Spectrometry, Hyphenated Methods, and Chemometrics
Modern mass spectrometry, hyphenated analytical methods, speciation, chemometrics.

Objective
Comprehensive knowledge about the analytical methods introduced in this course and their practical applications.

Content
Hyphenation of separation with identification methods such as GC-MS, LC-MS, GC-IR, LC-IR, LC-NMR etc.; importance of speciation. Modern mass spectrometry: time-of-flight, orbitrap and ion cyclotron resonance mass spectrometry, ICP-MS. Soft ionization methods, desorption methods, spray methods. Mass spectrometry imaging. Use of statistical and computer-assisted methods for processing analytical data (chemometrics).

Lecture notes
Lecture notes will be made available online.

Literature
Information about relevant literature will be available in the lecture & in the lecture notes.

Prerequisites / notice
Exercises are an integral part of the lecture.

Prerequisites:
529-0051-00 "Analytische Chemie I (3. Semester)"
529-0058-00 "Analytische Chemie II (4. Semester)"
(or equivalent)
Subject-specific Competencies: Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies: Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies: Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies: Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

636-0108-00L Biological Engineering and Biotechnology W 4 credits 3V M. Fussenegger

Abstract: Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective: Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.


Lecture notes: Handout during the course.

551-1407-00L RNA Biology Lecture Series I: Transcription & Processing & Translation W 4 credits 2V F. Allain, N. Ban, S. Jonas, U. Kutay, further lecturers

Abstract: This course covers aspects of RNA biology related to gene expression at the post-transcriptional level. These include RNA transcription, processing, alternative splicing, editing, export and translation. The students should obtain an understanding of these processes, which are at work during gene expression.

Objective: The students should obtain an understanding of these processes, which are at work during gene expression.

Content: Transcription & 3'end formation; splicing, alternative splicing, RNA editing; the ribosome & translation, translation regulation, RNP biogenesis & nuclear export, mRNA surveillance & mRNA turnover; signal transduction & RNA.

Prerequisites / notice: Basic knowledge of cell and molecular biology.

551-1409-00L RNA Biology Lecture Series II: Non-Coding RNAs: Biology and Therapeutics W 4 credits 2V J. Hall, M. Stoffel, further lecturers

Abstract: This course covers aspects of RNA biology related to the functions of non-coding RNAs as well as their use as drugs to treat diseases.

Objective: The students should get familiar with the wide array of roles, which non-coding RNAs play in cellular functions.

Content: Micro RNAs; computational approaches to miRNAs; micro RNA function in metabolism; viruses and viral RNAs; nucleic acid-based drugs; ncRNA-mediated genome regulation; epigenetic programming of genome remodelling in ciliates; telomerase and telomerases; tRNA biology. http://www.nccr-rna-and-disease.ch/tiki-index.php?page=LectureSeries

Prerequisites / notice: Basic knowledge of cell and molecular biology.

227-0939-00L Cell Biophysics W 6 credits 4G T. Zambelli

Abstract: Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.

Objective: Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars of thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding experimental results from the literature.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.
Content

- Basics of theory of probability
- Boltzmann's law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns

Theory and corresponding exercises are merged together during the classes.

Lecture notes

No lecture notes because the two proposed textbooks are more than exhaustive!

I am willingly available Mondays 17.00 o'clock - 18.00 in my office GLC F12.2 for whatever discussion about the lessons and the exercises.

!!! I am using OneNote. All lectures will be broadcast via ZOOM, while corresponding videos of the previous years (lectures and exercises) are available in Moodle !!!

Literature


As further deepening:


Prerequisites / notice

Participants need a good command of
- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies fostered

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management assessed

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity assessed
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

Cellular Matters: Properties, Functions and Applications of Biomolecular Condensates

551-0357-00L

W 4 credits 2S


Abstract

This Master level course delves into the emerging field of biomolecular condensates - membrane-less organelles in cells. Using interdisciplinary concepts from biology, chemistry, biophysics, and soft matter, we will explore the biological properties of these condensates, their functions in health and disease, and their potential as new biomimetic materials for various applications.
In the last decade, a novel type of cell compartments called biomolecular condensates have been discovered. This discovery is radically changing our understanding of the cell, its organization, and dynamics. The emerging picture is that the cytoplasm and nucleoplasm are highly complex fluids that can (meta)stably segregate into membrane-less compartments, similar to emulsions.

This interdisciplinary course encompasses milestone works and cutting-edge research questions in the young field of biomolecular condensates, including their properties, functions, and applications. The course begins with a lecture series that introduces the topic of condensates to an interdisciplinary audience and provides a theoretical foundation for understanding current research questions in the field. The lectures provide a base for student presentations of recent publications in the field, and for research seminars given by course lecturers, who are all active researchers with diverse expertise. Through this exciting interdisciplinary understanding of biomolecular condensates, bridging biology, chemistry, biophysics, and soft matter.

Students will not only learn how to critically read and evaluate scientific literature but will also gain valuable experience in giving scientific presentations to an interdisciplinary audience. Each presentation will require an introduction, critical analysis of the results, and a discussion of their significance, allowing student to substantiate their statements with a critical mindset that considers the pros and cons of chosen approaches and methods, as well as any limitations or possible follow-up experiments. This process will enable student to ask relevant querieis and actively participate in class discussions, further enhancing their scientific skills.

In preparing the presentations, the students will have the unique opportunity to interact closely with each other and with the lecturers, who are all internationally well-established experts, and receive guidance in select a topic for the final presentation and supporting literature.

The topic of biomolecular condensates goes beyond the boundaries of traditional disciplines and requires a multi-disciplinary approach that leverages and cross-fertilizes biology, physical chemistry, biophysics, and soft matter. This course will explore the properties, functions and potential applications of biomolecular condensates, including their role in neurodegenerative diseases such as Alzheimer's and Parkinson's, as well as their use as smart biomimetic materials.

This course is divided into two parts. The fist part will introduce the basic concepts essential to the study of biomolecular condensates and phase separation. Topics include: fundamental units and scales in soft matter, phase transitions in biology, biopolymers and molecular self-assembly, introduction to active matter. This will establish a foundation for the second part, which will explore milestone works and current research in the field of biomolecular condensates. Each lecture of this second part will consist of:

1) a short literature seminar, where student groups will present and discuss a milestone paper assigned in advance and 2) a research seminar, where one of the course lecturers will present their own state-of-the-art research in the field, building upon the milestone literature.

At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate this, students must confirm their registration by the beginning of the 3rd week of semester.

Lecture slides and some scripts will be provided.

Lecture notes: Literature

No compulsory textbooks. Literature will be provided during the course.

Chemical Biology and Synthetic Biochemistry

Overview of modern chemical biology and synthetic biochemistry techniques, focussed on protein modification and labeling and on methods to endow proteins with novel functionalities.

529-0733-02L

Objective: After taking this course, students should be capable of the following: A) Recall different possibilities for modifying proteins in vitro and in vivo and their applications in a biological context. B) Understand the chemical and biochemical consequences of modifications and assess the different reaction possibilities in the context of in vivo - in vitro. C) Critically analyze and assess current chemical biology articles. D) Question the approaches learned and apply them to new biological problems.

Content: Students will not only learn how to critically read and evaluate scientific literature but will also gain valuable experience in giving scientific presentations to an interdisciplinary audience and provides a theoretical foundation for understanding current research questions in the field.

Chemical Biology and Synthetic Biochemistry leverages and cross-fertilizes biology, physical chemistry, biophysics, and soft matter. This course will explore the properties, functions and potential applications of biomolecular condensates, including their role in neurodegenerative diseases such as Alzheimer's and Parkinson's, as well as their use as smart biomimetic materials.

Methods to endow proteins with novel functionalities. Advanced genetic code expansion methods (amber suppression, orthogonal ribosomes, unnatural base pairs, genome engineering and genome editing). Directed evolution and protein engineering.

Chemical biology of ubiquitin and targeted protein degradation.

A script will not be handed out. Handouts to the lecture will be provided through moodle.

K. Lang, M. Fottner

Autumn Semester 2024

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Data: 15.06.2024 12:39
Competencies

- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: fostered

- Social Competencies
  - Communication: fostered
  - Cooperation and Teamwork: fostered
  - Customer Orientation: fostered
  - Leadership and Responsibility: fostered
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered
  - Negotiation: fostered

- Personal Competencies
  - Adaptability and Flexibility: fostered
  - Creative Thinking: assessed
  - Critical Thinking: fostered
  - Integrity and Work Ethics: assessed
  - Self-presentation and Self-reflection: fostered
  - Sensitivity to Diversity: fostered
  - Negotiation: fostered

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#### Elective Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>551-0307-00L</td>
<td>Molecular and Structural Biology I: Protein Structure and Function</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>R. Glockshuber, K. Locher, E. Weber-Ban</td>
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<td>D-BIOL students are obliged to take part I and part II (next semester) as a two-semester course</td>
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<td><strong>Abstract</strong></td>
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<td>Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.</td>
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<td>Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.</td>
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<td><strong>Lecture notes</strong></td>
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<td>Scripts on the individual topics can be found under <a href="http://www.mol.bioli.ethz.ch/teaching">http://www.mol.bioli.ethz.ch/teaching</a>.</td>
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<td><strong>Literature</strong></td>
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<td>- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.</td>
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<td>Current topics: References will be given during the lectures.</td>
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<td>551-0309-00L</td>
<td>Concepts in Modern Genetics</td>
<td>W</td>
<td>6</td>
<td>4V</td>
<td>Y. Barral, A. Hajnal, O. Voinnet, University lecturers</td>
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<td><strong>Information for UZH students:</strong> Enrolment to this course unit only possible at ETH. No enrolment to module BIC348 at UZH.</td>
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<td><strong>Abstract</strong></td>
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<td>Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.</td>
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<td>This course focuses on the concepts of classical and modern genetics and genomics.</td>
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<td><strong>Content</strong></td>
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<td>The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.</td>
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<td>Scripts and additional material will be provided during the semester.</td>
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<td><strong>Competencies</strong></td>
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<td>Subject-specific Competencies</td>
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<td>Concepts and Theories: assessed</td>
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<td>Analytical Competencies: assessed</td>
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<td>Decision-making: fostered</td>
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<td>Media and Digital Technologies: fostered</td>
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<td>Problem-solving: assessed</td>
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<td>Creative Thinking: assessed</td>
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<td>Self-awareness and Self-reflection: fostered</td>
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<td>Self-direction and Self-management: fostered</td>
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<tr>
<td>551-0313-00L</td>
<td>Microbiology (Part I)</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>W.-D. Hardt, L. Eberl, B. Nguyen, J. Piel, M. Pilhofer, A. Vagstad</td>
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<td><strong>Abstract</strong></td>
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<td>Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.</td>
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<td>This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.</td>
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<td><strong>Content</strong></td>
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<td></td>
<td>Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.</td>
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<td><strong>Lecture notes</strong></td>
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<td>Updated handouts will be provided during the class.</td>
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### Immunology I

**Title:** Immunology I  
**W** 3 credits  
**V**  

**M. Kopf, A. Oxenius**

**Abstract:** Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

**Objective:** Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

**Content:**  
- Introduction and historical background  
- Innate and adaptive immunity, Cells and organs of the immune system  
- B cells and antibodies  
- Generation of diversity  
- Antigen presentation and Major Histoincompatibility (MHC) antigens  
- Thymus and T cell selection  
- Autoimmunity  
- Cytotoxic T cells and NK cells  
- Th1 and Th2 cells, regulatory T cells  
- Allergies  
- Hypersensitivities  
- Vaccines, immune-therapeutic interventions

**Lecture notes:** Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"

**Literature:** - Kuby, Immunology, 9th edition, Freemen + Co., New York, 2020

**Prerequisites / notice:** For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

**Competencies**  
- Subject-specific Competencies  
- Analytical Competencies  
- Decision-making  
- Problem-solving  
- Project Management  
- Communication  
- Cooperation and Teamwork  
- Adaptability and Flexibility  
- Creative Thinking  
- Critical Thinking  
- Self-direction and Self-management

### Nucleic Acids and Carbohydrates

**Title:** Nucleic Acids and Carbohydrates  
**W** 6 credits  
**G**  

**K. Lang, M. Frei, P. A. Kast, H. Wennemers**

**Note for BSc Biology students:** Only one of the two concept courses 529-0731-00 Nucleic Acids and Carbohydrates (autumn semester) or 529-0732-00 Proteins and Lipids (spring semester) can be counted for the Bachelor's degree.

**Abstract:** Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

**Objective:** Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

**Content:** Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

**Lecture notes:** No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).

**Literature:** Mainly based on original literature, a detailed list will be distributed during the lecture

**Competencies**  
- Subject-specific Competencies  
- Analytical Competencies  
- Problem-solving  
- Communication  
- Cooperation and Teamwork  
- Self-awareness and Self-reflection  
- Self-direction and Self-management

#### Recommended Master Courses

**Number**  
551-0575-00L  

**Title:** Writing Scientific Reports for MSc Biology  
**W** 2 credits  
**G**  

**R. Taylor**

**Abstract:** This short course is designed to accompany MSc students in writing their first reports in English, providing input on scientific writing in English as well as feedback on drafts sections of the report.

**Objective:** Students will learn to:  
- Plan, draft, structure, and edit scientific reports  
- Produce reader-friendly sentences  
- Establish a clear and logical flow between sentences and paragraphs  
- Select formal vocabulary and use it in a generally accurate and correct manner  
- Choose and use generally suitable grammatical structures, punctuation, and identify areas in which further development is needed
The course covers the process of writing reports in biology, helping students to focus on the language and communicative aspects of these reports. Topics covered include structuring sentences, paragraphs, and longer sections (introductions, methods, etc.); presenting and integrating non-textual elements such as graphs and tables; reviewing common grammar problems for advanced writers in English; and editing drafts and proofs. Sessions will consist of a mix of specialist input, group and pair work, and editing sessions.

Students who attend this course will turn in three sections of a report (approx. 500 words each) for feedback, revising these texts for a final portfolio that is graded.

Participants should be at a stage in their research where they can already start drafting parts of the report.

### Major in Biological Chemistry
#### Compulsory Concept Courses

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>529-0731-00L</td>
<td>Nucleic Acids and Carbohydrates</td>
<td>O</td>
<td>6</td>
<td>3G</td>
<td>K. Lang, M. Frei, P. A. Kast, H. Wennemers</td>
</tr>
</tbody>
</table>

**Abstract**
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombiant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

**Objective**
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombiant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

**Content**
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombiant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

**Lecture notes**
No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).

**Literature**
Mainly based on original literature, a detailed list will be distributed during the lecture

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Problem-solving: assessed
- Social Competencies
  - Communication: assessed
  - Cooperation and Teamwork: assessed
- Personal Competencies
  - Self-awareness and Self-reflection: assessed
  - Self-direction and Self-management: assessed

### Elective Compulsory Master Courses

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>529-0004-01L</td>
<td>Classical Simulation of (Bio)Molecular Systems</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>P. H. Hünenberger, J. Dolenc, S. Riniker</td>
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</table>

**Abstract**
Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

**Objective**
Introduction to classical (atomistic) computer simulation of (bio)molecular systems, development of skills to carry out and interpret these simulations.

**Content**
Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

**Lecture notes**
The powerpoint slides of the lectures will be made available weekly on the website in pdf format (on the day preceding each lecture).

**Literature**
See: www.csms.ethz.ch/education/CSBMS

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed
- Personal Competencies
  - Adaptability and Flexibility: fostered
  - Creative Thinking: fostered

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<tr>
<td>529-0233-01L</td>
<td>Organic Synthesis: Methods and Strategies</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>E. M. Carreira</td>
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</table>

**Abstract**
The complex relation between structural analysis, methods leading to desired transformations, and insight into reaction mechanisms is exemplified. Relations between retrosynthetic analysis of target structures, synthetic methods and their combination in a synthetic strategy.

**Objective**
Extension and deepening of the knowledge in organic synthesis and the principles of structure and reactivity.

**Content**

**Literature**

**Prerequisites / notice**
OC I-IV
### Transition Metal Catalysis: From Mechanisms to Applications

**W 6 credits 3G B. Morandi**

**Abstract**
Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint.

**Objective**
Understanding and critical evaluation of current research in transition metal catalysis. Design of mechanistic experiments to elucidate reaction mechanisms. Synthetic relevance of transition metal catalysis. Students will also learn about writing an original research proposal during a workshop.

**Content**
- Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint.
- Synthetic applications of these reactions.
- Introduction and application of tools for the elucidation of mechanisms. Selected examples of topics include: C-H activation, C-O activation, C-C activation, redox active ligands, main group redox catalysis, bimetallic catalysis.

**Prerequisites / notice**
Required level: Courses in organic and physical chemistry (kinetics in particular) of the first and second year as well as ACI and III.

**Competencies**

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**Modern Mass Spectrometry, Hyphenated Methods, and Chemometrics**

**W 6 credits 3G R. Zenobi, B. Hattendorf, P. Sinués Martinez-Lozano**

**Abstract**
Modern mass spectrometry, hyphenated analytical methods, speciation, chemometrics.

**Objective**
Comprehensive knowledge about the analytical methods introduced in this course and their practical applications.

**Content**
- Hyphenation of separation with identification methods such as GC-MS, LC-MS, GC-IR, LC-IR, LC-NMR etc.; importance of speciation.
- Modern mass spectrometry: time-of-flight, orbitrap and ion cyclotron resonance mass spectrometry, ICP-MS. Soft ionization methods, desorption methods, spray methods. Mass spectrometry imaging.
- Use of statistical and computer-assisted methods for processing analytical data (chemometrics).

**Prerequisites / notice**
Exercises are an integral part of the lecture.

**Competencies**

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**Prerequisites**
- 529-0051-00 "Analytische Chemie I (3. Semester)"
- 529-0058-00 "Analytische Chemie II (4. Semester)" (or equivalent)
This course covers aspects of RNA biology related to gene expression at the posttranscriptional level. These include RNA transcription, assessed 3G, and other processes.

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Critical Thinking assessed
Creative Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

529-0240-00L
Chemical Biology - Peptides
W 6 credits 3G H. Wennemers
Abstract
An advanced course on the synthesis, properties and function of peptides in chemistry and biology.

Objective
Knowledge of the synthesis, properties and function of peptides in chemistry and biology.

Content
Advanced peptide synthesis, conformational properties, combinatorial chemistry, therapeutic peptides, peptide based materials, peptides in nanotechnology, peptides in asymmetric catalysis.

Lecture notes
Citations from the original literature relevant to the individual lectures will be assigned weekly.

Literature

636-0108-00L
Biological Engineering and Biotechnology
W 4 credits 3V M. Fussenegger
Abstract
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content

Handout during the course.

551-1409-00L
RNA Biology Lecture Series II: Non-Coding RNAs: W 4 credits 2V J. Hall, M. Stoffel, further lecturers
Biology and Therapeutics
Does not take place this semester.

Abstract
This course covers aspects of RNA biology related to the functions of non-coding RNAs as well as their use as drugs to treat diseases.

Objective
The students should get familiar with the wide array of roles, which non-coding RNAs play in cellular functions.

Content
Micro RNAs; computational approaches to miRNAs; micro RNA function in metabolism; viruses and viral RNAs; nucleic acid-based drugs; ncRNA-mediated genome regulation; epigenetic programming of genome remodelling in ciliates; telomerase and telomeres; tRNA biology.

Prerequisites / notice
Basic knowledge of cell and molecular biology.

529-0241-10L
Selectivity in Organic Synthesis
W 6 credits 3G J. W. Bode
Abstract
Fundamentals of selective organic reactions, including current and historical examples of enantioselectivity, regioselectivity, chemoselectivity. Further aspects include recent developments in catalysis, strategies and tools for selective organic synthesis.

Objective
Understanding and explaining the origin of selectivity in organic synthesis and the application of selective organic reactions to the construction of complex organic and biological molecules.

Content
Fundamental concepts and recent advances for the selective synthesis of complex organic molecules, including natural products, pharmaceuticals, and biological molecules. Key concepts include the development of enantioselective and regioselective catalysts, the identification of new reaction mechanisms and pathways, and technological advances for facilitating the synthesis of organic molecules. Analysis of key primarily literature including identification of trends, key precendents, and emerging topics will be emphasized.

Lecture notes
will be provided in class and online

Literature
Suggesting Textbooks

**Abstract**

Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.

**Objective**

Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars of thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding experimental results from the literature.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

**Content**

- Basics of theory of probability
- Boltzmann's law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns

Theory and corresponding exercises are merged together during the classes.

**Lecture notes**

No lecture notes because the two proposed textbooks are more than exhaustive!

I am willingly available Mondays 17.00 o'clock - 18.00 in my office GLC F12.2 for whatever discussion about the lessons and the exercises.

!!! I am using OneNote. All lectures will be broadcast via ZOOM, while corresponding videos of the previous years (lectures and exercises) are available in Moodle !!!

**Literature**


As further deepening:


**Prerequisites / notice**

Participants need a good command of

- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation

Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

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In the last decade, a novel type of cell compartments called biomolecular condensates have been discovered. This discovery is radically changing our understanding of the cell, its organization, and dynamics. The emerging picture is that the cytoplasm and nucleoplasm are highly complex fluids that can (meta)stably segregate into membrane-less compartments, similar to emulsions.

At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate this, students must confirm their registration by the beginning of the 3rd week of semester.

This interdisciplinary course encompasses milestone works and cutting-edge research questions in the young field of biomolecular condensates, including their properties, functions, and applications. The course begins with a lecture series that introduces the topic of condensates to an interdisciplinary audience and provides a theoretical foundation for understanding current research questions in the field. The lectures provide a base for student presentations of recent publications in the field, and for research seminars given by course lecturers, who are all active researchers with diverse expertise.

In preparing the presentations, the students will have the unique opportunity to interact closely with each other and with the lecturers, who are all internationally well-established experts, and receive guidance in selecting a topic for the final presentation and supporting literature.

Students will not only learn how to critically read and evaluate scientific literature but will also gain valuable experience in giving scientific presentations to an interdisciplinary audience. Each presentation will require an introduction, critical analysis of the results, and a discussion of their significance, allowing student to substantiate their statements with a critical mindset that considers the pros and cons of chosen approaches and methods, as well as any limitations or possible follow-up experiments. This process will enable student to ask relevant questions and actively participate in class discussions, further enhancing their scientific skills.

The topic of biomolecular condensates goes beyond the boundaries of traditional disciplines and requires a multi-disciplinary approach that leverages and cross-fertilizes biology, physical chemistry, biophysics, and soft matter. This course will explore the properties, functions and potential applications of biomolecular condensates, including their role in neurodegenerative diseases such as Alzheimer's and Parkinson's, as well as their use as smart biomimetic materials.

This course is divided into two parts. The first part will introduce the basic concepts essential to the study of biomolecular condensates and phase separation. Topics include: fundamental units and scales in soft matter, phase transitions in biology, biopolymers and molecular self-assembly, introduction to active matter. This will establish a foundation for the second part, which will explore milestone works and current research in the field of biomolecular condensates. Each lecture of this second part will consist of:

1) a short literature seminar, where student groups will present and discuss a milestone paper assigned in advance and
2) a research seminar, where one of the course lecturers will present their own state-of-the-art research in the field, building upon the milestone literature.

At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate this, students must confirm their registration by the beginning of the 3rd week of semester.

No compulsory textbooks. Literature will be provided during the course.
Chemical Biology and Synthetic Biochemistry

**Abstract**
Overview of modern chemical biology and synthetic biochemistry techniques, focused on protein modification and labeling and on methods to endow proteins with novel functionalities.

**Objective**
After taking this course, students should be capable of the following: A) Recall different possibilities for modifying proteins in vitro and in vivo and their applications in a biological context, B) Understand the chemical and biochemical consequences of modifications and assess the different reaction possibilities in the context of in vivo - in vitro, C) Critically analyze and assess current chemical biology articles D) Question the approaches learned and apply them to new biological problems.

**Content**
- principles of protein labeling and protein modification (fluorescent proteins, enzyme-mediated labeling, bioorthogonal chemistries)
- advanced genetic code expansion methods (amber suppression, orthogonal ribosomes, unnatural base pairs, genome engineering and genome editing)
- directed evolution and protein engineering
- chemical biology of ubiquitin and targeted protein degradation

**Lecture notes**
A script will not be handed out. Handouts to the lecture will be provided through moodle.

**Literature**
Citations from the original literature relevant to the individual lectures will be assigned during the lectures.

**Prerequisites / notice**
Knowledge provided in the bachelor lectures ‘Nucleic Acids and Carbohydrates’ and ‘Proteins and Lipids’ is assumed for this lecture.

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: fostered
  - Project Management: fostered
- Social Competencies
  - Communication: assessed
  - Cooperation and Teamwork: assessed
  - Customer Orientation: fostered
  - Leadership and Responsibility: assessed
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: assessed
  - Negotiation: fostered
- Personal Competencies
  - Adaptability and Flexibility: fostered
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

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**Elective Concept Courses**

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<th>Title</th>
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<tr>
<td>551-0307-00L</td>
<td>Molecular and Structural Biology I: Protein Structure and Function</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>R. Glockshuber, K. Locher, E. Weber-Ban</td>
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**Abstract**
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

**Objective**
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

**Lecture notes**
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.
Current topics: References will be given during the lectures.

551-0319-00L  Cellular Biochemistry (Part I)  W  3 credits  2V  U. Kutay, F. Allain, T. Kleele, I. Zemp

Abstract
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Content
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Lecture notes
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Literature
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed
assessed

551-1299-00L  Bioinformatics  W  6 credits  4G  S. Sunagawa, P. Beltrao, V. Boevoa, A. Kahles, C. von Mering, N. Zambo

Abstract
Students will study bioinformatic concepts in the areas of metagenomics, genomics, transcriptomics, proteomics, biological networks and biostatistics. Through integrated lectures, practical hands-on exercises and project work, students will also be trained in analytical and programming skills to meet the emerging increase in data-driven knowledge generation in biology in the 21st century.

Objective
Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

Prerequisites / notice
Course participants have already acquired basic programming skills in UNIX, Python and R.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed
assessed

Method-specific Competencies
Analytical Competencies
assessed
Decision-making
assessed
Media and Digital Technologies
assessed
Problem-solving
assessed
Project Management
fostered

Social Competencies
Communication
fostered

Personal Competencies
Adaptability and Flexibility
fostered
Creative Thinking
assessed
Critical Thinking
assessed
Integrity and Work Ethics
fostered
Self-awareness and Self-reflection
fostered
Self-direction and Self-management
fostered

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 316 of 2653
### Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Objective**
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Content**
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Prerequisites / notice**
The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

### Writing Scientific Reports for MSc Biology

**Number** 551-0313-00L
**Title** Microbiology (Part I)

**Abstract**
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Objective**
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Content**
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Prerequisites / notice**
The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

### Major in Microbiology and Immunology

#### Compulsory Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>551-0313-00L</td>
<td>Microbiology (Part I)</td>
<td>O</td>
<td>3</td>
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<td>W.-D. Hardt, L. Eberl, B. Nguyen, J. Piel, M. Pilhofer, A. Vagstad</td>
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**Abstract**
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Objective**
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Content**
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Lecture notes**
Updated handouts will be provided during the class.

**Literature**
Current literature references will be provided during the lectures.

### Immunology I

**Number** 551-0317-00L
**Title** Immunology I

**Abstract**
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

**Objective**
Basic knowledge of the mechanisms and the regulation of an immune response.

**Content**
- Introduction and historical background
- Basic knowledge of the mechanisms and the regulation of an immune response.
- Antigen presentation and Major Histocompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

**Lecture notes**
Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"

**Literature**
- Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

<table>
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Elective Compulsory Master Courses

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<td>W</td>
<td>4 credits</td>
<td>2V</td>
<td>M. Kopf, S. B. Freigang, S. R. Leibundgut, F. Mair, A. Oxenius, C. Schneider, E. Slack, R. Spörri, further lecturers</td>
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</table>

Abstract

This course provides a detailed understanding of:
- Development of T and B cells
- The dynamics of an immune response during acute and chronic infection
- Mechanisms of immunopathology
- Modern vaccination strategies

Key experimental results will be shown to help understanding how immunological text book knowledge has evolved.

Objective

Obtain a detailed understanding of:
- The development, activation, and differentiation of different types of T cells and their effector mechanisms during immune responses,
- Recognition of pathogenic microorganisms by the host cells and molecular events thereafter,
- Events and signals for maturation of naïve B cells to antibody producing plasma cells and memory B cells,
- Optimization of B cell responses by intelligent design of new vaccines

Content

- Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg)
- NK T cells and responses to lipid antigens
- Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17
- Overview of cytokines and their effector function
- Co-stimulation (signals 1-3)
- Dendritic cells
- Evolution of the "Danger" concept
- Cells expressing Pattern Recognition Receptors and their downstream signals
- T cell function and dysfunction in acute and chronic viral infections

Literature

Documents of the lectures are available for download at:
https://moodle-app2.let.ethz.ch/course/view.php?id=2581&notifyeditingon=1

Prerequisites / notice

Immunology I and II recommended but not compulsory

551-0512-00L Current Topics in Molecular and Cellular Neurobiology

Abstract

This course is a literature seminar or "journal club". Each Friday a student, or a member of the Suter Lab in the Institute of Molecular Health Sciences, will present a paper from the recent literature.

Objective

The course introduces you to recent developments in the fields of cellular and molecular neurobiology. It also supports you to develop your skills in critically reading the scientific literature. You should be able to grasp what the authors wanted to learn i.e. their goals, why the authors chose the experimental approach they used, the strengths and weaknesses of the experiments and the data presented, and how the work fits into the wider literature in the field. You will present one paper yourself, which provides you with practice in public speaking.

Content

You will present one paper yourself. Give an introduction to the field of the paper, then show and comment on the main results (all the papers we present are available online, so you can show original figures with a beamer). Finish with a summary of the main points and a discussion of their significance.

Lecture notes

Presentations will be made available after the seminars.

Prerequisites / notice

You must attend at least 80% of the journal clubs, and give a presentation of your own. At the end of the semester there will be a 30 minute oral exam on the material presented during the semester. The grade will be based on the exam (45%), your presentation (45%), and a contribution based on your active participation in discussion of other presentations (10%).

551-1117-00L Cutting Edge Topics: Immunology and Infection Biology

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module BIO636 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html

Abstract

Weekly seminar about cutting edge topics in immunology and infection biology. Internationally renowned experts present their current research followed by an open discussion.
### ImmunoPathology: The Structure and Function of Innate and Adaptive Immunity

**Objective**
Weekly seminar about cutting edge topics in immunology and infection biology. Internationally renowned experts present their current research followed by an open discussion. The aim of this course is to confront students with current research topics and with scientific presentation. The course offers the opportunity to gain in depth knowledge about diverse topics which are often only briefly touched in the concept courses and to engage in discussion with experts in the field.

**Content**
- Immunology and infection biology.
- The specific topics are variable and depend each semester on the list of invited experts.

**Lecture notes**
Current research data (often not yet published) are presented in this seminar series. There is no script and we are not allowed to record or distribute the contents of the seminars. Thus, the ability of students to extract the most relevant points of each seminar is promoted, which is an important skill for the future attendance of scientific meetings.

**Literature**
Often parts of the presented seminars have already been published by the respective speakers and the respective primary research can be retrieved from scientific journals.

**Competencies**
- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies
- **Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
- **Social Competencies**
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
  - Negotiation
- **Personal Competencies**
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

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### Systems Biology of Metabolism

**Objective**
Develop a deeper understanding of how relevant biological problems can be solved, thereby providing advanced insights to key experimental and computational methods in systems biology.

**Content**
The course will be given as a mixture of lectures, studies of original research and guided discussions that focus on current research topics. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation networks in populations and single cells. Key methods to be covered are various modeling approaches, metabolic flux analyses, metabolomics and other omics.

**Lecture notes**
Script and original publications will be supplied during the course.

**Prerequisites / notice**
The course extends many of the generally introduced concepts and methods of the Concept Course in Systems Biology. It requires a good knowledge of biochemistry and basics of mathematics and chemistry.

**Competencies**
- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies
- **Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
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  - Self-direction and Self-management

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### Current Research Topics in Cellular Biochemistry

**Objective**
During this Masters level seminar style course, students will explore current research topics in cellular biochemistry focused on the structure, function and regulation of selected cell components, and the consequences of dysregulation for pathologies. Students will work with experts toward a critical analysis of cutting-edge research in the domain of cellular biochemistry, with emphasis on normal cellular processes and the consequences of their dysregulation. At the end of the course, students will be able to evaluate, critically discuss and write about scientific articles in the research area of cellular biochemistry, and they will identify open testable research questions.

**Literature**
Often parts of the presented seminars have already been published by the respective speakers and the respective primary research can be retrieved from scientific journals.
Content
Guided by an expert in the field, students will engage in classical round-table style discussions of current literature with frontal presentations. Guided by a faculty expert, students develop domain knowledge of the research area associated with a primary paper, and alternate as discussion leaders to present the research topic. By the end of the semester, students will formulate their ideas about open testable research questions that extend from the published work.

Literature
The literature will be provided during the course.

Prerequisites / notice
The course will be taught in English.

Competencies

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<th>Competencies</th>
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<th>Concept and Theories</th>
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| Competencies                      | Social Competencies           | Communication    | fostered |
|-----------------------------------| Personal Competencies         | Creative Thinking| fostered |

752-4009-00L Molecular Biology of Foodborne Pathogens

Abstract
The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Objective
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content
Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Literature
Recommendations will be given in the first lecture

Prerequisites / notice
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break !

Competencies

| Competencies                      | Subject-specific Competencies | Concept and Theories | assessed |
|-----------------------------------| Method-specific Competencies  | Analytical Competencies| assessed |
|                                   | Social Competencies           | Communication        | fostered |
|                                   |                              | Cooperation and Teamwork| fostered |
|                                   | Personal Competencies         | Adaptable and Flexibility| fostered |

751-4504-00L Plant Pathology I

Abstract
Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems.

Objective
Students will understand: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems as a basis for implementing disease management strategies in agroecosystems.
Course description: Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems. Topics under the first theme will include pathogen life cycles, disease cycles, and an overview of plant pathogenic nematodes, viruses, bacteria, and fungi. Topics under the second theme will include plant defense strategies, host range, passive and active defenses, and chemical and structural defenses. Topics under the third theme will include the disease triangle and cultural control strategies.

Lecture Topics and Tentative Schedule

Week 1  The nature of plant diseases, symbiosis, parasites, mutualism, biotrophs and necrotrophs, disease cycles and pathogen life cycles.

Week 2  Nematode attack strategies and types of damage. Viral pathogens, classification, reproduction and transmission, attack strategies and types of damage. Examples TMV, BYDV. Bacterial pathogens and phytoplasmas, classification, reproduction and transmission.

Week 3  Bacterial attack strategies and symptoms. Example bacterial diseases: fire blight, Agrobacterium crown gall, soft rots. Fungal and oomycete pathogens, classification, growth and reproduction, sexual and asexual spores, transmission.

Week 4  Fungal and oomycete life cycles, disease cycles, infection processes, colonization, phytotoxins and mycotoxins. Attack strategies of fungal necrotrophs and biotrophs. Symptoms and signs of fungal infection. Example fungal diseases: potato late blight.

Week 5  Example fungal diseases: wheat stem rust, grape powdery mildew, wheat septoria tritici blotch. Plant defense mechanisms, host range and non-host resistance. Passive structural and chemical defenses, preformed chemical defenses. Active structural defense, histological and cellular (papillae).

Week 6  Active chemical defense, hypersensitive response, pathogenesis-related (PR) proteins, phytoalexins and disease resistance. Pisatin and pisatin demethylase. Local and systemic acquired resistance (LR, SAR), induced systemic resistance (ISR), signal molecules, defense activators (Bion). Pathogen effects on food quality. Positive and negative transformations.


Week 8  Epidemiology: Disease pyramid, environmental effects on epidemic development, plant effects on development of epidemics, including resistance, physiology, density, uniformity.

Week 9  Disease assessment: incidence and severity measures, keys, diagrams, scales, measurement errors. Correlations between incidence and severity. Molecular detection and diagnosis of pathogens. Host indexing, serology, monoclonal and polyclonal antibodies, ELISA.

Week 10  Molecular detection and diagnosis of pathogens: PCR, rDNA and loop-mediated isothermal amplification. Strategies for minimizing disease risks: calculating disease thresholds, disease forecasting systems.


Week 12  Physical control methods. Cultural control methods: avoidance, tillage practices, crop sanitation.

Week 13  Cultural control methods: fertilizers, crop rotations.

Week 14  Open lecture.

Competencies

Subject-specific Competencies

Computational Biology

W 6 credits

3G+2A

T. Vaughan, C. Magnus, T. Stadler

Abstract

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Objective

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

* stochastic models in molecular evolution
* phylogenetic & phylodynamic inference
* maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

* epidemiology
* pathogen evolution
* macroevolution of species

Content

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylogeography, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes

Lecture slides will be available on moodle.

Literature

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

* Yang, Z. 2006. Computational Molecular Evolution.
* Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.
The focus is on primary literature, but for some parts the following text books provide good background information:

- **Creative Thinking**
- **Communication**
- **Analytical Competencies**
- **Concepts and Theories**
- **Evolutionary Medicine for Infectious Diseases**
- **Applied Bioinformatics: Microbiomes**

This course explores infectious disease from both the host and pathogen perspective. Through short lectures, reading and active discussion, students will identify areas where evolutionary thinking can improve our understanding of infectious diseases and, ultimately, our ability to treat them effectively.

**Objective**

Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses.

**Content**

We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (< 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

**Literature**

The focus is on primary literature, but for some parts the following text books provide good background information:

- **Schmid Hempel 2011 Evolutionary Parasitology**
- **Stearns & Medzhitov 2016 Evolutionary Medicine**

**Prerequisites / notice**

A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: fostered
  - Techniques and Technologies: fostered

- **Method-specific Competencies**
  - Problem-solving: fostered
  - Project Management: fostered
  - Cooperation and Teamwork: fostered

- **Personal Competencies**
  - Creative Thinking: fostered
  - Critical Thinking: fostered

**Prerequisites / notice**

No specific pre-requisites, but students should have some familiarity with microbiology, molecular biology, programming (Python), bioinformatics, and statistics.

Students will bring and work on their own laptop computers.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Problem-solving: fostered
  - Project Management: fostered
  - Cooperation and Teamwork: fostered

- **Social Competencies**
  - Communication: assessed

- **Personal Competencies**
  - Creative Thinking: fostered
  - Critical Thinking: assessed

**Prerequisites / notice**

No specific pre-requisites, but students should have some familiarity with microbiology, molecular biology, programming (Python), bioinformatics, and statistics.

All software used in the course is free and open-source.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed

- **Social Competencies**
  - Communication: assessed

- **Personal Competencies**
  - Creative Thinking: fostered
  - Critical Thinking: assessed

**Prerequisites / notice**

- **Prerequisites**
  - Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place in Basel before the start of the semester.

- **Competencies**
  - **Subject-specific Competencies**
    - Concepts and Theories: assessed
    - Techniques and Technologies: assessed
  - **Method-specific Competencies**
    - Analytical Competencies: assessed
    - Decision-making: assessed
    - Problem-solving: assessed

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<td>W</td>
<td>3</td>
<td>2V</td>
<td>M. Loessner, A. Harms</td>
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**Data:** 15.06.2024 12:39  **Autumn Semester 2024**  **Page 322 of 2653**
Abstract
This lecture is the first part of a one-year course. It offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts and molds present in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.

Objective
The lecture offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts, molds and protozoa in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.

Content
1. History of Food Microbiology
1.1. Short synopsis of foodborne microorganisms
1.2. Spoilage of Foods
1.3. Foodborne Disease
1.4. Food Preservation
1.5. VIP's of Food Microbiology
2. Overview of Microorganisms in Foods
2.1 Origin of foodborne Microorganisms
2.2. Bacteria
2.3. Yeasts
2.4. Molds
3. Microbial Spoilage of Foods
3.1. Intrinsic and Extrinsic Parameters
3.2. Meats, Seafoods, Eggs
3.3. Milk and Milk Products
3.4. Vegetable and Fruit Products
3.5. Miscellaneous (baked goods, nuts, spices, ready-to-eat products)
3.6. Drinks and Canned Foods
4. Foodborne Disease
4.1. Significance and Transmission of Foodborne pathogens
4.2. Staphylococcus aureus
4.3. Gram-positive Sporeformers (Bacillus & Clostridium)
4.4. Listeria monocytogenes
4.5. Salmonella, Shigella, Escherichia coli
4.6. Vibrio, Yersinia, Campylobacter
4.7. Brucella, Mycobacterium
4.8. Parasites
4.9. Viruses and Bacteriophages
4.10. Mycotoxins
4.11. Bioactive Amines
4.12. Miscellaneous (Antibiotic-resistant Bacteria, Biofilms)

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download.

Literature
Recommendations will be given in the first lecture.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Decision-making assessed

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Self-presentation and Social Influence fostered
Project Management assessed
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Evolutionary Genetics
W 6 credits
4V T. Städerl, A. Widmer, S. Fior, M. Fischer, J. Stapley

Abstract
The concept course 'Evolutionary Genetics' consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics (emphasis on basic concepts) and ecological genetics (more emphasis on evolutionary and ecological processes of adaptation and speciation).

Objective
The aim of the course is to provide students with a solid introduction to the fields of population genetics, quantitative genetics, and ecological genetics. The concepts and research methods developed in these fields have undergone profound transformations; they are of fundamental importance in our understanding of evolutionary processes, both past and present. Students should gain an appreciation for the concepts, methods and explanatory power of evolutionary genetics.

Content
Population genetics - Types and sources of genetic variation; randomly mating populations and the Hardy-Weinberg equilibrium; effects of inbreeding; natural selection; random genetic drift and effective population size; gene flow and hierarchical population structure; molecular population genetics: neutral theory of molecular evolution and basics of coalescent theory.
Quantitative genetics - Continuous variation; measurement of quant. characters; genes, environments and their interactions; measuring their influence; response to selection; inbreeding and crosbreeding, effects on fitness; Fisher's fundamental theorem.
Ecological Genetics - Concepts and methods for the study of genetic variation and its role in adaptation, reproductive isolation, hybridization and speciation.

Lecture notes
Handouts

Literature

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Critical Thinking fostered

Molecular Life of Plants
W 6 credits
4V S. C. Zeeman, K. Bomblies

Abstract
The concept course ‘Molecular Life of Plants’ consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics (emphasis on basic concepts) and ecological genetics (more emphasis on evolutionary and ecological processes of adaptation and speciation).

Objective
The aim of the course is to provide students with a solid introduction to the fields of population genetics, quantitative genetics, and ecological genetics. The concepts and research methods developed in these fields have undergone profound transformations; they are of fundamental importance in our understanding of evolutionary processes, both past and present. Students should gain an appreciation for the concepts, methods and explanatory power of evolutionary genetics.

Content
Population genetics - Types and sources of genetic variation; randomly mating populations and the Hardy-Weinberg equilibrium; effects of inbreeding; natural selection; random genetic drift and effective population size; gene flow and hierarchical population structure; molecular population genetics: neutral theory of molecular evolution and basics of coalescent theory.
Quantitative genetics - Continuous variation; measurement of quant. characters; genes, environments and their interactions; measuring their influence; response to selection; inbreeding and crosbreeding, effects on fitness; Fisher’s fundamental theorem.
Ecological Genetics - Concepts and methods for the study of genetic variation and its role in adaptation, reproductive isolation, hybridization and speciation.

Lecture notes
Handouts

Literature

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Critical Thinking fostered
The course "Molecular Life of Plants" will cover the following topics:

Seed structure and physiology, their dormancy and germination.
Seedling establishment and early development.
Structure and Function of Meristems, including stem cells.
Plant organ development (leaves, roots, flowers etc.).
Plant reproduction.
The plant vasculature for long-distance transport and other specialized tissues.
Sensing and responding to the abiotic environment
Plant-microbe interactions; beneficial friends or pathogenic foes?
Polyploidy; the benefits, problems and solutions to of multiple genomes.
Photosynthesis and carbon partitioning.
Photosynthesis and the evolution of C4 metabolism.
Starch biosynthesis and degradation.
Chloroplast development and chlorophyll biosynthesis.
Senescence mechanisms in plants.
General principles of RNA silencing
MicroRNAs: discovery, general principle and modes of action at the cellular and system levels.
Chromatin-based RNA silencing.
Antiviral RNA silencing.
RNA silencing & defense against non-viral pathogens.
RNA silencing movement and amplification.

Abstract
The advanced course introduces students to plants through a concept-based discussion of developmental processes that integrates physiology and biochemistry with genetics, molecular biology, and cell biology. The course follows the life of the plant, starting with the seed, progressing through germination to the seedling and mature plant, and ending with reproduction and senescence.

Objective
The new course "Molecular Life of Plants" reflects the rapid advances that are occurring in the field of experimental plant biology as well as the changing interests of students being trained in this discipline. Contemporary plant biology courses emphasize a traditional approach to experimental plant biology by discussing discrete topics that are removed from the context of the plant life cycle. The course will take an integrative approach that focuses on developmental concepts. Whereas traditional plant physiology courses were based on research carried out on intact plants or plant organs and were often based on phenomenological observations, current research in plant biology emphasizes work at the cellular, subcellular and molecular levels.

The goal of "Molecular Life of Plants" is to train students in integrative approaches to understand the function of plants in a developmental context. While the course focuses on plants, the training integrative approaches will also be useful for other organisms.

Content
The course "Molecular Life of Plants" will cover the following topics:

Scripts and additional material will be provided during the semester.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
<th>Media and Digital Technologies</th>
<th>Analytical Competencies</th>
<th>Techniques and Technologies</th>
<th>Problem-solving</th>
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<td>Cooperation and Teamwork</td>
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<td>Self-direction and Self-management</td>
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551-0307-00L Molecular and Structural Biology I: Protein Structure and Function
D-BIOL students are obliged to take part I and part II (next semester) as a two-semester course

Abstract
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

Objective
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

Lecture notes
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.

Literature
Basics:
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

551-0309-00L Concepts in Modern Genetics
Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/university-of-zurich.html

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.
### 551-0319-00L Cellular Biochemistry (Part I)

**Abstract**
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

**Objective**
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

**Content**
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

**Lecture notes**
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.bioc.ethz.ch)

**Literature**
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

**Prerequisites / notice**
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

**Competencies**

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Techniques and Technologies</td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Project Management</td>
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<td>Communication</td>
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<td>Adaptable and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
<td>fostered</td>
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</table>

### 551-1299-00L Bioinformatics

**Abstract**
Students will study bioinformatic concepts in the areas of metagenomics, genomics, transcriptomics, proteomics, biological networks and biostatistics. Through integrated lectures, practical hands-on exercises and project work, students will also be trained in analytical and programming skills to meet the emerging increase in data-driven knowledge generation in biology in the 21st century.

**Objective**
Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

**Prerequisites / notice**
Course participants have already acquired basic programming skills in UNIX, Python and R.

**Competencies**

| Competencies                  | Subject-specific Competencies | Concepts and Theories | assessed |
|-------------------------------|------------------------------| Techniques and Technologies | assessed |
|                               |                              | Decision-making           | assessed |
|                               |                              | Media and Digital Technologies | assessed |
|                               |                              | Problem-solving           | assessed |
|                               |                              | Project Management        | fostered |
|                               |                              | Communication             | fostered |
|                               |                              | Cooperation and Teamwork  | fostered |
|                               |                              | Adaptable and Flexibility | fostered |
|                               |                              | Creative Thinking         | assessed |
|                               |                              | Critical Thinking         | fostered |
|                               |                              | Integrity and Work Ethics | fostered |
|                               |                              | Self-awareness and Self-reflection | fostered |
|                               |                              | Self-direction and Self-management | fostered |

### 529-0731-00L Nucleic Acids and Carbohydrates

**Note for BSc Biology students:** Only one of the two concept courses 529-0731-00 Nucleic Acids and Carbohydrates (autumn semester) or 529-0732-00 Proteins and Lipids (spring semester) can be counted for the Bachelor's degree.

**Abstract**
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines.

**Objective**
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines.

**Content**
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines.
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

The course covers the process of writing reports in biology, helping students to focus on the language and communicative aspects of these reports. Topics covered include structuring sentences, paragraphs, and longer sections (introductions, methods, etc.); presenting and integrating non-textual elements such as graphs and tables; reviewing common grammar problems for advanced writers in English; and editing drafts and proofs. Sessions will consist of a mix of specialist input, group and pair work, and editing sessions.

Students who attend this course will turn in three sections of a report (approx. 500 words each) for feedback, reviewing these texts for a final portfolio that is graded.

Participants should be at a stage in their research where they can already start drafting parts of the report.

### Major in Molecular and Structural Biology

#### Compulsory Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>551-0307-00L</td>
<td>Molecular and Structural Biology I: Protein Structure and Function</td>
<td>O</td>
<td>3 credits</td>
<td>2V</td>
<td>R. Glockshuber, K. Locher, E. Weber-Ban</td>
</tr>
</tbody>
</table>

Abstract

Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

Objective

Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

Lecture notes

Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.

Literature

Basics:  
- Creighton, T.E., Proteins, Freeman, (1993)  
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.  

Current topics: References will be given during the lectures.

#### Elective Compulsory Concept Courses

See D-BIOL Master Studies Guide

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>551-0319-00L</td>
<td>Cellular Biochemistry (Part I)</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>U. Kutay, F. Allain, T. Kleele, I. Zemp</td>
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</tbody>
</table>
This course focuses on the concepts of classical and modern genetics and genomics. Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis. The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies
  - Analytical Competencies
  - Problem-solving
  - Cooperation and Teamwork
  - Self-presentation and Social Influence
  - Creative Thinking
  - Critical Thinking
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

- **Method-specific Competencies**
  - Communication
  - Cooperation and Teamwork
  - Self-presentation and Social Influence
  - Creative Thinking
  - Critical Thinking
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

- **Social Competencies**

- **Personal Competencies**

**Abstract**

Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Objective**

This course focuses on the concepts of classical and modern genetics and genomics. The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Lecture notes**

Scripts and additional material will be provided during the semester.

**Prerequisites / notice**

Students bring their own computer with keyboard, internet access (browser) and software to connect to the ETH network via VPN.
Objective | Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Content | Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Lecture notes | No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).

Literature | Mainly based on original literature, a detailed list will be distributed during the lecture

Competencies | Subject-specific Competencies: Concepts and Theories, Techniques and Technologies
Method-specific Competencies: Analytical Competencies, Problem-solving
Social Competencies: Communication, Cooperation and Teamwork
Personal Competencies: Self-awareness and Self-reflection, Self-direction and Self-management

Elective Compulsory Master Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>551-1401-00L</td>
<td>Advanced Protein Engineering (University of Zurich)</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>University lecturers</td>
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<tr>
<td>551-1153-00L</td>
<td>Systems Biology of Metabolism</td>
<td>W</td>
<td>4 credits</td>
<td>2V</td>
<td>U. Sauer, N. Zamboni</td>
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</tbody>
</table>

Abstract | Introduction to current research strategies in protein science.
Objective | To understand current research strategies in protein science.
Content | Proteins have become an object of intense study in modern science, ranging from their use as therapeutics to elucidating their structure and function in the cell. Moreover, it is now possible to engineer and evolve tailor-made proteins, opening up many new areas of science. This course will attempt to cover the frontiers and remaining challenges, emphasizing the biochemical foundations of the various approaches.
Lecture notes | Slides and references will be available on OLAT server.
Literature | PDFs will be available on OLAT server.
Prerequisites / notice | Solid knowledge in biochemistry strongly recommended

Abstract | Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.
Objective | Develop a deeper understanding of how relevant biological problems can be solved, thereby providing advanced insights to key experimental and computational methods in systems biology.
Content | The course will be given as a mixture of lectures, studies of original research and guided discussions that focus on current research topics. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation networks in populations and single cells. Key methods to be covered are various modeling approaches, metabolic flux analyses, metabolomics and other omics.
Lecture notes | Script and original publications will be supplied during the course.
Prerequisites / notice | The course extends many of the generally introduced concepts and methods of the Concept Course in Systems Biology. It requires a good knowledge of biochemistry and basics of mathematics and chemistry.

Abstract | Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).
Objective | Introduction to classical (atomistic) computer simulation of (bio)molecular systems, development of skills to carry out and interpret these simulations.
Content | Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).
Lecture notes | The powerpoint slides of the lectures will be made available weekly on the website in pdf format (on the day preceding each lecture).
Literature | See: www.csms.ethz.ch/education/CSBMS
Prerequisites / notice | Since the exercises on the computer do convey and test essentially different skills than those being conveyed during the lectures and tested at the oral exam, the results of the exercises are taken into account when evaluating the results of the exam (learning component, possible bonus of up to 0.25 points on the exam mark).

For more information about the lecture: www.csms.ethz.ch/education/CSBMS

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 328 of 2653
The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling. 

**Adaptability and Flexibility**

Using R for Data Analysis and Graphics (Part I)

<table>
<thead>
<tr>
<th>Competencies</th>
<th>W</th>
<th>5 credits</th>
<th>2V+1U</th>
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<tbody>
<tr>
<td><strong>Abstract</strong></td>
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<tr>
<td>This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning &quot;good practice&quot; that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.</td>
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<td><strong>Literature</strong></td>
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<td>Montgomery et al. (2006): Introduction to Linear Regression Analysis</td>
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<td>Creative Thinking</td>
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The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

**Content**

Applied Statistical Regression

<table>
<thead>
<tr>
<th>Competencies</th>
<th>W</th>
<th>5 credits</th>
<th>2V+1U</th>
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<tr>
<td><strong>Abstract</strong></td>
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<tr>
<td>This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning &quot;good practice&quot; that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.</td>
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Using R for Data Analysis and Graphics (Part I)

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<tr>
<td><strong>Abstract</strong></td>
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<tr>
<td>The course provides the first part an introduction to the statistical/graphical/data science software R (<a href="https://www.r-project.org/">https://www.r-project.org/</a>) for scientists. Topics covered are data generation and selection, graphical and basic statistical functions, creating simple functions, basic types of objects.</td>
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<td><strong>Objective</strong></td>
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<tr>
<td>The students will be able to use the software R for simple data analysis and graphics.</td>
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<td><strong>Content</strong></td>
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<tr>
<td>The course provides the first part of an introduction to the statistical software R for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>An Introduction to R. <a href="http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf">http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf</a></td>
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<td><strong>Prerequisites / notice</strong></td>
<td>The course resources will be provided via the Moodle web learning platform. Subscribing via Mystudies “automatically” makes you a student participant of the Moodle course of this lecture, which is at <a href="https://moodle-app2.let.ethz.ch/course/view.php?id=20847">https://moodle-app2.let.ethz.ch/course/view.php?id=20847</a></td>
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<td>Note: Part I of UsingR is complemented and extended by Part II, which is offered during the second part of the semester and which can be taken independently from Part I.</td>
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Modern Mass Spectrometry, Hyphenated Methods, and Chemometrics

**W** 6 credits  3G  R. Zenobi, B. Hattendorf, P. Sinués Martinez-Lozano

**Abstract**
Modern mass spectrometry, hyphenated analytical methods, speciation, chemometrics.

**Objective**
Comprehensive knowledge about the analytical methods introduced in this course and their practical applications.

**Content**
Hyphenation of separation with identification methods such as GC-MS, LC-MS, GC-IR, LC-IR, LC-NMR etc.; importance of speciation. Modern mass spectrometry: time-of-flight, orbitrap and ion cyclotron resonance mass spectrometry, ICP-MS. Soft ionization methods, desorption methods, spray methods. Mass spectrometry imaging. Use of statistical and computer-assisted methods for processing analytical data (chemometrics).

**Lecture notes**
Lecture notes will be made available online.

**Literature**
Information about relevant literature will be available in the lecture & in the lecture notes.

**Prerequisites / notice**
Exercises are an integral part of the lecture.

**551-1407-00L** RNA Biology Lecture Series I: Transcription & Processing & Translation

**W** 4 credits  2V  F. Allain, N. Ban, S. Jonas, U. Kutay, further lecturers

**Abstract**
This course covers aspects of RNA biology related to gene expression at the posttranscriptional level. These include RNA transcription, processing, alternative splicing, editing, export and translation.

**Objective**
The students should obtain an understanding of these processes, which are at work during gene expression.

**Content**
Transcription & 3'end formation; splicing, alternative splicing, RNA editing; the ribosome & translation, translation regulation, RNP biogenesis & nuclear export, mRNA surveillance & mRNA turnover; signal transduction & RNA.

**Prerequisites / notice**
Basic knowledge of cell and molecular biology.

**551-1409-00L** RNA Biology Lecture Series II: Non-Coding RNAs: Biology and Therapeutics

**W** 4 credits  2V  J. Hall, M. Stoffel, further lecturers

**Abstract**
This course covers aspects of RNA biology related to the functions of non-coding RNAs as well as their use as drugs to treat diseases.

**Objective**
The students should obtain an understanding of these processes, which are at work during gene expression.

**Content**
Micro RNAs; computational approaches to miRNAs; micro RNA function in metabolism; viruses and viral RNAs; nucleic acid-based drugs; ncRNA-mediated genome regulation; epigenetic programming of genome remodelling in ciliates; telomerase and telomeres; tRNA biology. http://www.nccr-rna-and-disease.ch/tiki-index.php?page=LectureSeries

**Prerequisites / notice**
Basic knowledge of cell and molecular biology.

**227-0939-00L** Cell Biophysics

**W** 6 credits  4G  T. Zambelli

**Abstract**
Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.
Objective

Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars of thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding experimental results from the literature.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

Content

- Basics of theory of probability
- Boltzmann’s law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns

Theory and corresponding exercises are merged together during the classes.

Lecture notes

No lecture notes because the two proposed textbooks are more than exhaustive!

I am willingly available Mondays 17.00 o’clock - 18.00 in my office GLC F12.2 for whatever discussion about the lessons and the exercises.

!!! I am using OneNote. All lectures will be broadcast via ZOOM, while corresponding videos of the previous years (lectures and exercises) are available in Moodle !!!

Literature


As further deepening:


Prerequisites / notice

Participants need a good command of
- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton’s and Coulomb’s laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.

Competencies

<table>
<thead>
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<tr>
<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Customer Orientation</td>
<td>Creative Thinking</td>
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<td>Fostered</td>
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<td>Critical Thinking</td>
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<td>Assessed</td>
<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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</table>
principles of protein labeling and protein modification (fluorescent proteins, enzyme-mediated labeling, bioorthogonal chemistries)

directed evolution and protein engineering

chemical biology of ubiquitin and targeted protein degradation

A script will not be handed out. Handouts to the lecture will be provided through moodle.

Citations from the original literature relevant to the individual lectures will be assigned during the lectures.

Knowledge provided in the bachelor lectures ‘Nucleic Acids and Carbohydrates’ and ‘Proteins and Lipids’ is assumed for this lecture.

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Recommended Master Courses

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>551-0575-00L</td>
<td>Writing Scientific Reports for MSc Biology</td>
<td>W</td>
<td>2 credits</td>
<td>1G</td>
<td>R. Taylor</td>
</tr>
</tbody>
</table>

Abstract
This short course is designed to accompany MSc students in writing their first reports in English, providing input on scientific writing in English as well as feedback on drafts sections of the report.

Objective
Students will learn to:
- Plan, draft, structure, and edit scientific reports
- Produce reader-friendly sentences
- Establish a clear and logical flow between sentences and paragraphs
- Select formal vocabulary and use it in a generally accurate and correct manner
- Choose and use generally suitable grammatical structures, punctuation, and identify areas in which further development is needed

Content
The course covers the process of writing reports in biology, helping students to focus on the language and communicative aspects of these reports. Topics covered include structuring sentences, paragraphs, and longer sections (introductions, methods, etc.); presenting and integrating non-textual elements such as graphs and tables; reviewing common grammar problems for advanced writers in English; and editing drafts and proofs. Sessions will consist of a mix of specialist input, group and pair work, and editing sessions.

Prerequisites / notice
Participants should be at a stage in their research where they can already start drafting parts of the report.

Major in Molecular Mechanisms of Disease

Elective Compulsory Concept Courses

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<th>Number</th>
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<tr>
<td>551-1299-00L</td>
<td>Bioinformatics</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>S. Sunagawa, P. Beltrao, V. Boeva, A. Kahles, C. von Mering, N. Zamboni</td>
</tr>
</tbody>
</table>

Abstract
Students will study bioinformatic concepts in the areas of metagenomics, genomics, transcriptomics, proteomics, biological networks and biostatistics. Through integrated lectures, practical hands-on exercises and project work, students will also be trained in analytical and programming skills to meet the emerging increase in data-driven knowledge generation in biology in the 21st century.

Objective
Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

Prerequisites / notice
Course participants have already acquired basic programming skills in UNIX, Python and R.

Students bring their own computer with keyboard, internet access (browser) and software to connect to the ETH network via VPN.
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Basic knowledge of the mechanisms and the regulation of an immune response.
Content
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histocompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Lecture notes
Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"

Prerequisites / notice
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Method-specific Competencies
  - Analytical Competencies: fostered
  - Decision-making: fostered
  - Problem-solving: fostered
  - Project Management: fostered
- Social Competencies
  - Communication: fostered
  - Cooperation and Teamwork: fostered
- Personal Competencies
  - Adaptability and Flexibility: fostered
  - Critical Thinking: assessed
  - Self-direction and Self-management: fostered

Elective Compulsory Master Courses

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<tr>
<td>656-0108-00L</td>
<td>Biological Engineering and Biotechnology</td>
<td>W</td>
<td>4</td>
<td>3V</td>
<td>M. Fussenegger</td>
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</tbody>
</table>

Abstract
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content

Lecture notes
Handout during the course.

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<tbody>
<tr>
<td>551-1303-00L</td>
<td>Current Research Topics in Cellular Biochemistry</td>
<td>W</td>
<td>4</td>
<td>2S</td>
<td>T. Kleele, V. Korkhov, G. Neurohr, V. Panse, M. Peter, A. E. Smith, F. van Drogen</td>
</tr>
</tbody>
</table>

Abstract
During this Masters level seminar style course, students will explore current research topics in cellular biochemistry focused on the structure, function and regulation of selected cell components, and the consequences of dysregulation for pathologies.

Objective
Students will work with experts toward a critical analysis of cutting-edge research in the domain of cellular biochemistry, with emphasis on normal cellular processes and the consequences of their dysregulation. At the end of the course, students will be able to evaluate, critically discuss and write about scientific articles in the research area of cellular biochemistry, and they will identify open testable research questions.

Content
Guided by an expert in the field, students will engage in classical round-table style discussions of current literature with frontal presentations. Guided by a faculty expert, students develop domain knowledge of the research area associated with a primary paper, and alternate as discussion leaders to present the research topic. By the end of the semester, students will formulate their ideas about open testable research questions that extend from the published work.

Lecture notes
The literature will be provided during the course.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1305-00L</td>
<td>Development of the Nervous System (University of Zurich)</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 334 of 2653
Evolutionary Medicine for Infectious Diseases

Objective
On successful completion of the module the student should be able to:
- relate structure and function of the nervous system to its development - apply principles of molecular, cellular, and developmental biology to the development of the nervous system
- identify key steps in development underlying neurological syndromes and diseases

Key skills
On successful completion of the module the student should be able to:
- interpret and critically evaluate original research reports
- apply knowledge and relate experimental approaches from molecular, cellular and developmental biology to the developing nervous system

Content
The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.

Lecture notes
Must be downloaded from OLAT: https://www.olat.uzh.ch/olat/dmz/ as BIO344

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on OLAT.

Prerequisites / notice
BIO142 Developmental Biology, BIO143 Neurobiology

701-1703-00L Evolutionary Medicine for Infectious Diseases W 3 credits 2G A. Hall

Abstract
This course explores infectious disease from both the host and pathogen perspective. Through short lectures, reading and active discussion, students will identify areas where evolutionary thinking can improve our understanding of infectious diseases and, ultimately, our ability to treat them effectively.

Objective
Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses.

Content
We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (< 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

Literature
The focus is on primary literature, but for some parts the following text books provide good background information:

- Stearns & Medzhitov 2016 Evolutionary Medicine
- Schmid Hempel 2011 Evolutionary Parasitology
- Stearns & Medzhitzov 2016 Evolutionary Medicine

Prerequisites / notice
A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

Competencies
Subject-specific Competencies
- Concepts and Theories
  - assessed
- Techniques and Technologies
  - fostered

Method-specific Competencies
- Problem-solving
  - fostered
- Project Management
  - fostered

Social Competencies
- Communication
  - assessed
- Cooperation and Teamwork
  - fostered

Personal Competencies
- Creative Thinking
  - fostered
- Critical Thinking
  - assessed

551-0571-00L From DNA to Diversity: the Evolution of Multicellular Organisms (University of Zurich) W 2 credits 2V A. Hajnal, D. Bopp

Abstract
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: BIO336

Mental the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html

Objective
By the end of this module, each student should be able to:
- recognize the universal principles underlying the development of different animal body plans.
- explain how the genes encoding the molecular toolkit have evolved to create animal diversity.
- relate changes in gene structure or function to evolutionary changes in animal development.

Key skills:
By the end of this module, each student should be able to:
- present and discuss a relevant evolutionary topic in an oral presentation
- select and integrate key concepts in animal evolution from primary literature
- participate in discussions on topics presented by others

551-0223-00L Immunology III W 4 credits 2V M. Kopf, S. B. Freigang, S. R. Leibundgut, F. Mair,
This course provides a detailed understanding of
- development of T and B cells
- the dynamics of a immune response during acute and chronic infection
- mechanisms of immunopathology
- modern vaccination strategies

Key experimental results will be shown to help understanding how immunological text book knowledge has evolved.

**Objective**

Obtain a detailed understanding of
- the development, activation, and differentiation of different types of T cells and their effectormechanisms during immune responses,
- Recognition of pathogenic microorganisms by the host cells and molecular events thereafter,
- events and signals for maturation of naive B cells to antibody producing plasma cells and memory B cells.
- Optimization of B cell responses by intelligent design of new vaccines

**Content**

- Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg)
- NK T cells and responses to lipid antigens
- Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17
- Overview of cytokines and their effector function
- Co-stimulation (signals 1-3)
- Dendritic cells
- Evolution of the "Danger" concept
- Cells expressing Pattern Recognition Receptors and their downstream signals
- T cell function and dysfunction in acute and chronic viral infections

**Literature**

Documents of the lectures are available for download at:
https://moodle-app2.let.ethz.ch/course/view.php?id=15568

**Prerequisites / notice**

Immunology I and II recommended but not compulsory

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**551-1171-00L Immunology: From Milestones to Current Topics**

**W 4 credits 2S**

B. Ludewig, N. Pikor, University lecturers

**Abstract**

Milestones in Immunology: on old concepts and modern experiments

**Objective**

The course will cover the current grand topics in immunology: B cells, innate immunity, antigen presentation, tumor immunity, T cells, monocytic cells and stromal cells. For each topic two or four hours will be allocated. Historical milestone papers will be presented by the tutor/lecturer providing an overview on the development of the theoretical framework and critical technological advances. The students will read the historical milestone papers and contribute to the discussion. In the second part of the lecture, students will present recent high impact research papers that have emerged from the landmark achievements of the previously discussed milestone concepts.

**Content**

Milestones and current topics of innate immunity, antigen presentatino, B cells, thymus and T cells, cytotoxic T cells, NK cells, stromal cells, CNS immunity and tumor immunology.

**Lecture notes**

Original and review articles will be distributed by the respective lecturer.

**Literature**

Literaturunterlagen werden vor Beginn des Kurses auf folgender website zugänglich sein: https://moodle-app2.let.ethz.ch/course/view.php?id=15568

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
- Social Competencies
  - Communication
  - Self-presentation and Social Influence
- Personal Competencies
  - Critical Thinking
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

**752-4009-00L Molecular Biology of Foodborne Pathogens**

**W 3 credits 2V**

M. Loesener, A. Harms, M. Schuppier, E. Slack

**Abstract**

The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

**Objective**

Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

**Content**

Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

**Lecture notes**

Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

**Literature**

Recommendations will be given in the first lecture

**Prerequisites / notice**

Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break !

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Problem-solving
- Social Competencies
  - Communication
- Personal Competencies
  - Creative Thinking
  - Critical Thinking

**376-1305-01L Molecular Neurophysiology: From Molecules to Systems**

**W 3 credits 2V**

G. Schratr, R. Fiore, W. von der Behrens, J. Winterer

Information for UZH students:
Enrolment to this course unit only possible at ETH.
Please mind the ETH enrolment deadlines for UZH students: https://ethz.ch/en/studies/non-
The course covers the physiology of nerve cells, from the single cell through the neuronal network to the systemic level. The focus is on molecular and cellular mechanisms – synaptic transmission, signal transduction, gene expression, synaptic plasticity.

Based on an understanding of molecular and cellular mechanisms, the aim is to provide a deepened insight into neurophysiological processes underlying complex brain functions – learning/memory, sleep, sensory.

First, basic molecular and cellular mechanisms in nerve cells (excitability, neurotransmission, signal transduction, gene expression, synaptic plasticity) are introduced. Afterwards, their significance for selected neurophysiological processes (learning/memory, sleep, sensory) will be illuminated.

The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on Moodle.

Basic knowledge of cell and molecular biology.

Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.

The course extends many of the generally introduced concepts and methods of the Concept Course in Systems Biology. It requires a good knowledge of biochemistry and basics of mathematics and chemistry.

Each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation networks in populations and single cells. Key methods to be covered are various modeling approaches, metabolic flux analyses, metabolomics and other omics.

This lecture will guide you through drug development from bench to bedside and provide industry perspectives which support you in your first industry role or when building a startup. Students should be able to apply this knowledge in drug development programs in Pharma, Biotech or their own spin-off.

Key steps of drug development and their interdependencies. Project management, communication & funding options. Students should be able to apply this knowledge in drug development programs in Pharma, Biotech or their own spin-off.

Positive and negative examples will be illustrated by distinguished guest speakers.
Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered
Method-specific Competencies
Analytical Competencies fostered
Decision-making assessed
Problem-solving assessed
Project Management fostered
Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Negotiation fostered
Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered

Recommended Master Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>551-0575-00L</td>
<td>Writing Scientific Reports for MSc Biology</td>
<td>W</td>
<td>2 credits</td>
<td>1G</td>
<td>R. Taylor</td>
</tr>
</tbody>
</table>

Abstract
This short course is designed to accompany MSc students in writing their first reports in English, providing input on scientific writing in English as well as feedback on drafts sections of the report.

Objective
Students will learn to:
- Plan, draft, structure, and edit scientific reports
- Produce reader-friendly sentences
- Establish a clear and logical flow between sentences and paragraphs
- Select formal vocabulary and use it in a generally accurate and correct manner
- Choose and use generally suitable grammatical structures, punctuation, and identify areas in which further development is needed

Content
The course covers the process of writing reports in biology, helping students to focus on the language and communicative aspects of these reports. Topics covered include structuring sentences, paragraphs, and longer sections (introductions, methods, etc.); presenting and integrating non-textual elements such as graphs and tables; reviewing common grammar problems for advanced writers in English; and editing drafts and proofs. Sessions will consist of a mix of specialist input, group and pair work, and editing sessions.

Students who attend this course will turn in three sections of a report (approx. 500 words each) for feedback, revising these texts for a final portfolio that is graded.

Prerequisites / notice
Participants should be at a stage in their research where they can already start drafting parts of the report.

Elective Major: Molecular Plant Biology

Compulsory Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0311-00L</td>
<td>Molecular Life of Plants</td>
<td>O</td>
<td>6 credits</td>
<td>4V</td>
<td>S. C. Zeeman, K. Bomblies, O. Voinnet</td>
</tr>
</tbody>
</table>

Abstract
The advanced course introduces students to plants through a concept-based discussion of developmental processes that integrates physiology and biochemistry with genetics, molecular biology, and cell biology. The course follows the life of the plant, starting with the seed, progressing through germination to the seedling and mature plant, and ending with reproduction and senescence.

Objective
The new course "Molecular Life of Plants" reflects the rapid advances that are occurring in the field of experimental plant biology as well as the changing interests of students being trained in this discipline. Contemporary plant biology courses emphasize a traditional approach to experimental plant biology by discussing discrete topics that are removed from the context of the plant life cycle. The course will take an integrative approach that focuses on developmental concepts. Whereas traditional plant physiology courses were based on research carried out on intact plants or plant organs and were often based on phenomenological observations, current research in plant biology emphasizes work at the cellular, subcellular and molecular levels.

The goal of "Molecular Life of Plants" is to train students in integrative approaches to understand the function of plants in a developmental context. While the course focuses on plants, the training integrative approaches will also be useful for other organisms.

Content
The course "Molecular Life of Plants" will cover the following topics:

- Seed structure and physiology, their dormancy and germination.
- Seedling establishment and early development.
- Structure and Function of Meristems, including stem cells.
- Plant organ development (leaves, roots, flowers etc.).
- Plant reproduction.
- The plant vasculature for long-distance transport and other specialized tissues.
- Sensing and responding to the abiotic environment.
- Plant-microbe interactions; beneficial friends or pathogenic foes?
- Polyploidy; the benefits, problems and solutions to of multiple genomes.
- Photosynthesis and carbon partitioning.
- Photoregulation and the evolution of C4 metabolism.
- Starch biosynthesis and degradation.
- Chloroplast development and chlorophyll biosynthesis.
- Senescence mechanisms in plants.
- General principles of RNA silencing.
- MicroRNAs; discovery, general principle and modes of action at the cellular and system levels.
- Chromatin-based RNA silencing.
- Antiviral RNA silencing.
- RNA silencing & defense against non-viral pathogens.
- RNA silencing movement and amplification.
## Compulsory Master Courses

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>551-0120-00L</td>
<td>Plant Biology Colloquium (Autumn Semester)</td>
<td>W</td>
<td>2 credits</td>
<td>1K</td>
<td>S. C. Zeeman, K. Bomblies, O. Voinnet</td>
</tr>
</tbody>
</table>

### Abstract
Current topics in Molecular Plant Biology presented by internal and external speakers from academia.

### Objective
Getting insight into actual areas and challenges of Molecular Plant Biology.

### Content

### Competencies
- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- **Method-specific Competencies**
  - Analytical Competencies: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: fostered
- **Social Competencies**
  - Communication: fostered
  - Cooperation and Teamwork: fostered
- **Personal Competencies**
  - Creative Thinking: fostered
  - Critical Thinking: fostered
  - Self-direction and Self-management: fostered

## Elective Compulsory Concept Courses

See D-BIOL Master Studies Guide

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<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
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<tbody>
<tr>
<td>551-0307-00L</td>
<td>Molecular and Structural Biology I: Protein Structure and Function</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>R. Glockshuber, K. Locher, E. Weber-Ban</td>
</tr>
</tbody>
</table>

### Abstract
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

### Objective
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

### Literature
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

### Lecture notes
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.

### Current topics:
References will be given during the lectures.

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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>551-0309-00L</td>
<td>Concepts in Modern Genetics</td>
<td>W</td>
<td>6 credits</td>
<td>4V</td>
<td>Y. Barral, A. Hajnal, O. Voinnet, University lecturers</td>
</tr>
</tbody>
</table>

### Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

### Objective
This course focuses on the concepts of classical and modern genetics and genomics.

### Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

### Lecture notes
Scripts and additional material will be provided during the semester.
### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Communication</td>
<td>Creative Thinking</td>
</tr>
<tr>
<td>Analytical Competencies</td>
<td>assessed</td>
<td>cooperation and team work</td>
<td>Critical Thinking</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
<td>self-presentation and social influence</td>
<td>self-awareness and self-reflection</td>
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### Microbiology (Part I)

<table>
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<tr>
<th>Code</th>
<th>Subject</th>
<th>Title</th>
<th>Type</th>
<th>Credits</th>
<th>ECTS</th>
<th>Language</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0313-00L</td>
<td>Microbiology</td>
<td>Advanced course providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>English</td>
<td></td>
</tr>
<tr>
<td>551-0319-00L</td>
<td>Cellular Biochemistry (Part I)</td>
<td>Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into function, regulation and individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division &amp; growth, and cell migration.</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>English</td>
<td>To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.</td>
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</table>

### Cell Biology II: Microbiology

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<tr>
<th>Code</th>
<th>Subject</th>
<th>Title</th>
<th>Type</th>
<th>Credits</th>
<th>ECTS</th>
<th>Language</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-2413-00L</td>
<td>Evolutionary Genetics</td>
<td>The concept course Evolutionary Genetics consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics (emphasis on basic concepts) and ecological genetics (more emphasis on evolutionary and ecological processes of adaptation and speciation).</td>
<td>W</td>
<td>6 credits</td>
<td>4V</td>
<td>English</td>
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### Nucleic Acids and Carbohydrates

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
<th>Title</th>
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<th>Credits</th>
<th>ECTS</th>
<th>Language</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0731-00L</td>
<td>Nucleic Acids and Carbohydrates</td>
<td>Note for BSc Biology students: Only one of the two concept courses 529-0731-00 Nucleic Acids and Carbohydrates (autumn semester) or 529-0732-00 Proteins and Lipids (spring semester) can be counted for the Bachelor's degree. Structure, function and chemistry of nucleic acids and carbohydrates, DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>English</td>
<td></td>
</tr>
</tbody>
</table>
Objective
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNA; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Content
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNA; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Lecture notes
No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).

Literature
Mainly based on original literature, a detailed list will be distributed during the lecture

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Social Competencies
Communication assessed

Personal Competencies
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

551-1299-00L Bioinformatics

Abstract
Students will study bioinformatic concepts in the areas of metagenomics, genomics, transcriptomics, proteomics, biological networks and biostatistics. Through integrated lectures, practical hands-on exercises and project work, students will also be trained in analytical and programming skills to meet the emerging increase in data-driven knowledge generation in biology in the 21st century.

Objective
Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

Prerequisites / notice
Course participants have already acquired basic programming skills in UNIX, Python and R.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Elective Compulsory Master Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>751-5121-00L</td>
<td>Insect Ecology</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>C. De Moraes, N. Stanczyk</td>
</tr>
<tr>
<td>551-1153-00L</td>
<td>Systems Biology of Metabolism</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>U. Sauer, N. Zamboni</td>
</tr>
<tr>
<td>751-4504-00L</td>
<td>Plant Pathology I</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>B. McDonald</td>
</tr>
</tbody>
</table>
Content

Course description: Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems. Topics under the first theme will include pathogen life cycles, disease cycles, and an overview of plant pathogenic nematodes, viruses, bacteria, and fungi. Topics under the second theme will include plant defense strategies, host range, passive and active defenses, and chemical and structural defenses. Topics under the third theme will include the disease triangle and cultural control strategies.

Objective

Students will understand: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems as a basis for implementing disease management strategies in agroecosystems.

Abstract

Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems. Topics under the first theme will include pathogen life cycles, disease cycles, and an overview of plant pathogenic nematodes, viruses, bacteria, and fungi. Topics under the second theme will include plant defense strategies, host range, passive and active defenses, and chemical and structural defenses. Topics under the third theme will include the disease triangle and cultural control strategies.
After taking this course, students should be capable of the following: A) Recall different possibilities for modifying proteins in vitro and in vivo and their applications in a biological context. B) Understand the chemical and biochemical consequences of modifications and assess the different reaction possibilities in the context of in vivo - in vitro. C) Critically analyze and assess current chemical biology articles. D) Question the approaches learned and apply them to new biological problems.

principles of protein labeling and protein modification (fluorescent proteins, enzyme-mediated labeling, bioorthogonal chemistries)

advanced genetic code expansion methods (amber suppression, orthogonal ribosomes, unnatural base pairs, genome engineering and genome editing)

directed evolution and protein engineering

chemical biology of ubiquitin and targeted protein degradation

A script will not be handed out. Handouts to the lecture will be provided through moodle.

Citations from the original literature relevant to the individual lectures will be assigned during the lectures.

Knowledge provided in the bachelor lectures ‘Nucleic Acids and Carbohydrates’ and ‘Proteins and Lipids’ is assumed for this lecture.

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data.

Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

* stochastic models in molecular evolution
* phylogenetic & phylodynamic inference
* maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

* epidemiology
* pathogen evolution
* macroevolution of species

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Finally, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

* Yang, Z. 2006. Computational Molecular Evolution.
* Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.

Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course ‘Introduction to Programming’, which takes place in Basel before the start of the semester.
The course provides the first part an introduction to the statistical/graphical/data science software R (https://www.r-project.org/) for scientists. Topics covered are data generation and selection, graphical and basic statistical functions, creating simple functions, basic types of objects. The students will be able to use the software R for simple data analysis and graphics. The course provides the first part of an introduction to the statistical software R for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.

Part I of the course covers the following topics:
- What is R?
- R Basics: reading and writing data from/to files, creating vectors & matrices, selecting elements of dataframes, vectors and matrices, arithmetics;
- Types of data: numeric, character, logical and categorical data, missing values;
- Simple (statistical) functions: summary, mean, var, etc., simple statistical tests;
- Writing simple functions;
- Introduction to graphics: scatter-, boxplots and other high-level plotting functions, embellishing plots by title, axis labels, etc., adding elements (lines, points) to existing plots.

The course focuses on practical work at the computer with R. We will make use of the graphical user interface RStudio: www.rstudio.org

Note: Part I of UsingR is complemented and extended by Part II, which is offered during the second part of the semester and which can be taken independently from Part I.

401-6217-00L  Using R for Data Analysis and Graphics (Part II)  W  1.5 credits  1G  M. Mächler

Abstract
The course provides the second part an introduction to the statistical software R for scientists. Topics are data generation and selection, graphical functions, important statistical functions, types of objects, models, programming and writing functions. The students will be able to use the software R efficiently for data analysis, graphics and simple programming.

Note: This part builds on "Using R... (Part I)", but can be taken independently if the basics of R are already known.

Objective
The students will be able to use the software R for simple data analysis and graphics.

Content
The course focuses on practical work at the computer with R. We will make use of the graphical user interface RStudio: www.rstudio.org.

Lecture notes
An Introduction to R. http://stat.ethz.ch/CRC/contrib/Lam-IntroductionToR_LHL.pdf

Prerequisites / notice
Basic knowledge of R equivalent to "Using R... (Part I)" (= 401-6215-00L) is a prerequisite for this course.

The course resources will be provided via the Moodle web learning platform.

https://moodle-app2.let.ethz.ch/course/view.php?id=20847

Competencies
Subject-specific Competencies
Concepts and Theories  assessed
Techniques and Technologies  assessed

Method-specific Competencies
Analytical Competencies  assessed
Media and Digital Technologies  assessed
Problem-solving  assessed

Social Competencies
Cooperation and Teamwork  fostered

Personal Competencies
Creative Thinking  assessed

401-0649-00L  Applied Statistical Regression  W  5 credits  2V+1U  M. Dettling

Abstract
This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

Objective
The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models; this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

This short course is designed to accompany MSc students in writing their first reports in English, providing input on scientific writing in English as well as feedback on drafts sections of the report.

Students who attend this course will turn in three sections of a report (approx. 500 words each) for feedback, revising these texts for a final editing drafts and proofs. Sessions will consist of a mix of specialist input, group and pair work, and editing sessions.
Participants should be at a stage in their research where they can already start drafting parts of the report.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-2413-00L</td>
<td><strong>Evolutionary Genetics</strong></td>
<td>O</td>
<td>6 credits</td>
<td>4V</td>
<td>T. Säubler, A. Widmer, S. Fior, M. Fischer, J. Stapley</td>
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</table>

**Abstract**
The concept course 'Evolutionary Genetics' consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics (emphasis on basic concepts) and ecological genetics (more emphasis on evolutionary and ecological processes of adaptation and speciation).

**Objective**
The aim of the course is to provide students with a solid introduction to the fields of population genetics, quantitative genetics, and ecological genetics. The concepts and research methods developed in these fields have undergone profound transformations; they are of fundamental importance in our understanding of evolutionary processes, both past and present. Students should gain an appreciation for the concepts, methods and explanatory power of evolutionary genetics.

**Content**
Population genetics - Types and sources of genetic variation; randomly mating populations and the Hardy-Weinberg equilibrium; effects of inbreeding; natural selection; random genetic drift and effective population size; gene flow and hierarchical population structure; molecular population genetics: neutral theory of molecular evolution and basics of coalescent theory. Quantitative genetics - Continuous variation; measurement of quant. characters; genes, environments and their interactions; measuring their influence; response to selection; inbreeding and crossbreeding, effects on fitness; Fisher’s fundamental theorem. Ecological Genetics - Concepts and methods for the study of genetic variation and its role in adaptation, reproductive isolation, hybridization and speciation.

**Lecture notes**
Handouts

**Literature**

**Selected required readings (peer reviewed literature). Optional recommended readings with additional information.**

### Elective Compulsory Master Courses

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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>701-1409-00L</td>
<td><strong>Research Seminar: Ecological Genetics</strong></td>
<td>W</td>
<td>2 credits</td>
<td>1S</td>
<td>S. Fior</td>
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</table>

**Abstract**
In this research seminar we will critically discuss recent publications on current topics in Ecological Genetics.

**Objective**
It is our aim that participants gain insight into current research topics and approaches in Ecological Genetics and learn to critically assess and appreciate scientific publications in this field.

**Lecture notes**
none

**Literature**
Selected required readings (peer reviewed literature). Optional recommended readings with additional information.

**Prerequisites / notice**
Active and regular participation in the discussions, together with the presentation of a scientific paper are required to successfully pass this course. It is strongly recommended that participants have in advance successfully participated in the course Evolutionary Genetics (701-2413-00) or Ecological Genetics (701-1413-01).

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>751-5121-00L</td>
<td><strong>Insect Ecology</strong></td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>C. De Moraes, N. Stanczyk</td>
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</tbody>
</table>

**Abstract**
This is an introductory class on insect ecology. During the course you will learn about insect interactions with, and adaptations to, their environment and other organisms, and the importance of insect roles in our ecosystems. This course includes in-person lectures, small group discussions and outside readings.

**Objective**
The aim of the course is for you to be able to describe examples of insect interactions and evaluate their impact on broader ecosystems. Important topics include: insect-plant interactions, chemical ecology, predator-prey interactions, vectors of disease, social insects, mutual and parasitic interactions, and examining insect ecology in an evolutionary context.

**Lecture notes**
Provided to students through Moodle

**Literature**
Selected required readings (peer reviewed literature). Optional recommended readings with additional information.

### Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Critical Thinking

### Social Competencies

- Communication
- Cooperation and Teamwork

### Personal Competencies

- Critical Thinking

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>401-0625-01L</td>
<td><strong>Applied Analysis of Variance and Experimental Design</strong></td>
<td>W</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>L. Meier</td>
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</table>

**Abstract**
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

**Objective**
Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

**Content**
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

**Literature**

**Prerequisites / notice**
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

### Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Critical Thinking

### Personal Competencies

- Critical Thinking

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<tr>
<th>Number</th>
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<tr>
<td>401-0649-00L</td>
<td><strong>Applied Statistical Regression</strong></td>
<td>W</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>M. Dettling</td>
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</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 346 of 2653
This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

**Objective**
The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

**Content**
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

**Lecture notes**
A script will be available.

**Literature**
Faraway (2005): Linear Models with R
Faraway (2006): Extending the Linear Model with R
Draper & Smith (1988): Applied Regression Analysis
Fox (2008): Applied Regression Analysis and GLMs
Montgomery et al. (2006): Introduction to Linear Regression Analysis

**Prerequisites / notice**
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concept and Theories</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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<td></td>
<td>Analytical Competencies</td>
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<td></td>
<td>Decision-making</td>
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<td></td>
<td>Media and Digital Technologies</td>
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<td></td>
<td>Problem-solving</td>
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<td></td>
<td>Project Management</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Communication</td>
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<td></td>
<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Social Competencies</td>
<td>Negotiation</td>
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<td>Adaptable and Flexibility</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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**701-0301-00L Applied Systems Ecology**

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<tr>
<th>W</th>
<th>3 credits</th>
<th>2V</th>
<th>A. Gessler</th>
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**Abstract**
This course provides the ecological systems' knowledge needed to question applied solutions to current environmental issues. Our central aim is to balance participants' respect for complexity with a sense of possibility by providing examples from the vast solution space offered by ecological systems, such as e.g. green infrastructure to manage water.

**Objective**
At the end of the course...
...you know how to structure your inquiry and how to proceed the analysis when faced with a complex environmental issue. You can formulate the relevant questions, find answers (supported by discussions, input from the lecturers and the literature), and you are able to present your conclusions clearly and cautiously.
...you understand the complexity of interactions and structures in ecosystems. You know how ecosystem processes, functions and services interact and feed back across multiple spatio-temporal scales (in general, plus in depth case examples).
...you understand that biodiversity and the interaction between organisms are an integral part of ecosystems. You are aware that the link between biodiversity and process/function/service is rarely fully understood. You know how to honestly deal with this lack of understanding and can nevertheless find, critically analyse and communicate solutions.
...you understand the importance of ecosystem services for society.
...you have an overview of the methods of ecosystem research and have a deeper insight into some of them, e.g. ecosystem observation, manipulation and modelling.
...you have reflected on ecology as a young discipline at the heart of significant applied questions.

**Content**
This course provides the ecological systems' knowledge needed to question applied sustainability solutions. We will critically assess the complexity of current environmental issues, illustrating basic ecological concepts and principles. Our central aim is to balance participants' respect for complexity with a sense of possibility by providing examples from the vast solution space offered by ecological systems, such as e.g. green infrastructure to manage water.

The course is structured around four larger topical areas: (1) Integrated Water Management -- Green infrastructure (land management options) as an alternative to engineered solutions (e.g. large reservoirs) in flood and drought management; (2) Fire dynamics, the water cycle and biodiversity -- The surprising dynamics of species life cycles and populations in arid landscapes; (3) Rewilding, e.g. re-introducing apex predators (e.g. wolves), or large ungulates (e.g. bisons) in protected areas -- A nature conservation trend with counterintuitive effects; (4) Coupling of aquatic and terrestrial systems: carbon, nitrogen and phosphorus transfers of global importance on landscape scale.

**Lecture notes**
Case descriptions, commented glossary and a list of literature and further resources per case.

**Literature**
Schulze et al. (2005) Plant Ecology; Springer.
The course provides the first part of an introduction to the statistical/graphical/data science software R (https://www.r-project.org/) for scientists. Topics covered are data generation and selection, graphical and basic statistical functions, creating simple functions, basic types of objects.

Part of the course covers the following topics:
- What is R?
- R Basics: reading and writing data from/to files, creating vectors & matrices, selecting elements of dataframes, vectors and matrices, arithmetics;
- Types of data: numeric, character, logical and categorical data, missing values;
- Simple (statistical) functions: summary, mean, var, etc., simple statistical tests;
- Writing simple functions;
- Introduction to graphics: scatter-, boxplots and other high-level plotting functions, embellishing plots by title, axis labels, etc., adding elements (lines, points) to existing plots.

The course focuses on practical work at the computer. We will make use of the graphical user interface RStudio: www.rstudio.org

Note: Part I of UsingR is complemented and extended by Part II, which is offered during the second part of the semester and which can be taken independently from Part I.

The students will be able to use the software R for simple data analysis and graphics.

Part II of the course builds on Part I and covers the following additional topics:
- Elements of the R language: control structures (if, else, loops), lists, overview of R objects, attributes of R objects;
- More on R functions;
- Applying functions to elements of vectors, matrices and lists;
- Object oriented programming with R: classes and methods;
- Tayloring R: options
- Extending basic R: packages

The course focuses on practical work at the computer. We will make use of the graphical user interface RStudio: www.rstudio.org

Note: Part I of UsingR is complemented and extended by Part II, which is offered during the second part of the semester and which can be taken independently from Part I.

The students will be able to use the software R for simple data analysis and graphics.

The course combines elements of a classic lecture, group discussions and problem based learning. It is helpful, but not essential to be familiar with the "seven stages" method (see e.g. course 701-0352-00L "Analysis and Assessment of Environmental Sustainability" by Christian Pohl et al.).

The course resources will be provided via the Moodle web learning platform. Subscribing via Mystudies "automatically" makes you a student participant of the Moodle course of this lecture, which is at https://moodle-app2.let.ethz.ch/course/view.php?id=20847

The course focuses on practical work at the computer. We will make use of the graphical user interface RStudio: www.rstudio.org

Note: Part I of UsingR is complemented and extended by Part II, which is offered during the second part of the semester and which can be taken independently from Part I.

The students will be able to use the software R for simple data analysis and graphics.
Abstract

Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems.

Objective

Students will understand: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems as a basis for implementing disease management strategies in agroecosystems.

Content

Course description: Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems. Topics under the first theme will include pathogen life cycles, disease cycles, and an overview of plant pathogenic nematodes, viruses, bacteria, and fungi. Topics under the second theme will include plant defense strategies, host range, passive and active defenses, and chemical and structural defenses. Topics under the third theme will include the disease triangle and cultural control strategies.

Lecture Topics and Tentative Schedule

Week 1  The nature of plant diseases, symbiosis, parasites, mutualism, biotrophs and necrotrophs, disease cycles and pathogen life cycles.

Week 2  Nematode attack strategies and types of damage. Viral pathogens, classification, reproduction and transmission, attack strategies and types of damage. Examples TMV, BYDV. Bacterial pathogens and phytoplasmas, classification, reproduction and transmission.

Week 3  Bacterial attack strategies and symptoms. Example bacterial diseases: fire blight, Agrobacterium crown gall, soft rots. Fungal and oomycete pathogens, classification, growth and reproduction, sexual and asexual spores, transmission.

Week 4  Fungal and oomycete life cycles, disease cycles, infection processes, colonization, phytotoxins and mycotoxins. Attack strategies of fungal necrotrophs and biotrophs. Symptoms and signs of fungal infection. Example fungal diseases: potato late blight.

Week 5  Example fungal diseases: wheat stem rust, grape powdery mildew, wheat septoria triticum blotch. Plant defense mechanisms, host range and non-host resistance. Passive structural and chemical defenses, preformed chemical defenses. Active structural defense, histological and cellular (papillae).

Week 6  Active chemical defense, hypersensitive response, pathogenesis-related (PR) proteins, phytoalexins and disease resistance. Pisatin and pisatin demethylase. Local and systemic acquired resistance (LAR, SAR), induced systemic resistance (ISR), signal molecules, defense activators (Bion). Pathogen effects on food quality. Positive and negative transformations.


Week 8  Epidemiology: Disease pyramid, environmental effects on epidemic development, plant effects on development of epidemics, including resistance, physiology, density, uniformity.

Week 9  Disease assessment: incidence and severity measures, keys, diagrams, scales, measurement errors. Correlations between incidence and severity. Molecular detection and diagnosis of pathogens. Host indexing, serology, monoclonal and polyclonal antibodies, ELISA.

Week 10  Molecular detection and diagnosis of pathogens: PCR, rDNA and loop-mediated isothermal amplification. Strategies for minimizing disease risks: calculating disease thresholds, disease forecasting systems.


Week 12  Physical control methods. Cultural control methods: avoidance, tillage practices, crop sanitation.

Week 13  Cultural control methods: fertilizers, crop rotations.

Lecture notes

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

636-0017-00L  Computational Biology  W  6 credits  3G+2A  T. Vaughan, C. Magnus, T. Studler

Abstract

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Objective

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

- epidemiology
- pathogen evolution
- macroevolution of species

Content

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamic, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes

Lecture slides will be available on moodle.
The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

* Yang, Z. 2006. Computational Molecular Evolution.
* Drummond, A. & Bouckraet. R. 2015. Bayesian evolutionary analysis with BEAST.

Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place in Basel before the start of the semester.

### 701-1471-00L
**Ecological Parasitology**

*W* 3 credits  
1V+1P  
F. Feijen, J. Jokela, C. Vorburger

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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</table>

### Content

- **Objective**
  1. Identify common macroparasites in invertebrates
  2. Understand ecological and evolutionary processes in host-parasite interactions
  3. Conduct parasitological research

- **Social Competencies**
  - Communication
    - Cooperation and Teamwork | assessed
  - Leadership and Responsibility | fostered
  - Self-presentation and Social Influence | fostered
  - Sensitivity to Diversity | fostered
  - Negotiation | fostered

- **Personal Competencies**
  - Adaptability and Flexibility | fostered
  - Creative Thinking | assessed
  - Critical Thinking | assessed
  - Integrity and Work Ethics | fostered
  - Self-awareness and Self-reflection | fostered
  - Self-direction and Self-management | assessed

### Abstract

The course will not take place fall semester 2024.

Course focuses on the ecology and evolution of macroparasites and their hosts. Through lectures and practical work, students learn about diversity and natural history of parasites, adaptations of parasites, ecology of host-parasite interactions, applied parasitology, and human macroparasites in the modern world.

- **Objective**
  1. Identify common macroparasites in invertebrates
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  - Self-direction and Self-management | assessed

### Literature

- Schmid Hempel 2011 Evolutionary Parasitology
- Stearns & Medzhitov 2016 Evolutionary Medicine
- *Drummond, A.* & *Bouckraet, R.* 2015. *Bayesian evolutionary analysis with BEAST.*

### Prerequisites

*W* 3 credits  
1V+1P  
F. Feijen, J. Jokela, C. Vorburger

- **Objective**
  1. Identify common macroparasites in invertebrates
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- *Drummond, A.* & *Bouckraet, R.* 2015. *Bayesian evolutionary analysis with BEAST.*
### COURSE GOALS

The goal of this course is to understand and to appreciate mathematical models and computational methods that provide insight into the evolutionary process in general and tumor evolution in particular. Students should analyze and evaluate models and their application critically and be able to design new models.

### LEARNING OBJECTIVES

The learning objectives follow from the course goals. After attending this course, students should be able to:

- Describe key processes affecting the size of populations and abundance of species within ecological communities.
- Provide insight to students on the ecological impacts of anthropogenic change, and how an understanding of ecological processes can help us predict these ecological impacts and design conservation / restoration actions to mitigate their negative impacts.
- Introduce students to the major ecological processes that together shape the composition and abundance of species within ecological communities.
- Introduce students to the major ecological processes that together shape the composition and abundance of species within ecological communities.
- Teach students to critically summarize and analyze primary ecological literature, understanding how ecological studies contribute to our knowledge, how to critically evaluate their strengths and weaknesses, and practice designing follow up studies.

### Literature


### Prerequisites

Prerequisites: Basic mathematics (linear algebra, calculus, probability)

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### Lecture notes

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### Lecture notes

All course materials (videos, lecture notes, primary literature) will be provided on the course moodle.

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### Literature


### Prerequisites

Prerequisites: Basic mathematics (linear algebra, calculus, probability)
**Objective**

Learn to apply bioinformatics and computational methods for analysis of microbiome next-generation sequencing data. A secondary goal is to critically examine the relevance of microorganisms to food quality, safety, and human health, through application of theory and appropriate experimental design. Students completing this course will thus be able to both apply appropriate methodology to study microorganisms (or other high-dimensional data) in different systems, as well as evaluate and interpret bioinformatics results.

**Content**

1. Introduction to microbiomes and microbial bioinformatics toolkit. Python, Pandas, Jupyter, GitHub, visualization libraries for Python.
3. Microbial diversity, function, and ecology. Molecular ecology, diversity metrics, ordination methods.

This course requires extensive engagement in learning outside of the classroom (using online resources and practical exercises), with a focus on active learning in the classroom.

**Prerequisites / notice**

No specific pre-requisites, but students should have some familiarity with microbiology, molecular biology, programming (Python), bioinformatics, and statistics.

Students will bring and work on their own laptop computers.

All software used in the course is free and open-source.

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**Elective Concept Courses**

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<tbody>
<tr>
<td>551-0313-00L</td>
<td>Microbiology (Part I)</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>W.-D. Hardt, L. Eberl, B. Nguyen, J. Piel, M. Pilhofer, A. Vagstad</td>
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**Abstract**

Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Objective**

This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Content**

Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Lecture notes**

Updated handouts will be provided during the class.

**Literature**

Current literature references will be provided during the lectures.

**Prerequisites / notice**

The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

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<td>551-0309-00L</td>
<td>Concepts in Modern Genetics</td>
<td>W</td>
<td>6 credits</td>
<td>4V</td>
<td>Y. Barral, A. Hajnal, O. Voinnet, University lecturers</td>
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**Abstract**

Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

**Objective**

This course focuses on the concepts of classical and modern genetics and genomics.

**Content**

Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Lecture notes**

Scripts and additional material will be provided during the semester.

**Competencies**

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**Abstract**

Students will study bioinformatic concepts in the areas of metagenomics, genomics, transcriptomics, proteomics, biological networks and biostatistics. Through integrated lectures, practical hands-on exercises and project work, students will also be trained in analytical and programming skills to meet the emerging increase in data-driven knowledge generation in biology in the 21st century.
Objective

Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

Prerequisites / notice

Course participants have already acquired basic programming skills in UNIX, Python and R.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies

- Communication
- Cooperation and Teamwork

Personal Competencies

- Adaptable and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

- Choose and use generally suitable grammatical structures, punctuation, and identify areas in which further development is needed

Prerequisites / notice

Students bring their own computer with keyboard, internet access (browser) and software to connect to the ETH network via VPN.

- Students who attend this course will turn in three sections of a report (approx. 500 words each) for feedback, revising these texts for a final portfolio that is graded.

- Students should be at a stage in their research where they can already start drafting parts of the report.

Recommended Master Courses

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<td>551-0575-00L</td>
<td>Writing Scientific Reports for MSc Biology</td>
<td>W</td>
<td>2</td>
<td>1G</td>
<td>R. Taylor</td>
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</tbody>
</table>

Objective

This short course is designed to accompany MSc students in writing their first reports in English, providing input on scientific writing in English as well as feedback on drafts sections of the report.

Content

The course covers the process of writing reports in biology, helping students to focus on the language and communicative aspects of these reports. Topics covered include structuring sentences, paragraphs, and longer sections (introductions, methods, etc.); presenting and integrating non-textual elements such as graphs and tables; reviewing common grammar problems for advanced writers in English; and editing drafts and proofs. Sessions will consist of a mix of specialist input, group and pair work, and editing sessions.

Prerequisites / notice

Participants should be at a stage in their research where they can already start drafting parts of the report.

Major in Systems Biology

Elective Compulsory Concept Courses

See D-BIOL Master Studies Guide

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<tr>
<td>551-0319-00L</td>
<td>Cellular Biochemistry (Part I)</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>U. Kutay, F. Allain, T. Kleele, I. Zemp</td>
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Objective

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

Content

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

- Students will learn to:
  - Plan, draft, structure, and edit scientific reports
  - Produce reader-friendly sentences
  - Establish a clear and logical flow between sentences and paragraphs
  - Select formal vocabulary and use it in a generally accurate and correct manner
  - Choose and use generally suitable grammatical structures, punctuation, and identify areas in which further development is needed

- Students who attend this course will turn in three sections of a report (approx. 500 words each) for feedback, revising these texts for a final portfolio that is graded.

- Students should be at a stage in their research where they can already start drafting parts of the report.

Prerequisites / notice

Participants should be at a stage in their research where they can already start drafting parts of the report.

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Information for UZH students:

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Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-
Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.

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551-0313-00L Microbiology (Part I) W 3 credits 2V W.-D. Hardt, L. Eberl, B. Nguyen, J. Piel, M. Pilhofer, A. Vagstad

Abstract
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Objective
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Content
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Lecture notes
Updated handouts will be provided during the class.

Literature
Current literature references will be provided during the lectures.

Prerequisites / notice
English The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

551-1299-00L Bioinformatics W 6 credits 4G S. Sunagawa, P. Beltrao, V. Boeva, A. Kahles, C. von Mering, N. Zamboni

Abstract
Students will study bioinformatic concepts in the areas of metagenomics, genomics, transcriptomics, proteomics, biological networks and biostatistics. Through integrated lectures, practical hands-on exercises and project work, students will also be trained in analytical and programming skills to meet the emerging increase in data-driven knowledge generation in biology in the 21st century.

Objective
Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

Prerequisites / notice
Course participants have already acquired basic programming skills in UNIX, Python and R. Students bring their own computer with keyboard, internet access (browser) and software to connect to the ETH network via VPN.

Competencies

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<th>Competencies</th>
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<th>Analytical Competency</th>
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<td>Concepts and Theories</td>
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<td>Self-direction and Self-management</td>
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636-0007-00L Computational Systems Biology W 6 credits 3V+2U J. Stelling

Abstract
Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

Objective
The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 354 of 2653
Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks. We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

Lecture notes
http://www.csb.ethz.ch/education/lectures.html


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<th>Number</th>
<th>Title</th>
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<tbody>
<tr>
<td>636-0706-00L</td>
<td>Spatio-Temporal Modelling in Biology</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>D. Iber</td>
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</tbody>
</table>

Abstract
This course focuses on modeling spatio-temporal problems in biology, in particular on the cell and tissue level. The main focus is on mechanisms and concepts, but mathematical and numerical techniques are introduced as required. Biological examples discussed in the course provide an introduction to key concepts in developmental biology.

Objective
Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides an introduction to dynamical systems, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

Content
1. Introduction to Modelling in Biology
2. Bioimage Analysis
3. Morphogen Gradients
4. Precision & Robustness of Patterning
5. Mathematical Description of Growing Biological Systems
6. Travelling Waves & Wave Pinning
7. Turing Patterns
8. Chemotaxis
9. Epithelial Organisation
10. Tissue Simulation Frameworks
11. Tissue Mechanics & Fluid Dynamics
12. Growth Control
13. Image-Based Modelling
14. Summary

Literature
The lecture course is not based on any textbook. The following textbooks are related to some of its content. The textbooks may be of interest for further reading, but are not necessary to follow the course:

- Murray, Mathematical Biology, Springer
- Forgacs and Newman, Biological Physics of the Developing Embryo, CUP
- Keener and Sneyd, Mathematical Physiology, Springer
- Fall et al., Computational Cell Biology, Springer
- Szallasi et al., System Modeling in Cellular Biology, MIT Press
- Wolkenhauer, Systems Biology
- Kreyszig, Engineering Mathematics, Wiley

Prerequisites / notice
The course is self-contained. The course assumes no background in biology but a good foundation regarding mathematical and computational techniques.

For more information, visit: http://www.csb.ethz.ch/education/lectures.html
Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars of thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding experimental data in the literature.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation. Experimental results from the literature.

By the end of this module, each student should be able to:

- recognize the universal principles underlying the development of different animal body plans.
- explain how the genes encoding the molecular toolkit have evolved to create animal diversity.
- relate changes in gene structure or function to evolutionary changes in animal development.

Key skills:

By the end of this module, each student should be able to:

- present and discuss a relevant evolutionary topic in an oral presentation
- select and integrate key concepts in animal evolution from primary literature
- participate in discussions on topics presented by others

Objective

By the end of this module, each student should be able to:

- understand and appreciate mathematical models and computational methods that provide insight into the evolutionary process in general and tumor evolution in particular.
- analyze and evaluate models and their application critically and be able to design new models.

Abstract

Evolutionary dynamics is concerned with the mathematical principles according to which life has evolved. This course offers an introduction to mathematical modeling of evolution, including deterministic and stochastic models, with an emphasis on tumor evolution.

Objective

The goal of this course is to understand and appreciate mathematical models and computational methods that provide insight into the evolutionary process in general and tumor evolution in particular. Students should analyze and evaluate models and their application critically and be able to design new models.

Content

Evolutionary dynamics is concerned with the mathematical principles according to which life has evolved. This course offers an introduction to mathematical modeling of evolution, including deterministic and stochastic models, with an emphasis on tumor evolution.

Prerequisites: Basic mathematics (linear algebra, calculus, probability)

Literature


Competencies

<table>
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<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Analytical Competencies</th>
<th>Problem-solving</th>
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<td>Method-specific Competencies</td>
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<td>Cooperation and Teamwork</td>
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<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>Self-direction and Self-management</td>
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Literature


As further deepening:

Prerequisites / notice

Participants need a good command of:
- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.

Competencies

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Recommended Master Courses

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<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>551-0575-00L</td>
<td>Writing Scientific Reports for MSc Biology</td>
<td>W</td>
<td>2</td>
<td>1G</td>
<td>R. Taylor</td>
</tr>
</tbody>
</table>

Objective

Students will learn to:
- Plan, draft, structure, and edit scientific reports
- Produce reader-friendly sentences
- Establish a clear and logical flow between sentences and paragraphs
- Select formal vocabulary and use it in a generally accurate and correct manner
- Choose and use generally suitable grammatical structures, punctuation, and identify areas in which further development is needed

Content

The course covers the process of writing reports in biology, helping students to focus on the language and communicative aspects of these reports. Topics covered include structuring sentences, paragraphs, and longer sections (introductions, methods, etc.); presenting and integrating non-textual elements such as graphs and tables; reviewing common grammar problems for advanced writers in English; and editing drafts and proofs. Sessions will consist of a mix of specialist input, group and pair work, and editing sessions.

Prerequisites / notice

Students who attend this course will turn in three sections of a report (approx. 500 words each) for feedback, revising these texts for a final portfolio that is graded.

Research Projects

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>551-1801-10L</td>
<td>Research Project I</td>
<td>O</td>
<td>16</td>
<td>34A</td>
<td>Lecturers</td>
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Abstract

Research projects, with themes from the chosen scientific fields of interest, are intended to familiarise candidates with scientific procedures and operational methodologies through supervised participation in current research work.

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<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>551-1801-11L</td>
<td>Research Project II</td>
<td>O</td>
<td>16</td>
<td>34A</td>
<td>Lecturers</td>
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Abstract

Research projects, with themes from the chosen scientific fields of interest, are intended to familiarise candidates with scientific procedures and operational methodologies through supervised participation in current research work.

Master's Thesis

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<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>551-1800-10L</td>
<td>Master's Thesis</td>
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<td>32</td>
<td>69D</td>
<td>Lecturers</td>
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</table>

Only students who fulfill the following criteria are allowed to begin with their master thesis:
- a. successful completion of the bachelor programme;
- b. fulfilling of any additional requirements necessary to
The Master research will be carried out on a theme in the chosen subject area and must be completed with a written report (Thesis) within six months.

Master Studies (Programme Regulations 2018)

Elective Major Subject Areas

Elective Major: Ecology and Evolution

Elective Major: Biological Chemistry

Elective Major: Microbiology and Immunology

Elective Major: Cell Biology

Elective Compulsory Concept Courses

See D-BIOL Master Studies Guide

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>551-0319-00L</td>
<td>Cellular Biochemistry (Part I)</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>U. Kutay, F. Allain, T. Kleele, I. Zemp</td>
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</table>

Abstract

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Content

Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Literature

Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prequisites / notice

To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

Competencies

Subject-specific Competencies: Concepts and Theories, Techniques and Technologies

Techniques and Technologies: assessed

Methods and Technologies: assessed

In this course, students will gain a profound understanding of the biochemistry of the cell. They will learn how to interpret and analyze complex biochemical processes at the molecular level.

Number    | Title                        | Type | ECTS | Hours | Lecturers                  |
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<tr>
<td>551-0309-00L</td>
<td>Concepts in Modern Genetics</td>
<td>W</td>
<td>6 credits</td>
<td>4V</td>
<td>Y. Barral, A. Hajnal, O. Voinnet, University lecturers</td>
</tr>
</tbody>
</table>

Abstract

Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

Objective

This course focuses on the concepts of classical and modern genetics and genomics.

Content

The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Competencies

Subject-specific Competencies: Concepts and Theories, Techniques and Technologies

Techniques and Technologies: assessed

Methods and Technologies: assessed

In this course, students will gain a profound understanding of the biochemistry of the cell. They will learn how to interpret and analyze complex biochemical processes at the molecular level.

Number    | Title                        | Type | ECTS | Hours | Lecturers                  |
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<tr>
<td>551-0317-00L</td>
<td>Immunology I</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>M. Kopf, A. Oxenius</td>
</tr>
</tbody>
</table>

Abstract

Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.
Objective
Introduction into structural and functional aspects of the immune system.
Basic knowledge of the mechanisms and the regulation of an immune response.

Content
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Lecture notes
Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien".

Literature
- Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020

Prerequisites / notice
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed
assessed

Techniques and Technologies
assessed

Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving
Project Management
fostered
fostered
fostered
fostered

Social Competencies
Communication
Cooperation and Teamwork
fostered
fostered

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Self-direction and Self-management
fostered
fostered
fostered
fostered

Abstract
Students will study bioinformatic concepts in the areas of metagenomics, genomics, transcriptomics, proteomics, biological networks and biostatistics. Through integrated lectures, practical hands-on exercises and project work, students will also be trained in analytical and programming skills to meet the emerging increase in data-driven knowledge generation in biology in the 21st century.

Objective
Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

Prerequisites / notice
Course participants have already acquired basic programming skills in UNIX, Python and R.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed
assessed

Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management
assessed
assessed
assessed
assessed
fostered

Social Competencies
Communication
Cooperation and Teamwork
fostered
fostered

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management
fostered
fostered
fostered
fostered
fostered

551-0512-00L
Current Topics in Molecular and Cellular Neurobiology

Does not take place this semester.

Abstract
The course is a literature seminar or "journal club". Each Friday a student, or a member of the Suter Lab in the Institute of Molecular Health Sciences, will present a paper from the recent literature.

Objective
The course introduces you to recent developments in the fields of cellular and molecular neurobiology. It also supports you to develop your skills in critically reading the scientific literature. You should be able to grasp what the authors wanted to learn i.e. their goals, why the authors chose the experimental approach they used, the strengths and weaknesses of the experiments and the data presented, and how the work fits into the wider literature in the field. You will present one paper yourself, which provides you with practice in public speaking.

Content
You will present one paper yourself. Give an introduction to the field of the paper, then show and comment on the main results (all the papers we present are available online, so you can show original figures with a beamer). Finish with a summary of the main points and a discussion of their significance.

Lecture notes
Presentations will be made available after the seminars.
### Prerequisites / notice
You must attend at least 80% of the journal clubs, and give a presentation of your own. At the end of the semester there will be a 30 minute oral exam on the material presented during the semester. The grade will be based on the exam (45%), your presentation (45%), and a contribution based on your active participation in discussion of other presentations (10%).

### 551-0571-00L From DNA to Diversity: the Evolution of Multicellular Organisms (University of Zurich)

<table>
<thead>
<tr>
<th>Type</th>
<th>Credits</th>
<th>Hours/Week</th>
<th>Instructor(s)</th>
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<tbody>
<tr>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>A. Hajnal, D. Bopp</td>
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</table>

*No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.*

**UZH Module Code:** BIO336


**Abstract**
The evolution of the various body-plans is investigated by means of comparison of developmentally essential control genes of molecularly analysed model organisms.

**Objective**
By the end of this module, each student should be able to:
- recognize the universal principles underlying the development of different animal body plans.
- explain how the genes encoding the molecular toolkit have evolved to create animal diversity.
- relate changes in gene structure or function to evolutionary changes in animal development.

**Key skills:**
By the end of this module, each student should be able to:
- present and discuss a relevant evolutionary topic in an oral presentation
- select and integrate key concepts in animal evolution from primary literature
- participate in discussions on topics presented by others

### 551-1117-00L Cutting Edge Topics: Immunology and Infection Biology

<table>
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<tr>
<th>Type</th>
<th>Credits</th>
<th>Hours/Week</th>
<th>Instructor(s)</th>
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<tbody>
<tr>
<td>W</td>
<td>2</td>
<td>1S</td>
<td>A. Oxenius, B. Becher, C. Halin Winter, M. Kopf, S. R. Leibundgut, C. Münz, L. Tortola, M. van den Broek</td>
</tr>
</tbody>
</table>

*Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIO636 at UZH.*

**Abstract**
Weekly seminar about cutting edge topics in immunology and infection biology. Internationally renowned experts present their current research followed by an open discussion.

**Objective**
The aim of this course is to confront students with current research topics and with scientific presentation. The course offers the opportunity to gain in depth knowledge about diverse topics which are often only briefly touched in the concept courses and to engage in discussion with experts in the field.

**Content**
Immunology and infection biology.

The specific topics are variable and depend each semester on the list of invited experts.

**Lecture notes**
Current research data (often not yet published) are presented in this seminar series. There is no script and we are not allowed to record or distribute the contents of the seminars. Thus, the ability of students to extract the most relevant points of each seminar is promoted, which is an important skill for the future attendance of scientific meetings.

**Literature**
Often parts of the presented seminars have already been published by the respective speakers and the respective primary research can be retrieved from scientific journals.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
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<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
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<td>Project Management</td>
<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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**Assessed:**
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

**Fostered:**
- Creative Thinking
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

### 551-1153-00L Systems Biology of Metabolism

<table>
<thead>
<tr>
<th>Type</th>
<th>Credits</th>
<th>Hours/Week</th>
<th>Instructor(s)</th>
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<tr>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>U. Sauer, N. Zamboni</td>
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*Number of participants limited to 15.*

**Abstract**
Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.

**Objective**
Develop a deeper understanding of how relevant biological problems can be solved, thereby providing advanced insights to key experimental and computational methods in systems biology.
The course will be given as a mixture of lectures, studies of original research and guided discussions that focus on current research topics. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation networks in populations and single cells. Key methods to be covered are various modeling approaches, metabolic flux analyses, metabolomics and other omics.

Script and original publications will be supplied during the course. The course extends many of the generally introduced concepts and methods of the Concept Course in Systems Biology. It requires a good knowledge of biochemistry and basics of mathematics and chemistry.

**551-1177-00L  RNA Biology Lecture Series II: Non-Coding RNAs: Subject-specific Competencies**

**Abstract**

Milestones in RNA biology: on old concepts and modern experiments

**Objective**

The course will cover the current grand topics in RNA biology: ncRNA-mediated genome regulation; epigenetic programming of genome remodelling in ciliates; telomerase and telomeres; tRNA biology.

**Literature**

Lecture notes

Compeptencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Social Competencies

Communication

Personal Competencies

Critical Thinking

Self-awareness and Self-reflection

Self-direction and Self-management

**551-1177-00L  RNA Biology Lecture Series II: Transcription & Processing & Translation**

**Abstract**

This course covers aspects of RNA biology related to gene expression at the posttranscriptional level. These include RNA transcription, processing, alternative splicing, editing, export and translation.

**Objective**

The students should obtain an understanding of these processes, which are at work during gene expression.

**Content**

Transcription & 3'end formation; splicing, alternative splicing, RNA editing; the ribosome & translation, translation regulation, RNP biogenesis & nuclear export, mRNA surveillance & mRNA turnover; signal transduction & RNA.

**Literature**

Lecture notes

Compeptencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Social Competencies

Communication

Personal Competencies

Cooperation and Teamwork

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Self-direction and Self-management

**551-1177-00L  RNA Biology Lecture Series II: Non-Coding RNAs: Biology and Therapeutics**

**Abstract**

This course covers aspects of RNA biology related to the functions of non-coding RNAs as well as their use as drugs to treat diseases. The students should get familiar with the wide array of roles, which non-coding RNAs play in cellular functions.

**Objective**

Micro RNAs; computational approaches to miRNAs; micro RNA function in metabolism; viruses and viral RNAs; nucleic acid-based drugs; ncRNA-mediated genome regulation; epigenetic programming of genome remodelling in ciliates; telomerase and telomeres; TRNA biology.

**Content**

Micro RNAs; computational approaches to miRNAs; micro RNA function in metabolism; viruses and viral RNAs; nucleic acid-based drugs; ncRNA-mediated genome regulation; epigenetic programming of genome remodelling in ciliates; telomerase and telomeres; TRNA biology.

**Literature**

Lecture notes

Compeptencies

Subject-specific Competencies

Basic knowledge of cell and molecular biology.
Abstract
This course provides a detailed understanding of
- development of T and B cells
- the dynamics of an immune response during acute and chronic infection
- mechanisms of immunopathology
- modern vaccination strategies
Key experimental results will be shown to help understanding how immunological text book knowledge has evolved.

Objective
Obtain a detailed understanding of
- the development, activation, and differentiation of different types of T cells and their effector mechanisms during immune responses,
- Recognition of pathogenic microorganisms by the host cells and molecular events thereafter,
- events and signals for maturation of naive B cells to antibody producing plasma cells and memory B cells.
- Optimization of B cell responses by intelligent design of new vaccines

Content
- Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg)
- NK T cells and responses to lipid antigens
- Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17
- Overview of cytokines and their effector function
- Co-stimulation (signals 1-3)
- Dendritic cells
- Evolution of the "Danger" concept
- Cells expressing Pattern Recognition Receptors and their downstream signals
- T cell function and dysfunction in acute and chronic viral infections

Literature
Documents of the lectures are available for download at:
https://moodle-app2.let.ethz.ch/course/view.php?id=2581&notifyeditingon=1

Prerequisites / notice
Immunology I and II recommended but not compulsory
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<td>Sensitivity to Diversity</td>
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<td>Sensitivity to Diversity</td>
<td>Self-direction and Self-management</td>
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</table>

### Complementary Courses

**376-1305-00L Development of the Nervous System (University of Zurich)**

- Abstract: The lecture will cover molecular and cellular processes underlying the development of the nervous system (neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation). The importance of these processes in the context of developmental diseases is discussed.

- Objective: On successful completion of the module the student should be able to
  - relate structure and function of the nervous system to its development - apply principles of molecular, cellular, and developmental biology to the development of the nervous system
  - identify key steps in development underlying neurological syndromes and diseases

- Key skills: On successful completion of the module the student should be able to
  - interpret and critically evaluate original research reports
  - apply knowledge and relate experimental approaches from molecular, cellular and developmental biology to the developing nervous system.

- Content: The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.

- Lecture notes: Must be downloaded from OLAT: [https://www.olat.uzh.ch/olat/dmz/as BIO344](https://www.olat.uzh.ch/olat/dmz/as BIO344)

- Literature: The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on OLAT.

- Prerequisites / notice: BIO142 Developmental Biology, BIO143 Neurobiology

**376-1305-01L Molecular Neurophysiology: From Molecules to Systems**

- Abstract: The course covers the physiology of nerve cells, from the single cell through the neuronal network to the systemic level. The focus is on molecular and cellular mechanisms – synaptic transmission, signal transduction, gene expression, synaptic plasticity.

- Objective: Based on an understanding of molecular and cellular mechanisms, the aim is to provide a deepened insight into neurophysiological processes underlying complex brain functions – learning/memory, sleep, sensory.

- Literature: The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on Moodle.

- Competencies: Subject-specific Competencies
  - Concepts and Theories Assessed
  - Analytical Competencies Assessed

### Chemical Biology and Synthetic Biochemistry

- Abstract: Overview of modern chemical biology and synthetic biochemistry techniques, focussed on protein modification and labeling and on methods to endow proteins with novel functionalities.
Objective

After taking this course, students should be capable of the following: A) Recall different possibilities for modifying proteins in vitro and in vivo and their applications in a biological context, B) Understand the chemical and biochemical consequences of modifications and assess the different reaction possibilities in the context of in vivo - in vitro, C) Critically analyze and assess current chemical biology articles D) Question the approaches learned and apply them to new biological problems.

Content

principles of protein labeling and protein modification (fluorescent proteins, enzyme-mediated labeling, bioorthogonal chemistries)
directed evolution and protein engineering
chemical biology of ubiquitin and targeted protein degradation
advanced genetic code expansion methods (amber suppression, orthogonal ribosomes, unnatural base pairs, genome engineering and genome editing)

Lecture notes

A script will not be handed out. Handouts to the lecture will be provided through moodle.

Literature

Citations from the original literature relevant to the individual lectures will be assigned during the lectures.

Prerequisites / notice

Knowledge provided in the bachelor lectures 'Nucleic Acids and Carbohydrates' and 'Proteins and Lipids' is assumed for this lecture.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Recommended Master Courses

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<td>551-0575-00L</td>
<td>Writing Scientific Reports for MSc Biology</td>
<td>W</td>
<td>2</td>
<td>1G</td>
<td>R. Taylor</td>
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<td>This short course is designed to accompany MSc</td>
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<td>Students in writing their first reports in English</td>
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<td>providing input on scientific writing in English</td>
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<td>report.</td>
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<td>- Plan, draft, structure, and edit scientific</td>
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<td>reports</td>
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<td>- Produce reader-friendly sentences</td>
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<td>language and communicative aspects of these</td>
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Elective Major: Molecular Health Sciences

Elective Compulsory Concept Courses

See D-BIOL Master Studies Guide

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<tr>
<th>Number</th>
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<td>Concepts in Modern Genetics</td>
<td>W</td>
<td>6</td>
<td>4V</td>
<td>Y. Barral, A. Hajnal, O. Voinnet, University lecturers</td>
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<td>Information for UZH students:</td>
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<td>Enrollment to this course unit only possible at ETH</td>
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<td>Concepts of modern genetics and genomics, including</td>
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<td>principles of classical genetics; yeast genetics;</td>
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<td>gene mapping; forward and reverse Genetics;</td>
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<td>analysis of developmental processes; epigenetics</td>
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<td>and modern genetics and genomics.</td>
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The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

551-1299-00L Bioinformatics

Abstract
Students will study bioinformatic concepts in the areas of metagenomics, genomics, transcriptomics, proteomics, biological networks and biostatistics. Through integrated lectures, practical hands-on exercises and project work, students will also be trained in analytical and programming skills to meet the emerging increase in data-driven knowledge generation in biology in the 21st century.

Objective
Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

Prerequisites / notice
Course participants have already acquired basic programming skills in UNIX, Python and R.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

551-0317-00L Immunology I

Abstract
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Objective
Basic knowledge of the mechanisms and the regulation of an immune response. Students will write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Content
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Lecture notes
Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"

Literature
- Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020

Prerequisites / notice
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: fostered
- Problem-solving: fostered
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Self-direction and Self-management: fostered
By the end of this module, each student should be able to foster assessed assessed

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmssss/en/studies/application/deadline s.html

The evolution of the various body-plans is investigated by means of comparison of developmentally essential control genes of molecularly analysed model organisms.

By the end of this module, each student should be able to foster assessed assessed

- recognize the universal principles underlying the development of different animal body plans.
- explain how the genes encoding the molecular toolkit have evolved to create animal diversity.
- relate changes in gene structure or function to evolutionary changes in animal development.

Key skills:
By the end of this module, each student should be able to foster assessed assessed

- present and discuss a relevant evolutionary topic in an oral presentation
- select and integrate key concepts in animal evolution from primary literature
- participate in discussions on topics presented by others

The literature will be provided during the course. The course will be taught in English.

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

The course will be taught in English.

During this Masters level seminar style course, students will explore current research topics in cellular biochemistry focused on the structure, function and regulation of selected cell components, and the consequences of dysregulation for pathologies.

Students will work with experts toward a critical analysis of cutting-edge research in the domain of cellular biochemistry, with emphasis on normal cellular processes and the consequences of their dysregulation. At the end of the course, students will be able to evaluate, critically discuss and write about scientific articles in the research area of cellular biochemistry, and they will identify open testable research questions.

Guided by an expert in the field, students will engage in classical round-table style discussions of current literature with frontal presentations. Guided by a faculty expert, students develop domain knowledge of the research area associated with a primary paper, and alternate as discussion leaders to present the research topic. By the end of the semester, students will formulate their ideas about open testable research questions that extend from the published work.

The course will be taught in English.

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

The literature will be provided during the course.

The course will be taught in English.

Student-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

- participate in discussions on topics presented by others
- select and integrate key concepts in animal evolution from primary literature
- present and discuss a relevant evolutionary topic in an oral presentation
- recognize the universal principles underlying the development of different animal body plans.

The course will be taught in English.

Students will work with experts toward a critical analysis of cutting-edge research in the domain of cellular biochemistry, with emphasis on normal cellular processes and the consequences of their dysregulation. At the end of the course, students will be able to evaluate, critically discuss and write about scientific articles in the research area of cellular biochemistry, and they will identify open testable research questions.

Guided by an expert in the field, students will engage in classical round-table style discussions of current literature with frontal presentations. Guided by a faculty expert, students develop domain knowledge of the research area associated with a primary paper, and alternate as discussion leaders to present the research topic. By the end of the semester, students will formulate their ideas about open testable research questions that extend from the published work.

The course will be taught in English.

Student-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

- recognize the universal principles underlying the development of different animal body plans.
- relate changes in gene structure or function to evolutionary changes in animal development.

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

The literature will be provided during the course.

The course will be taught in English.

Student-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

- recognize the universal principles underlying the development of different animal body plans.
- relate changes in gene structure or function to evolutionary changes in animal development.

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

The literature will be provided during the course.

The course will be taught in English.

Student-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

- recognize the universal principles underlying the development of different animal body plans.
Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.

**Objective**
Develop a deeper understanding of how relevant biological problems can be solved, thereby providing advanced insights to key experimental and computational methods in systems biology.

**Content**
The course will be given as a mixture of lectures, studies of original research and guided discussions that focus on current research topics. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation networks in populations and single cells. Key methods to be covered are various modeling approaches, metabolic flux analyses, metabolomics and other omics.

**Lecture notes**
Script and original publications will be supplied during the course.

**Prerequisites / notice**
The course extends many of the generally introduced concepts and methods of the Concept Course in Systems Biology. It requires a good knowledge of biochemistry and basics of mathematics and chemistry.

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**551-1171-00L Immunology: From Milestones to Current Topics**

| Subject-specific Competencies | Method-specific Competencies | Social Competencies | Personal Competencies |  
| Concepts and Theories | Analytical Competencies | Communication | Critical Thinking |  
| Techniques and Technologies | Self-presentation and Social Influence | | Self-awareness and Self-reflection |  
| assessed | fostered | assessed | assessed |  
| fostered | fostered | fostered | fostered |  

**Abstract**
Milestones in Immunology: on old concepts and modern experiments

**Objective**
The course will cover the current grand topics in immunology: B cells, innate immunity, antigen presentation, tumor immunity, T cells, myeloid cells and stromal cells. For each topic two or four hours will be allocated. Historical milestone papers will be presented by the tutor/lecturer providing an overview on the development of the theoretical framework and critical technological advances. The students will read the historical milestone papers and contribute to the discussion. In the second part of the lecture, students will present recent high impact research papers that have emerged from the landmark achievements of the previously discussed milestone concepts.

**Content**
Milestones and current topics of innate immunity, antigen presentation, B cells, thymus and T cells, cytotoxic T cells, NK cells, stromal cells, CNS immunity and tumor immunology.

**Lecture notes**
Original and review articles will be distributed by the respective lecturer.

**Literature**
Litteraturunterlagen werden vor Beginn des Kurses auf folgender website zugänglich sein: https://moodle-app2.let.ethz.ch/course/view.php?id=15568

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**752-4009-00L Molecular Biology of Foodborne Pathogens**

| Subject-specific Competencies | Method-specific Competencies | Social Competencies | Personal Competencies |  
| Concepts and Theories | Analytical Competencies | Communication | Critical Thinking |  
| Techniques and Technologies | Decision-making | | Self-awareness and Self-reflection |  
| assessed | assessed | fostered | assessed |  
| fostered | fostered | fostered | fostered |  

**Abstract**
The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

**Objective**
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

**Content**
Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

**Lecture notes**
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

**Literature**
Recommendations will be given in the first lecture

**Prerequisites / notice**
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break !

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**376-0300-00L Essentials in Translational Science**

| Subject-specific Competencies | Method-specific Competencies | Social Competencies | Personal Competencies |  
| Concepts and Theories | Analytical Competencies | Communication | Creative Thinking |  
| Techniques and Technologies | Decision-making | | Critical Thinking |  
| assessed | assessed | fostered | fostered |  
| fostered | fostered | fostered | fostered |  

**Abstract**
Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people (e.g. Medicines). The course should help to clarify basics of translational science, illustrate successful applications and enable students to integrate key features into their future projects.

**Objective**
After completing this course, students will be able to understand:
Key steps of drug development and their interdependencies. Project management, communication & funding options. Students should be able to apply this knowledge in drug development programs in Pharma, Biotech or their own spin-off.
This lecture will guide you through drug development from bench to bedside and provide industry perspectives which support you in your first industry role or when building a startup. The course will integrate knowledge across the many disciplines which are required to develop new medicines which are transformational for patients.

Key steps of the Drug development process
- Disease Biology and mechanism of action
- Translation of 'Mechanism of Action' into patient and payer benefit
- Drug design
- Drug formulation
- Toxicology
- Pharmacokinetics & pharmacodynamics
- Translational medicine
- Clinical trials
- Regulatory requirements
- Patenting
- Market access
- How are these steps connected and impacting each other?

Positive and negative examples will be illustrated by distinguished guest speakers.

### Competencies

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### 701-1703-00L Evolutionary Medicine for Infectious Diseases

**W** 3 credits  **2G**  **A. Hall**

**Abstract**

This course explores infectious disease from both the host and pathogen perspective. Through short lectures, reading and active discussion, students will identify areas where evolutionary thinking can improve our understanding of infectious diseases and, ultimately, our ability to treat them effectively.

**Objective**

Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses.

**Content**

We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (< 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

**Literature**

The focus is on primary literature, but for some parts the following text books provide good background information:

- Schmid Hempel 2011 Evolutionary Parasitology
- Stearns & Medzhitov 2011 Evolutionary Medicine

**Prerequisites / notice**

A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

**Competencies**

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### 636-0108-00L Biological Engineering and Biotechnology

**W** 4 credits  **3V**  **M. Fussenegger**

**Abstract**

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

**Objective**

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

**Content**


**Lecture notes**

Handout during the course.

### 551-1407-00L RNA Biology Lecture Series I: Transcription & Processing & Translation

**W** 4 credits  **2V**  **F. Allain, N. Ban, S. Jonas, U. Kutay, further lecturers**

**Abstract**

This course covers aspects of RNA biology related to gene expression at the posttranscriptional level. These include RNA transcription, processing, alternative splicing, editing, export and translation.
### 376-1305-00L Development of the Nervous System (University of Zurich)

**Objective**
On successful completion of the module the student should be able to:
- relate structure and function of the nervous system to its development
- apply principles of molecular, cellular, and developmental biology to the development of the nervous system
- identify key steps in development underlying neurological syndromes and diseases

**Content**
The lecture will cover molecular and cellular processes underlying the development of the nervous system (neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation). The importance of these processes in the context of developmental diseases is discussed.

**Lecture notes**
Must be downloaded from OLAT: https://www.olat.uzh.ch/olat/dmz/

**Literature**
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on OLAT.

**Prerequisites / notice**
BIO142 Developmental Biology, BIO143 Neurobiology

### 376-1305-01L Molecular Neurophysiology: From Molecules to Systems

**Objective**
Based on an understanding of molecular and cellular mechanisms, the aim is to provide a deepened insight into neurophysiological processes underlying complex brain functions – learning/memory, sleep, sensory.

**Content**
First, basic molecular and cellular mechanisms in nerve cells (excitability, neurotransmission, signal transduction, gene expression, synaptic plasticity) are introduced. Afterwards, their significance for selected neurophysiological processes (learning/memory, sleep, sensory) will be illuminated.

**Literature**
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on Moodle.

**Competencies**
- **Subject-specific Competencies**
  - Concepts and Theories assessed
  - Analytical Competencies assessed

### 551-1409-00L RNA Biology Lecture Series II: Non-Coding RNAs

**Objective**
The students should get familiar with the wide array of roles, which non-coding RNAs play in cellular functions.

**Content**
Micro RNAs; computational approaches to miRNAs; micro RNA function in metabolism; viruses and viral RNAs; ncRNA-mediated genome regulation; epigenetic programming of genome remodelling in ciliates; telomerase and telomeres; tRNA biology.

**Abstract**
This course covers aspects of RNA biology related to the functions of non-coding RNAs as well as their use as drugs to treat diseases.

**Prerequisites / notice**
Basic knowledge of cell and molecular biology.

### 551-0223-00L Immunology III

**Objective**
This course provides a detailed understanding of:
- development of T and B cells
- the dynamics of an immune response during acute and chronic infection
- mechanisms of immunopathology
- modern vaccination strategies

**Abstract**
Key experimental results will be shown to help understanding how immunological text book knowledge has evolved.
Objective
Obtain a detailed understanding of
- the development, activation, and differentiation of different types of T cells and their effectormechanisms during immune responses,
- Recognition of pathogenic microorganisms by the host cells and molecular events thereafter,
- events and signals for maturation of naive B cells to antibody producing plasma cells and memory B cells.
- Optimization of B cell responses by intelligent design of new vaccines

Content
- Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg)
- NK T cells and responses to lipid antigens
- Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17
- Overview of cytokines and their effector function
- Co-stimulation (signals 1-3)
- Dendritic cells
- Evolution of the "Danger" concept
- Cells expressing Pattern Recognition Receptors and their downstream signals
- T cell function and dysfunction in acute and chronic viral infections

Literature
Documents of the lectures are available for download at:
https://moodle-app2.let.ethz.ch/course/view.php?id=2581&notifyeditingon=1

Prerequisites / notice
immunology I and II recommended but not compulsory

Recommended Master Courses

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<tr>
<th>Number</th>
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<tr>
<td>551-0575-00L</td>
<td>Writing Scientific Reports for MSc Biology</td>
<td>W</td>
<td>2</td>
<td>1G</td>
<td>R. Taylor</td>
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Abstract
This short course is designed to accompany MSc students in writing their first reports in English, providing input on scientific writing in English as well as feedback on drafts sections of the report.

Objective
Students will learn to:
- Plan, draft, structure, and edit scientific reports
- Produce reader-friendly sentences
- Establish a clear and logical flow between sentences and paragraphs
- Select formal vocabulary and use it in a generally accurate and correct manner
- Choose and use generally suitable grammatical structures, punctuation, and identify areas in which further development is needed

Content
The course covers the process of writing reports in biology, helping students to focus on the language and communicative aspects of these reports. Topics covered include structuring sentences, paragraphs, and longer sections (introductions, methods, etc.); presenting and integrating non-textual elements such as graphs and tables; reviewing common grammar problems for advanced writers in English; and editing drafts and proofs. Sessions will consist of a mix of specialist input, group and pair work, and editing sessions.

Prerequisites / notice
Participants should be at a stage in their research where they can already start drafting parts of the report.

Elective Major: Biochemistry

See Major in Biochemistry

Elective Major: Molecular Plant Biology

See Major in Molecular Plant Biology

Elective Major: Systems Biology

See Major in Systems Biology

Elective Major: Molecular and Structural Biology

See Major in Molecular and Structural Biology
### Research Projects

Research projects neither accepted nor registered nor approved will not be credited.

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### Master's Thesis

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<td>Only students who fulfill the following criteria are allowed to begin with their master thesis: a. successful completion of the bachelor programme; b. fulfilling of any additional requirements necessary to gain admission to the master programme; c. have acquired at least 30 credits in the category &quot;research projects&quot;.</td>
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<td></td>
<td>Abstract</td>
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<td>The Master research will be carried out on a theme in the chosen subject area and must be completed with a written report (Thesis) within six months</td>
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</table>

### Master's Examination

Only students who fulfill the following criteria are admitted for the master examination:

- a. successful completion of the bachelor programme;
- b. fulfilling of any additional requirements necessary to gain admission to the master programme.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1800-01L</td>
<td>Master's Examination</td>
<td>O</td>
<td>4 credits</td>
<td></td>
<td>Lecturers</td>
</tr>
<tr>
<td></td>
<td>Only students who fulfill the following criteria are admitted for the master examination</td>
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<tr>
<td></td>
<td>a. successful completion of the bachelor programme; b. fulfilling of any additional requirements necessary to gain admission to the master programme.</td>
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<td></td>
<td>Abstract</td>
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<td>In the Master’s examination a student must provide proof of general knowledge in the elective major field. Starting with a discussion based on the Master’s thesis further experiments and experimental strategies should be discussed in order to test the general understanding.</td>
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### Science in Perspective

[see Science in Perspective: Language Courses ETH/UZH](#)

[see Science in Perspective: Type A: Enhancement of Reflection Capability](#)

[Recommended Science in Perspective (Type B) for D-BIOL](#)

### Biology Master - Key for Type

| O   | Compulsory                  | E-  | Recommended, not eligible for credits |
| W+  | Eligible for credits and recommended | Z   | Courses outside the curriculum |
| W   | Eligible for credits        | Dr  | Suitable for doctorate |

### Key for Hours

| V   | lecture                     | P   | practical/laboratory course |
| G   | lecture with exercise       | A   | independent project |
| U   | exercise                    | D   | diploma thesis |
| S   | seminar                    | R   | revision course / private study |
| K   | colloquium                  |     |                            |

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Biomedical Engineering Master

Track Courses

Bioelectronics

Track Core Courses

During the Master programme, a minimum of 12 CP must be obtained from track core courses.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>151-0604-00L</td>
<td>Microrobotics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>B. Nelson</td>
</tr>
<tr>
<td>Abstract</td>
<td>Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.</td>
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<tr>
<td>Objective</td>
<td>The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.</td>
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<tr>
<td>Content</td>
<td>Main topics of the course include:</td>
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<td></td>
<td>- Scaling laws at micro/nano scales</td>
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<td></td>
<td>- Electrostatics</td>
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<td></td>
<td>- Electromagnetism</td>
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<td></td>
<td>- Low Reynolds number flows</td>
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<td>- Observation tools</td>
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<td>- Materials and fabrication methods</td>
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<tr>
<td></td>
<td>- Applications of biomedical microrobots</td>
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<tr>
<td>Lecture notes</td>
<td>The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The lecture will be taught in English.</td>
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</table>

| 151-0621-00L  | Microsystems I: Process Technology and Integration     | W    | 6    | 3V+2U | M. Haluska, C. Hierold |
| Abstract      | Students are introduced to the fundamentals of semiconductors, the basics of micromachining and silicon process technology and will learn about the fabrication of microsystems and -devices by a sequence of defined processing steps (process flow). |
| Objective     | Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystem devices by the combination of unit process steps ( = process flow). |
| Content       | - Introduction to microsystems technology (MST) and micro electro mechanical systems (MEMS) |
|               | - Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition. |
|               | - Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties. |
| Lecture notes | Application of selected technologies will be demonstrated on case studies. |
| Literature    | Handouts (available online)                             |
|               | - S.M. Sze: Semiconductor Devices, Physics and Technology |
|               | - W. Menz, J. Mohr, O.Paul: Microsystem Technology      |
|               | - Hong Xiao: Introduction to Semiconductor Manufacturing Technology |
|               | - T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications |
| Prerequisites / notice | Prerequisites: Physics I and II |

| 227-0105-00L  | Introduction to Estimation and Machine Learning         | W    | 6    | 4G    | H.-A. Loeliger      |
| Abstract      | Students master the basic mathematical concepts and algorithms of estimation and machine learning. |
| Objective     | Mathematical basics of estimation and machine learning, with a view towards applications in signal processing. |
| Content       | Review of probability theory; basics of statistical estimation; least squares and linear learning; Hilbert spaces; singular-value decomposition; kernel methods, neural networks, and more |
| Lecture notes | Lecture notes will be handed out as the course progresses. |
| Prerequisites / notice | Prerequisites: solid basics in linear algebra and probability theory |

| 227-0166-00L  | Analog Integrated Circuits                              | W    | 6    | 4G    | T. Jang             |
| Abstract      | This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies. |
| Objective     | Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems. |
| Content       | The basic elements, design issues and techniques for analog integrated circuits will be taught in this course. |
| Lecture notes | Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors. |

| 227-0311-00L  | Qubits, Electrons, Photons                              | W    | 6    | 3V+2U | T. Zambelli         |
| Abstract      | In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis). |
Objective

Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics.

Starting from the axioms of quantum mechanics, we will derive the fascinating theory describing spin and qubits, electron transitions and transfer, photons and LASER: quantum mechanics is different because it mocks our daily Euclidean intuition!

In this way, students will work out a robust quantum mechanics (theoretical!!!) basis which will help them in their advanced studies of the following masters: EEIT (batteries), Biomedical Engineering (NMR, bioelectronics), Quantum Engineering, Micro- and Nanosystems.

IMPORTANT: "qubits" from the point of view of NMR (and NOT from that of quantum computing!).

Content

- Lagrangian and Hamiltonian: Symmetries and Poisson Brackets
- Postulates of QM: Hilbert Spaces and Operators
- Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator
- Density Operator
- Spin: Qubits, Bloch Equations, and NMR
- Entanglement
- Symmetries and Corresponding Operators
- Schrödinger's Wave Mechanics: Electrons in a Periodic Potential and Energy Bands
- Harmonic Oscillator: Creation and Annihilation Operators
- Identical Particles: Bosons and Fermions
- Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER
- Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener

Lecture notes

No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM, while corresponding videos of the previous years are available in Moodle !!!

Literature


Supplementary material will be uploaded in Moodle.

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+ (as rigorous and profound presentation of the mathematical framework) G. Dell'Antonio, "Lectures on the Mathematics of Quantum Mechanics I", 2015, Springer

+ (as account of those formidable years) G. Gamow, "Thirty Years that Shook Physics", 1985, Dover Publications Inc.

Prerequisites / notice

The course has been intentionally conceived to be self-consistent with respect to QM for those master students not having encountered it in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) QM introduction course like the D-ITET "Physics II".

A solid base of Analysis I & II as well as of Linear Algebra is really helpful.

Competencies

Subject-specific Competencies
- Concepts and Theories evaluated
- Techniques and Technologies fostered

Method-specific Competencies
- Analytical Competencies evaluated
- Decision-making assessed
- Media and Digital Technologies evaluated
- Problem-solving assessed
- Project Management evaluated

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity assessed
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility evaluated
- Creative Thinking evaluated
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

227-0385-10L Biomedical Imaging 6 credits 5G S. Kozerke, K. P. Prüssmann

Abstract

Introduction to diagnostic medical imaging based on electromagnetic and acoustic fields including X-ray planar and tomographic imaging, radio-tracer based nuclear imaging techniques, magnetic resonance imaging and ultrasound-based procedures.

Objective

Upon completion of the course students are able to:

- Explain the physical and mathematical foundations of diagnostic medical imaging systems
- Characterize system performance based on signal-to-noise ratio, contrast-to-noise ratio and transfer function
- Design a basic diagnostic imaging system chain including data acquisition and data reconstruction
- Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications
## Content
- Introduction (intro, overview, history)
- Signal theory and processing (foundations, transforms, filtering, signal-to-noise ratio)
- X-rays (production, tissue interaction, contrast, modular transfer function)
- X-rays (resolution, detection, digital subtraction angiography, Radon transform)
- X-rays (filtered back-projection, spiral computed tomography, image quality, dose)
- Nuclear imaging (radioactive tracer, collimation, point spread function, SPECT/PET)
- Nuclear imaging (detection principles, image reconstruction, kinetic modelling)
- Magnetic Resonance (magnetic moment, spin transitions, excitation, relaxation, detection)
- Magnetic Resonance (plane wave encoding, Fourier reconstruction, pulse sequences)
- Magnetic Resonance (contrast mechanisms, gradient- and spin-echo, applications)
- Ultrasound (mechanical wave generation, propagation in tissue, reflection, transmission)
- Ultrasound (spatial and temporal resolution, phased arrays)
- Ultrasound (Doppler shift, implementations, applications)
- Summary, example exam questions

## Lecture notes
Lecture notes and handouts

## Literature
Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

## Prerequisites / notice
Analysis, Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming

## Competencies

<table>
<thead>
<tr>
<th>Category</th>
<th>Competencies</th>
<th>Type</th>
</tr>
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<tbody>
<tr>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
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<tr>
<td>Personal Competencies</td>
<td>Adaptable and Flexibility</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
</tr>
</tbody>
</table>

## Abstract
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the basic vocabulary of biomedical engineering and getting familiar with concepts that govern common medical instruments and the most important organs from an engineering point of view.

## Objective
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs.

In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

## Content
- History of BME and the role of biomedical engineers. Ethical issues related to BME.
- Biomedical sensors both wearable and also biochemical sensors.
- Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices.
- Bioinformatics: genomic and proteomic tools, databases and basic calculations.
- Equations describing basic reactions and enzyme kinetics.
- Medical optics: Optical components and systems used in hospitals.
- Basic concepts of tissue engineering and organ printing.
- Biomaterials and their medical applications.
- Function of the heart and the circulatory system.
- Transport and exchange of substances in the human body, compartment modeling.
- The respiratory system.
- Bioimaging.
- Orthopedic biomechanics.
- Lectures (2h), discussion of practical exercises (1h) and homework exercises.

## Lecture notes
Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

## Prerequisites / notice
No specific requirements, BUT
ITET, MAVT, PHY$S$ students will have to learn a lot of new words related to biochemistry, biology and medicine, while HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.).
Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving fostered
Project Management fostered

Social Competencies

Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies

Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Abstract

The course introduces bioelectricity and the sensing concepts that enable obtaining information about neurons and their networks. The sources of electrical fields and currents in the context of biological systems are discussed. The fundamental concepts and challenges of measuring bioelectronic signals and the basic concepts to record optogenetically modified organisms are introduced.

Objective

During this course the students will:
- learn the basic concepts in bioelectronics including the sources of bioelectronic signals and the methods to measure them
- be able to solve typical problems in bioelectronics
- learn about the remaining challenges in this field

Content

Lecture topics:

1. Introduction

Sources of bioelectronic signals
2. Membrane and Transport
3-4. Action potential and Hodgkin-Huxley

Measuring bioelectronic signals
5. Detection and Noise
6. Measuring currents in solutions, nanopore sensing and patch clamp pipettes
7. Measuring potentials in solution and core conductance model
8. Measuring electronic signals with wearable electronics, ECG, EEG
9. Measuring mechanical signals with bioelectronics

In vivo stimulation and recording
10. Functional electric stimulation
11. In vivo electrophysiology

Optical recording and control of neurons (optogenetics)
12. Measuring neurons optically, fundamentals of optical microscopy
13. Fluorescent probes and scanning microscopy, optogenetics, in vivo microscopy
14. Measuring biochemical signals

Lecture notes

A detailed script is provided to each lecture including the exercises and their solutions.

Literature

Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites / notice

The course requires an open attitude to the interdisciplinary approach of bioelectronics. In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).
Deep-Learning (DL) is a brain-inspired weak form of AI that allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve as an inspiring inspiration to think differently about state-of-the-art ANN training methods.

The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g., simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this, the lectures and exercises will merge ideas, concepts, and methods from machine learning and neuroscience.

These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today's neuroscience papers.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today's neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to 'error backpropagation' in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex.

Similar to their neocortical counterparts, ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing video games deep ANNs outperform humans (Minh et al., 2015, Silver et al., 2018). ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used. The participation in the course is subject to the following conditions:

1) The number of participants is limited to 120 students (MSc and PhDs).
2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Understanding of the characteristics of neuromorphic circuit elements.
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

Between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface properties of nerves are studied to understand both sensory transduction and the generation of nerve impulses along axons. The concept of local neural circuitry is illustrated in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.

The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.

Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intense in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

**227-1037-00L**

**Introduction to Neuroinformatics**

- **Abstract**: Understanding computation by neurons and neural circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monoculars of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the connections and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

- **Content**: This course covers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits is constructed in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.

- **Prerequisites / notice**: Particular: The course is highly recommended for those who intend to take the spring semester course ‘Neuromorphic Engineering II’, that teaches the conception, simulation, and physical layout of such circuits with chip design tools.

**376-1714-00L**

**Biocompatible Materials**

- **Abstract**: Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

- **Objective**: The course covers the following topics:
  1. Introduction to molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
  2. The concept of biocompatibility.
  3. Introduction into methodology used in biomaterials research and application.
  4. Introduction to different material classes in use for medical applications.

- **Content**: Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Literature**: Handouts are deposited online (moodle).

- **Handouts and references therin**
  - Comprehensive Biomaterials, Ducheyne P. et al., 1st Edition, 2011 (available online via ETH library)

- **Lecture notes**

**402-0674-00L**

**Physics in Medical Research: From Atoms to Cells**

- **Abstract**: Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epilatral growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.
The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X-rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

**Recommended Elective Courses**

These courses are particularly recommended for the Bioelectronics track. Please consult your track advisor if you wish to select other subjects.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0509-00L</td>
<td>Acoustics in Fluid Media: From Robotics to Additive Manufacturing</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>D. Ahmed</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course will provide you with the fundamentals of the new and exciting field of ultrasound-based microrobots to treat various diseases. Furthermore, we will explore how ultrasound can be used in additive manufacturing for tissue constructs and robotics.</td>
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<td>Objective</td>
<td>The course is designed to equip students with skills in the design and development of ultrasound-based manipulation devices and microrobots for applications in medicine and additive manufacturing.</td>
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<td>Content</td>
<td>Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity. Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices</td>
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<td>Prerequisites / notice</td>
<td>Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.</td>
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<td>Decision-making</td>
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<td>Problem-solving</td>
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<p>| 151-0905-00L | Medical Technology Innovation - From Concept to Clinics | W    | 4    | 3G    | I. Herrmann |
| Abstract     | Project-oriented learning on how to develop technological solutions to address unmet clinical needs. |
| Objective    | After completing the course, you will be able to effectively collaborate with medical doctors in order to identify important unmet clinical needs. You will be able to ideate and develop appropriate engineering solutions and implementation strategies for real-world clinical problems. This lecture aims to prepare you for typical engineering challenges in the real-world where - in addition to the development of an elegant solution - interdisciplinary team work and effective communication play a key role. |
| Lecture notes | will be available on the moodle. |
| Literature   | will be available on the moodle. |
| Prerequisites / notice | On site presence during (most) of the lectures highly encouraged! Graded innovation project will require on-site presence. |</p>
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151-0913-00L Introduction to Photonics  W  4 credits  2V+2U  R. Quidant, J. Ortega Arroyo

Abstract
This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

Objective
Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.

Content
I- BASICS OF WAVE THEORY
1) General concepts
2) Differential wave equation
3) Wavefront
4) Plane waves and Fourier decomposition of optical fields
5) Spherical waves and Huygens-Fresnel principle

II- ELECTROMAGNETIC WAVES
1) Maxwell equations
2) Wave equation for EM waves
3) Dielectric permittivity
4) Refractive index
5) Nonlinear optics
6) Polarisation and polarisation control

III- PROPAGATION OF LIGHT
1) Waves at an interface
2) The Fresnel coefficients
3) Total internal reflection
4) Evanescent waves
5) Dispersion diagram

IV- INTERFERENCES
1) General considerations
2) Temporal and spatial coherence
3) The Young double slit experiment
4) Diffraction gratings
5) The Michelson interferometer
6) Multi-wave interference
7) Antireflecting coating and interference filters
8) Optical holography

V- LIGHT MANIPULATION
1) Optical waveguides
2) Photonic crystals
3) Metamaterials and metasurfaces
4) Optical cavities

VI- OPTICAL FORCES AND OPTICAL TWEEZERS
1) History of optical forces
2) Theory of optical trapping
3) Atom cooling
4) Optomechanics
5) Applications of optical tweezers

VII- INTRODUCTION TO OPTICAL MICROSCOPY
1) Basic concepts
2) Direct and Fourier imaging
3) Image formation
4) Fluorescence microscopy
5) Scattering-based microscopy
6) Digital holography
7) Computational imaging
Molecular sensors are used in everyday life in health care, environmental monitoring, food safety, space and other fields. Sources of molecular information, its transport and fundamental concepts of molecular sensing will be discussed. In the scope of group projects, the acquired knowledge will be applied and deepened in case studies.

This course consists of a theoretical and a project-based learning block. In the first 10 semester weeks, theoretical knowledge will be provided through lectures and deepened in corresponding exercises. In the last 4 weeks, the students will apply the learned concepts through group projects to investigate case studies. The outcome will be present.

This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, neurons, and the development of autonomous robotic systems. The outcome will be present.

Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retina and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions.
Ultrasound waves are non-ionizing and thus provide a safe means to interrogate and treat biological tissues. Advantages such as real-time operation, low cost, and portability have led to ultrasound systems becoming standard tools in hospitals and research laboratories. Applications in biology and medicine include ultrasound and optoacoustic imaging, thermal therapy, or pulse stimulation. Specifically, standard and ultra-fast ultrasound imaging approaches will be covered along with new optoacoustic and transmission ultrasound imaging methods. The course will also describe mathematical modelling approaches and numerical methods as well as signal and image processing tools applicable in ultrasound-based imaging. Other topics include ultrasound sensors, laser ultrasound, therapeutic effects, or biomedical applications and contrast agents. The course will conclude with current and future research directions in the field of ultrasound in biomedicine.

The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used in the exercises. A basic understanding of computer-aided design, digital design, and computer-aided software engineering is helpful.

Course material
Handouts of presented slides. No script but an accompanying textbook is recommended.

Lecture notes
Basic knowledge in physics. Basic programming skills, preferably in Matlab.

Prerequisites
Background in physics. Basic knowledge of analog design is required.
This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers.

The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during the whole term to analyze circuits on a system level (analog continuous-time, analog discrete-time, mixed-signal and digital) and understand how signals propagate through them. The theory and CMOS implementation of active Filters is then discussed in detail using the example of Gm-C filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators follows. The link to the practical design of circuits and systems is done with an overview over different quality measures and figures of merit used in scientific literature and datasheets. Finally, an introduction to discrete-time and mixed-domain filters and circuits is given, including sensor read-out amplifiers, correlated double sampling, and chopping, and an introduction to sigma-delta A/D and D/A conversion on a system level.

This lecture does not go down to the details of transistor implementations. The lecture "227-0166-00L Analog Integrated Circuits" complements This lecture very well in that respect.

Lecture notes

The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the technical content.

Prerequisites / notice

Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria ...) and of the main properties of linear systems is necessary.

Competencies

| Subject-specific Competencies | Concepts and Theories | assessed |
| Method-specific Competencies | Analytical Competencies | assessed |
| | Decision-making | fostered |
| | Media and Digital Technologies | fostered |
| | Problem-solving | assessed |
| Social Competencies | Communication | fostered |
| | Cooperation and Teamwork | fostered |
| | Customer Orientation | fostered |
| | Leadership and Responsibility | fostered |
| | Self-presentation and Social Influence | fostered |
| | Sensitivity to Diversity | fostered |
| | Negotiation | fostered |
| Personal Competencies | Adaptability and Flexibility | fostered |
| | Creative Thinking | fostered |
| | Critical Thinking | assessed |
| | Integrity and Work Ethics | fostered |
| | Self-awareness and Self-reflection | fostered |
| | Self-direction and Self-management | fostered |

227-0621-00L Emerging Memory Technologies

This course focuses on the current state and prospects of memory technologies, emerging beyond the silicon transistor era. We explore resistive PCM and RRAM, magnetic MRAM and ferroelectric FRAM memories, covering physics, device aspects and the latest research in the field. Through interactive lectures and laboratory sessions, students gain up-to-date knowledge and compare emerging memory techs. Some material is protected by password; students from ETHZ who are interested can write to haschmid@ethz.ch to ask for the password even if they do not attend the lecture.

Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.

Emerging Memory Technologies

W 3 credits 1V+1U M. Yarena

The course is organized as a series of lectures, focusing on selected memory technologies. This class also includes practical laboratory sessions for the PCM research topics. Students will spend 2 hours per week in the class or laboratory and additional 2-3 hours per week to prepare for the exam. Lecture notes will be made available on the website.

Prerequisites / notice

No formal prerequisites, however, students are recommended to have a basic understanding of digital electronics and microprocessors.

Competencies

| Subject-specific Competencies | Concepts and Theories | assessed |
| Method-specific Competencies | Analytical Competencies | assessed |
| | Decision-making | fostered |
| | Media and Digital Technologies | fostered |
| | Problem-solving | assessed |
| Social Competencies | Communication | fostered |
| | Cooperation and Teamwork | fostered |
| | Customer Orientation | fostered |
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| Personal Competencies | Adaptability and Flexibility | fostered |
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Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.

Emerging Memory Technologies

W 3 credits 1V+1U M. Yarena

The course is organized as a series of lectures, focusing on selected memory technologies. This class also includes practical laboratory sessions for the PCM research topics. Students will spend 2 hours per week in the class or laboratory and additional 2-3 hours per week to prepare for the exam. Lecture notes will be made available on the website.

Prerequisites / notice

No formal prerequisites, however, students are recommended to have a basic understanding of digital electronics and microprocessors.
Cross-Disciplinary Research and Development in Medicine and Engineering

A maximum of 12 medical degree students and 12 (biomedical) engineering degree students can be admitted, their number should be equal.

IMPORTANT: Note that a special permission from the lecturers is required to register for this course. Contact the head lecturer to that end.

Abstract
Cross-disciplinary collaboration between engineers and medical doctors is indispensable for innovation in health care. This course brings together engineering students from ETH Zurich and medical students from the University of Zurich to experience the rewards and challenges of such interdisciplinary work in a project based learning environment.

Objective
The main goal of this course is to demonstrate the differences in communication between the fields of medicine and engineering. Since such differences become most evident during actual collaborative work, the course is based on a project in physiology, medical or clinical research that combines medicine and engineering.

For the engineering students, the specific aims of the course are to:
- Identify and precisely define a clinical need;
- Acquire a working understanding of the investigated system;
- Identify the engineering challenges in the project and communicate them to the medical students;
- Develop and implement, together with the medical students, solution strategies for the identified challenges;
- Present the solution concept to a cross-disciplinary audience; Preliminary need and solution validation;

Content
After a general introduction to interdisciplinary communication, need identification and product development, the engineering students will team up with medical students to 1) identify a clinically relevant need, 2) develop early-stage solution concepts to it. In the process, they will be supervised both by lecturers from ETH Zurich and the University of Zurich, receiving coaching customized to the project. The project is usually defined by the team itself, but can also be guided by the lecturers. The course will end with each team presenting identified need and solution concept to a cross-disciplinary audience.

Lecture notes
Lecture handouts and relevant material will be provided.

Prerequisites / notice
IMPORTANT: Note that a special permission from the lecturers is required to register for this course. Contact the head lecturer to that end.

Cell Biophysics

Abstract
Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular and cellular level, and critically compared with the corresponding experimental data in the literature.

Objective
Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars of thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding experimental results from the literature.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

Content
- Basics of theory of probability
- Boltzmann’s law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns

Theory and corresponding exercises are merged together during the classes.
No lecture notes because the two proposed textbooks are more than exhaustive!

I am willingly available Mondays 17.00 o'clock - 18.00 in my office GLC F12.2 for whatever discussion about the lessons and the exercises.

I am using OneNote. All lectures will be broadcast via ZOOM, while corresponding videos of the previous years (lectures and exercises) are available in Moodle!!

Lecture notes

I am willingly available Mondays 17.00 o'clock - 18.00 in my office GLC F12.2 for whatever discussion about the lessons and the exercises.

I am using OneNote. All lectures will be broadcast via ZOOM, while corresponding videos of the previous years (lectures and exercises) are available in Moodle!!

Literature


As further deepening:


Prerequisites / notice

Participants need a good command of

• differentiation and integration of a function with one or more variables (basics of Analysis),
• Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.

Competencies

Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies fostered

Method-specific Competencies

- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management assessed

Social Competencies

- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity assessed
- Negotiation fostered

Personal Competencies

- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

227-0976-00L Computational Psychiatry & Computational Psychosomatics

W 2 credits 4S K. Stephan

Abstract

This seminar deals with the development of clinically relevant computational tools and/or their application to psychiatry and psychosomatics. It is complementary to the annual Computational Psychiatry Course and serves to build bridges between computational scientists and clinicians. It is designed to foster in-depth exchange, with ample time for discussion.

Objective

Understanding strengths and weaknesses of current trends in the development of clinically relevant computational tools and their application to problems in psychiatry and psychosomatics.

Content

This seminar deals with the development of computational tools (e.g. generative models, machine learning) and/or their application to psychiatry and psychosomatics. The seminar includes (i) presentations by computational scientists and clinicians, (ii) group discussion with focus on methodology and clinical utility, (iii) self-study based on literature provided by presenters.

Literature

Literature for additional self-study of the topics presented in this seminar will be provided by the presenters and will be available online at https://www.tnu.ethz.ch/en/teaching

Prerequisites / notice

Participants are expected to be familiar with general principles of statistics (including Bayesian statistics) and have successfully completed the course “Computational Psychiatry” (Course number 227-0971-00L).

227-2037-00L Physical Modelling and Simulation

W 6 credits 4G J. Smajic

Abstract

This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.

Objective

Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.
Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will

Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Prerequisites / notice
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below.
- Students must have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/
Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/
Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19
Statistical Learning Theory
http://ml2.inf.ethz.ch/courses/sit/
Computational Statistics
https://stat.ethz.ch/lectures/ss19/comp-stats.php
Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18


course.

The course will provide students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various

Abstract
The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

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1. To introduce the fundamental problems of computer vision.
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4. To enable participants to make sense of the computer vision literature.
**Objective**

Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nanotechnology, nano-mechanics and other properties within manmade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

**Content**

Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered to start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

**Lecture notes**

All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
</table>
| 376-1176-00L | **Wearable and Mobile Technologies of the Future - Focus on Sports and Health** | 4 | - Students should be proficient in programming (any language);
| | | | - Note: assignments will be in MATLAB. Students are expected to learn MATLAB on their own if not experienced with this programming language.
| | | | - Course prerequisites:
| | | | For Biomedical Engineering Master's: none
| | | | For ITET Master's: none
| | | | For D-NAV Master's: none
| | | | For D-HEST Master's and PhD students:
| | | | • If BSc in electrical/mechanical engineering or computer science: none
| | | | • If any other BSc program: 376-0022-00L (Imaging and Computing in Medicine) or 376-1983-00L (Foundations of Data Science) |
| 376-1219-00L | **Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions** | 3 | R. Riener, O. Lamberty
| | | | Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.
| | | | Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution. This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.
Content
Introduction, problem definition, overview
Rehabilitation of visual function
- Anatomy and physiology of the visual sense
- Technical aids (glasses, sensor substitution)
- Retina and cortex implants
Rehabilitation of hearing function
- Anatomy and physiology of the auditory sense
- Hearing aids
- Cochlea Implants
Rehabilitation and use of kinesthetic and tactile function
- Anatomy and physiology of the kinesthetic and tactile sense
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
Rehabilitation of vestibular function
- Anatomy and physiology of the vestibular sense
- Rehabilitation strategies and devices (e.g. BrainPort)
Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces

Literature
Introductory Books:


Selected Journal Articles and Web Links:

Prerequisites / notice
Target Group:
Students of higher semesters and PhD students of
- D-MAVT, D-ITET, D-INFK, D-HEST
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich
Students of other departments, faculties, courses are also welcome
This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 387 of 2653
This course is an introduction to techniques in micro/nanotechnology and to microfluidics. It reviews how many familiar devices are built and can be used for research and biomedical applications. Transistors for DNA sequencing, beamers for patterning proteins, hard-disk technology for biosensing and microfluidics for point-of-care diagnostics are just a few examples of the covered topics.

The main objective of the course is to introduce micro/nanotechnology and microfluidics to students having any technical background. The course is multi-disciplinary and covers a broad range of techniques. For each lecture, a brief historical perspective is given to illustrate by whom and how the techniques were invented.

The second objective is to have life sciences students less intimidated by micro/nanotechnology and make them able to link instruments and techniques to specific problems that they might have in their projects/studies. This will also help students getting access to the ETHZ/IBM Nanotech Center infrastructure if needed.

Content
Mostly formal lectures (2 × 45 min), with few specific guest lectures on topics of particular relevance. For example, an introduction to cleanroom and micro/nanotechnology instruments and 3D printing will be provided. Last 3 weeks would be dedicated to the presentation and evaluation of projects by students (2 to 3 students per team). For this, about 12 recent technologies are listed and each team picks a technology and makes a short report and presentation describing how it works, its strengths and weaknesses, and describes what problem it solves.

In terms of technical content, the lectures will cover:
- an overview of the microelectronic industry, Moore’s law, field-effect transistors, next-generation DNA sequencing
- liquid crystal displays, organic light emitting diodes, electrophoretic displays, micromirrors and beamers, photocpatternning of proteins and cells, optogenetics, and flexible displays and electronics
- hard disk drives and the giant magnetoresistance effect, magnetic nanoparticles, photonics, magnetic sensing and optical biosensing
- cleanroom techniques and instruments, from design to microfabrication of simple devices and microfluidics, examples of DNA microarrays
- the principles of microfluidics, microfluidic functions and fabrication, from microfluidics for research to point-of-care diagnostics, and the (infamous) history of Theranos, as well as some discussions on diagnostics for COVID, R0, and (im)precision of diagnostic devices and why it matters
- 2 × 45 min will be covered by Yuksel Temiz, a master of Arduino programming and do-it-yourself electronics, who will present how to make 20$ electronic components that are synergistic to microfluidic devices and that can be controlled using a smartphone

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>Decision-making</td>
<td>assessed</td>
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<td>Media and Digital Technologies</td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Social Competencies</td>
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<td>Leadership and Responsibility</td>
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<td>Creative Thinking</td>
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</table>

Microfluidics describes the behaviour, control and manipulation of fluids geometrically constrained within sub-uL environments. Microfluidic devices enable physical and chemical processes to be controlled with exquisite precision and in an fast and efficient manner. This course introduces the underlying concepts, features and applications of microfluidic systems in the chemical and life sciences.

Objective
We will investigate the theoretical concepts behind microfluidic device operation, the methods of microfluidic device manufacture and the application of microfluidic architectures to important problems faced in modern day chemical and biological analysis.

A central component of this course is a research project. This will allow students to develop a practical understanding of the benefits of miniaturization in chemical and biological experimentation. Projects will be performed in groups of between four and six students and will include both experimental and simulation aspects. Each group, under the guidance of a mentor, will plan and execute a novel research project. The results of this activity will be disseminated through an "academic-style" research article and a "conference-style" oral presentation. Course grades will be evaluated through both a written exam and the project grade.
Specific topics covered in the course include, but are not limited to:

1. Theoretical Concepts
   Scaling laws, features of thermal/mass transport, diffusion, basic description of fluid flow in small volumes, microfluidic mixing strategies.

2. Microfluidic Device Manufacture
   Basic principles of conventional lithography of rigid materials, 'soft' lithography, polymer machining (injection molding, hot embossing, and 3D-printing).

3. Electrokinetics
   Principles of electrophoresis, electroosmosis, high performance capillary electrophoresis, electrokinetic scaling laws, chip-based electrophoresis and isoelectric focusing.

4. Mass Transfer Phenomena
   Key features of mass transport in microfluidic systems, diffusive transport, diffusion-convection, Pécelt number, Taylor-Aris diffusion, chaotic mixing and Damköhler numbers.

5. Heat Transfer Phenomena
   Key features of thermal transport in microfluidic systems, conduction, convection, heat transfer by convection in internal flows, heat transfer processes in microfluidic devices.

6. Microfluidic Systems for Materials Synthesis
   Microfluidic reactors for the controlled synthesis of colloidal nanomaterials, advanced automation for bespoke materials discovery & characterization.

7. Point-of-Care Diagnostics
   Microscale tools for diagnostics, challenges associated with point-of-care (PoC) diagnostic testing, requirements for PoC devices, common PoC device formats, applications of PoC diagnostics in the developing world.

8. Microscale DNA Amplification
   Amplification and analysis of nucleic acids using batch, continuous flow and droplet-based microfluidic reactors.

9. Small Scale Molecular Detection
   Spectroscopic approaches for analyte detection in small volumes with a particular focus on single molecule detection.

10. Droplets and Segmented Flows
    Formation, manipulation and use of liquid/liquid segmented flows in chemical and biological experimentation.

Lecture notes
Applications of microfluidic tools in cellular analysis, flow cytometry, enzymatic assays and single cell analysis.

Literature
There is no set text for the course. All relevant literature will be provided electronically through the course Moodle site.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking

ECTS Credits
- 3 credits
- 4 credits
- 5 credits

Number
- 636-0108-00L
- 227-0399-10L

Biology Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>636-0108-00L</td>
<td>Biological Engineering and Biotechnology</td>
<td>W</td>
<td>4</td>
<td>3V</td>
<td>M. Fussenegger</td>
</tr>
<tr>
<td>227-0399-10L</td>
<td>Physiology and Anatomy for Biomedical Engineers I</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Wyss</td>
</tr>
</tbody>
</table>

Abstract
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content

Lecture notes
Handout during the course.
**Objective**
To understand basic principles and structure of the human body in consideration of the clinical relevance and the medical terminology used in medical work and research.

**Content**
- The Human Body: nomenclature, orientations, tissues
- Musculoskeletal system, Muscle contraction
- Blood vessels, Heart, Circulation
- Blood, Immune system
- Respiratory system
- Acid-Base-Homeostasis

**Lecture notes**
Lecture notes and handouts

**Literature**
Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008
Faller A., Schuenke M. The Human Body; Thieme 2004
Netter F. Atlas of human anatomy; Elsevier 2014

<table>
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</thead>
<tbody>
<tr>
<td>227-0949-00L</td>
<td>Biological Methods for Engineers W</td>
<td>3</td>
<td>5P</td>
<td>C. Frei</td>
<td>X. L. Dean Ben</td>
</tr>
</tbody>
</table>

### Abstract
The course during 8 afternoons (13h to 18h) covers basic laboratory skills and safety, cell culture, protein analysis, RNA/DNA Isolation and RT-PCR. Each topic will be introduced, followed by practical work at the bench. Presence during the course is mandatory.

### Objective
The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology.

### Content
The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology.

### Prerequisites / notice
Enrollment is limited and students from the Master's programme in Biomedical Engineering (BME) have priority.

<table>
<thead>
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#### Bioimaging

#### Track Core Courses

_During the Master programme, a minimum of 12 CP must be obtained from track core courses._

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>227-0384-00L</td>
<td>Ultrasound Fundamentals and Applications in Biology and Medicine</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>X. L. Dean Ben</td>
</tr>
</tbody>
</table>

**Abstract**
Ultrasound waves are non-ionizing and thus provide a safe means to interrogate and treat biological tissues. Advantages such as real-time operation, low cost, and portability have led to ultrasound systems becoming standard tools in hospitals and research laboratories. Applications in biology and medicine include ultrasound and optoacoustic imaging, thermal therapy, or pulse stimulation.

**Objective**
The objective of the course is that students are able to understand how to use ultrasound in biology and medicine and generalize this knowledge to applications in other fields.

**Content**
The course will cover the basic physics of ultrasound (acoustic waves at frequencies higher than the audible range) in biological tissues as well as the instrumentation required to generate and detect these waves. Imaging methods will extensively be described in the course. Specifically, standard and ultra-fast ultrasound imaging approaches will be covered along with new optoacoustic and transmission ultrasound imaging methods. The course will also describe mathematical modelling approaches and numerical methods as well as signal and image processing tools applicable in ultrasound-based imaging. Other topics include ultrasound sensors, laser ultrasound, therapeutic effects, or biomedical applications and contrast agents. The course will conclude with current and future research directions in the field of ultrasound in biomedicine.

**Lecture notes**
The lecture slides will be made available to the students.

**Prerequisites / notice**
Basic knowledge in physics. Basic programming skills, preferably in Matlab.

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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0385-10L</td>
<td>Biomedical Imaging</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>S. Kozerke, K. P. Prüssmann</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to diagnostic medical imaging based on electromagnetic and acoustic fields including X-ray planar and tomographic imaging, radio-tracer based nuclear imaging techniques, magnetic resonance imaging and ultrasound-based procedures.

**Objective**
Upon completion of the course students are able to:

- Explain the physical and mathematical foundations of diagnostic medical imaging systems
- Characterize system performance based on signal-to-noise ratio, contrast-to-noise ratio and transfer function
- Design a basic diagnostic imaging system chain including data acquisition and data reconstruction
- Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications

**Content**
- Introduction (intro, overview, history)
- Signal theory and processing (foundations, transforms, filtering, signal-to-noise ratio)
- X-rays (production, tissue interaction, contrast, modular transfer function)
- X-rays (resolution, detection, digital subtraction angiography, Radon transform)
- X-rays (filtered back-projection, spiral computed tomography, image quality, dose)
- Nuclear imaging (radioactive tracer, collimation, point spread function, SPECT/ PET)
- Nuclear imaging (detection principles, image reconstruction, kinetic modelling)
- Magnetic Resonance (magnetic moment, spin transitions, excitation, relaxation, detection)
- Magnetic Resonance (plane wave encoding, Fourier reconstruction, pulse sequences)
- Magnetic Resonance (contrast mechanisms, gradient- and spin-echo, applications)
- Ultrasound (mechanical wave generation, propagation in tissue, reflection, transmission)
- Ultrasound (spatial and temporal resolution, phased arrays)
- Ultrasound (Doppler shift, implementations, applications)

**Lecture notes**
Lecture notes and handouts
Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

**Literature**

Analysis, Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming

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**227-0386-00L Biomedical Engineering**

**W 4 credits 3G**

J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong

**Abstract**

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the basic vocabulary of biomedical engineering and getting familiar with concepts that govern common medical instruments and the most important organs from an engineering point of view.

**Objective**

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

**Content**

History of BME and the role of biomedical engineers. Ethical issues related to BME. Biomedical sensors both wearable and also biochemical sensors. Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices. Equations describing basic reactions and enzyme kinetics. Medical optics: Optical components and systems used in hospitals. Basic concepts of tissue engineering and organ printing. Biomaterials and their medical applications. Function of the heart and the circulatory system. Transport and exchange of substances in the human body, compartment modeling. The respiratory system. Bioimaging. Orthopedic biomechanics. Lectures (2h), discussion of practical exercises (1h) and homework exercises.

**Lecture notes**

Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

AND

**moodle page of the course**

**Prerequisites / notice**

No specific requirements, BUT ITET, MAVT, PHYS students will have to learn a lot of new words related to biochemistry, biology and medicine, while HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.).

**Competencies**

**Subject-specific Competencies**

Concepts and Theories assessed
Techniques and Technologies assessed

**Method-specific Competencies**

Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed

**Social Competencies**

Communication assessed

**Personal Competencies**

Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-direction and Self-management fostered

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**227-0447-00L Image Analysis and Computer Vision**

**W 6 credits 3V+1U**

E. Konukoglu, E. Erdil, F. Yu

**Abstract**


**Objective**

Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Prerequisites:
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

227-0965-00L Micro and Nano-Tomography of Biological Tissues  W  4 credits  3G M. Stampanoni, F. Marone Welford
Abstract
The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

Objective
Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

Content
Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

Number Title Type ECTS Hours Lecturers
227-0311-00L Qubits, Electrons, Photons  W  6 credits  3V+2U T. Zambelli
Abstract
In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis).

Objective
Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics.

Starting from the axioms of quantum mechanics, we will derive the fascinating theory describing spin and qubits, electron transitions and transfer, photons and LASER: quantum mechanics is different because it mocks our daily Euclidean intuition!

In this way, students will work out a robust quantum mechanics (theoretical!!!) basis which will help them in their advanced studies of the following masters: EEIT (batteries), Biomedical Engineering (NMR, bioelectronics), Quantum Engineering, Micro- and Nanosystems.

Content
IMPORTANT: "qubits" from the point of view of NMR (and NOT from that of quantum computing!).

Important:
• Lagrangian and Hamiltonian: Symmetries and Poisson Brackets
• Postulates of QM: Hilbert Spaces and Operators
• Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator
• Density Operator
• Spin: Qubits, Bloch Equations, and NMR
• Entanglement
• Symmetries and Corresponding Operators
• Schrödinger’s Wave Mechanics: Electrons in a Periodic Potential and Energy Bands
• Harmonic Oscillator: Creation and Annihilation Operators
• Identical Particles: Bosons and Fermions
• Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER
• Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener

Lecture notes
No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

Literature

Supplementary material will be uploaded in Moodle.

IMPORTANT: “qubits” from the point of view of NMR (and NOT from that of quantum computing!!)

In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis).

Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics.

Starting from the axioms of quantum mechanics, we will derive the fascinating theory describing spin and qubits, electron transitions and transfer, photons and LASER: quantum mechanics is different because it mocks our daily Euclidean intuition!

In this way, students will work out a robust quantum mechanics (theoretical!!!) basis which will help them in their advanced studies of the following masters: EEIT (batteries), Biomedical Engineering (NMR, bioelectronics), Quantum Engineering, Micro- and Nanosystems.
The course has been intentionally conceived to be self-consistent with respect to QM for those master students not having encountered it in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) QM introduction course like the D-ITET "Physics II".

### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: assessed

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

#### Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

### Learning in Deep Artificial and Biological Neuronal Networks

#### Abstract
Deep-Learning (DL) a brain-inspired weak for of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods.

#### Objective
The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today's neuroscience papers.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today's neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to 'error backpropagation' in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

#### Content
The lecture slides will be provided as a PDF after each lecture.

**Prerequisites / notice**
This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

1) The number of participants is limited to 120 students (MSc and PhDs).

2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

### Computational Neuroimaging Clinic

#### Abstract
This seminar teaches problem solving skills for computational neuroimaging, based on analyses of neuroimaging and behavioural data. It deals with a wide variety of real-life problems that are brought to this meeting from the neuroimaging community at Zurich, e.g. mass-univariate and multivariate analyses of fMRI/EEG data, or generative models of fMRI, EEG, or behavioural data.

#### Objective
1. Consolidation of theoretical knowledge (obtained in the following courses: 'Methods & models for fMRI data analysis', 'Translational Neuroimaging', 'Computational Psychiatry') in the setting of concrete research questions.

#### Content
This seminar teaches problem solving skills for computational neuroimaging, based on analyses of neuroimaging and behavioural data. It deals with a wide variety of real-life problems that are brought to this meeting from the neuroimaging community at Zurich, e.g. mass-univariate and multivariate analyses of fMRI/EEG data, or generative models of fMRI, EEG, or behavioural data.

### Prerequisites / notice
Prerequisite: Successful completion of course "Methods & Models for fMRI Data Analysis", "Translational Neuroimaging" or "Computational Psychiatry".
This six-day course teaches state-of-the-art methods in computational psychiatry. It covers various computational models of cognition (e.g., assessed M. Payvand), assessed B. Grewe, G. Indiveri, K. Stephan), and assessed T. Delbrück, K. Stephan, S. M. Payvand)

Abstract

This course teaches methods and models for fMRI data analysis, covering all aspects of statistical parametric mapping (SPM), incl. pre-processing, the general linear model, statistical inference, multiple comparison corrections, event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data.

Objective

To obtain in-depth knowledge of the theoretical foundations of SPM and DCM and of their practical application to empirical fMRI data.

Content

This course covers state-of-the-art methods and models for fMRI data analysis in lectures and exercises. It covers all aspects of statistical parametric mapping (SPM), incl. pre-processing, the general linear model, frequentist and Bayesian inference, multiple comparison corrections, and event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. A particular emphasis of the course will be on methodological questions arising in the context of clinical studies in psychiatry and neurology. Practical exercises serve to consolidate the skills taught in lectures.

Prerequisites / notice

The participants are expected to have successfully completed at least one of the following courses:
- 'Methods & models for fMRI data analysis',
- 'Translational Neuromodeling',
- 'Computational Psychiatry'

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication

Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

227-0969-00L Methods & Models for fMRI Data Analysis W 6 credits 4V K. Stephan

Abstract

This course teaches methods and models for fMRI data analysis, covering all aspects of statistical parametric mapping (SPM), incl. pre-processing, the general linear model, statistical inference, multiple comparison corrections, event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data.

Objective

To obtain in-depth knowledge of the theoretical foundations of SPM and DCM and of their practical application to empirical fMRI data.

Content

This course teaches state-of-the-art methods and models for fMRI data analysis in lectures and exercises. It covers all aspects of statistical parametric mapping (SPM), incl. pre-processing, the general linear model, frequentist and Bayesian inference, multiple comparison corrections, event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. A particular emphasis of the course will be on methodological questions arising in the context of clinical studies in psychiatry and neurology. Practical exercises serve to consolidate the skills taught in lectures.

Prerequisites / notice

This course aims at bridging the gap between mathematical modelers and clinical neuroscientists by teaching computational techniques in the context of clinical applications. The hope is that the acquisition of a joint language and tool-kit will enable more effective communication and joint translational research between fields that are usually worlds apart.

Content

This course teaches state-of-the-art methods in computational psychiatry. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples. Furthermore, practical exercises provide in-depth exposure to different software packages. Please see http://www.translationalneuromodeling.org/cpcourse/ for details.

Prerequisites / notice

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

227-1033-00L Neuromorphic Engineering I W 6 credits 2V+3U K. Stephan

Abstract

This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Objective

Understanding of the characteristics of neuromorphic circuit elements.

Content

Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransoducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Literature

S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

Prerequisites / notice

Particular: The course is highly recommended for those who intend to take the spring semester course ‘Neuromorphic Engineering II’, that teaches the conception, simulation, and physical layout of such circuits with chip design tools.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.
Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.

**227-2037-00L Physical Modelling and Simulation**

**Objective**

This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.

**Content**

Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

**252-0543-01L Computer Graphics**

**Objective**

At the end of the course, the students will be able to build a rendering system based on path-tracing algorithms. The students will learn the principles of physically-based rendering and computer graphics. In addition, the course is intended to stimulate the student's curiosity to explore the field of computer graphics in subsequent classes or on their own.

**Content**

We will begin with an introduction to light emission and radiometric quantities, followed by an exploration of geometry representations and texture mapping.

Next, we will mathematically formulate the physics of light transport and appearance modeling. Subsequently, we will introduce relevant concepts from Monte Carlo integration and develop path-tracing algorithms to solve these equations by simulating light transport for direct and global illumination due to hard surfaces and participating media, such as fog, smoke, and translucent objects. Moreover, we will present techniques for significantly improving path-tracing efficiency, including importance sampling, multiple importance sampling, stratified sampling, denoising, and acceleration data structures.

The course lectures will conclude with an overview of image-based capture and rendering methods. Topics covered will include geometry reconstruction, material acquisition, differentiable rendering, and image-based rendering.

The programming assignments will be in C++. This will not be taught in the class.

**402-0674-00L Physics in Medical Research: From Atoms to Cells**

**Abstract**

Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epithelial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.
The seminar deals with the development of clinically relevant computational tools and/or their application to psychiatry and psychosomatics. The course deals with simple quantitative and graphical as well as more complex methods of biostatistics. Contents: Descriptive statistics, testing hypotheses, confidence intervals, correlation, simple and multiple linear regression, classification and prediction, diagnostic tests, measurement of agreement, causality versus association. Participants are expected to be familiar with general principles of statistics (including Bayesian statistics) and have successfully completed a basic course in statistics.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

<table>
<thead>
<tr>
<th>465-0953-00L</th>
<th>Biostatistics</th>
<th>W</th>
<th>4 credits</th>
<th>2V+1U</th>
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<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>The course deals with simple quantitative and graphical as well as more complex methods of biostatistics. Contents: Descriptive statistics, testing hypotheses, confidence intervals, correlation, simple and multiple linear regression, classification and prediction, diagnostic tests, measurement of agreement, causality versus association.</td>
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</table>
| **Objective** | - know the commonly used methods in biostatistics  
- perform simple data analysis with R |

<table>
<thead>
<tr>
<th>227-0976-00L</th>
<th>Computational Psychiatry &amp; Computational Psychosomatics</th>
<th>W</th>
<th>2 credits</th>
<th>4S</th>
<th>K. Stephan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This seminar deals with the development of clinically relevant computational tools and/or their application to psychiatry and psychosomatics. It is complementary to the annual Computational Psychiatry Course and serves to build bridges between computational scientists and clinicians. It is designed to foster in-depth exchange, with ample time for discussion.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Understanding strengths and weaknesses of current trends in the development of clinically relevant computational tools and their application to problems in psychiatry and psychosomatics.</td>
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<tr>
<td><strong>Content</strong></td>
<td>This seminar deals with the development of computational tools (e.g. generative models, machine learning) and/or their application to psychiatry and psychosomatics. The seminar includes (i) presentations by computational scientists and clinicians, (ii) group discussion with focus on methodology and clinical utility, (iii) self-study based on literature provided by presenters.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>Literature for additional self-study of the topics presented in this seminar will be provided by the presenters and will be available online at <a href="https://www.tnu.ethz.ch/en/teaching">https://www.tnu.ethz.ch/en/teaching</a></td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Participants are expected to be familiar with general principles of statistics (including Bayesian statistics) and have successfully completed the course “Computational Psychiatry” (Course number 227-0971-00L).</td>
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<th>Number</th>
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<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>227-0999-10L</td>
<td>Physiology and Anatomy for Biomedical Engineers I</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Wyss</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Students will be able to identify and enumerate important anatomical structures to describe basic physiological processes of the human body to use a 3d animation database/software to use 'anatomical language' to retrieve anatomical structures to understand basic medical terminology</td>
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<tr>
<td><strong>Objective</strong></td>
<td>To understand basic principles and structure of the human body in consideration of the clinical relevance and the medical terminology used in medical work and research.</td>
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</tr>
</tbody>
</table>
| **Content** | - The Human Body: nomenclature, orientations, tissues  
- Musculoskeletal system, Muscle contraction  
- Blood vessels, Heart, Circulation  
- Blood, Immune system  
- Respiratory system  
- Acid-Base-Homeostasis |
| **Lecture notes** | Lecture notes and handouts |
| **Literature** | Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008  
Fallen A., Schuenke M. The Human Body; Thieme 2004  
Netter F. Atlas of human anatomy; Elsevier 2014  

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 396 of 2653
## Subject-specific Competencies

The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology.

### Objective

The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology.

### Content

Enrollment is limited and students from the Master's programme in Biomedical Engineering (BME) have priority.

### Prerequisites / notice

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

- **Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Problem-solving
  - Project Management

- **Social Competencies**
  - Communication

- **Personal Competencies**
  - Adaptability and Flexibility
  - Critical Thinking
  - Integrity and Work Ethics

<table>
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<tr>
<th>Competencies</th>
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<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>Subject-specific Competencies</td>
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<tr>
<td>Concepts and Theories</td>
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<tr>
<td>Techniques and Technologies</td>
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<tr>
<td>Decision-making</td>
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<td>Adaptability and Flexibility</td>
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<td>Critical Thinking</td>
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<tr>
<td>Integrity and Work Ethics</td>
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## Biomechanics

### Track Core Courses

During the Master programme, a minimum of 12 CP must be obtained from track core courses.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0385-10L</td>
<td>Biomedical Imaging</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>S. Kozerke, K. P. Prüssmann</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to diagnostic medical imaging based on electromagnetic and acoustic fields including X-ray planar and tomographic imaging, radio-tracer based nuclear imaging techniques, magnetic resonance imaging and ultrasound-based procedures.</td>
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<tr>
<td>Objective</td>
<td>Upon completion of the course students are able to:</td>
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<td></td>
<td>- Explain the physical and mathematical foundations of diagnostic medical imaging systems</td>
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<td></td>
<td>- Characterize system performance based on signal-to-noise ratio, contrast-to-noise ratio and transfer function</td>
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<td></td>
<td>- Design a basic diagnostic imaging system chain including data acquisition and data reconstruction</td>
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<td></td>
<td>- Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications</td>
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<tr>
<td>Content</td>
<td>- Introduction (intro, overview, history)</td>
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<td></td>
<td>- Signal theory and processing (foundations, transforms, filtering, signal-to-noise ratio)</td>
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<td></td>
<td>- X-rays (production, tissue interaction, contrast, modular transfer function)</td>
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<td>- X-rays (resolution, detection, digital subtraction angiography, Radon transform)</td>
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<td></td>
<td>- X-rays (filtered back-projection, spiral computed tomography, image quality, dose)</td>
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<td></td>
<td>- Nuclear imaging (radioactive tracer, collimation, point spread function, SPECT/PET)</td>
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<td>- Nuclear imaging (detection principles, image reconstruction, kinetic modelling)</td>
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<td></td>
<td>- Magnetic Resonance (magnetic moment, spin transitions, excitation, relaxation, detection)</td>
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<tr>
<td></td>
<td>- Magnetic Resonance (plane wave encoding, Fourier reconstruction, pulse sequences)</td>
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<td></td>
<td>- Magnetic Resonance (contrast mechanisms, gradient- and spin-echo, applications)</td>
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<tr>
<td></td>
<td>- Ultrasound (mechanical wave generation, propagation in tissue, reflection, transmission)</td>
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<td></td>
<td>- Ultrasound (spatial and temporal resolution, phased arrays)</td>
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<td></td>
<td>- Ultrasound (Doppler shift, implementations, applications)</td>
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<td></td>
<td>- Summary, example exam questions</td>
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</table>

| Lecture notes | Lecture notes and handouts |
| Literature    | Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011 |
| Prerequisites / notice | Analysis, Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming |

<table>
<thead>
<tr>
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<th>Hours</th>
<th>Lecturers</th>
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<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<td>Decision-making</td>
<td>fostered</td>
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<td>Media and Digital Technologies</td>
<td>fostered</td>
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<tr>
<td>Problem-solving</td>
<td>fostered</td>
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<tr>
<td>Adaptability and Flexibility</td>
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<tr>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td>Integrity and Work Ethics</td>
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<tr>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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## Biomedical Engineering

### Abstract

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the basic vocabulary of biomedical engineering and getting familiar with concepts that govern common medical instruments and the most important organs from an engineering point of view.

### Objective

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs.

In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 397 of 2653
Content
History of BME and the role of biomedical engineers. Ethical issues related to BME.
Biomedical sensors both wearable and also biochemical sensors.
Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices.
Bioinformatics: genomic and proteomic tools, databases and basic calculations.
Equations describing basic reactions and enzyme kinetics.
Medical optics: Optical components and systems used in hospitals.
Basic concepts of tissue engineering and organ printing.
Biomaterials and their medical applications.
Function of the heart and the circulatory system.
Transport and exchange of substances in the human body, compartment modeling.
The respiratory system.
Bioimaging.
Orthopedic biomechanics.

Lecture notes
Introduction to Biomedical Engineering
by Enderle, Banchard, and Bronzino

AND

Prerequisites / notice
No specific requirements, BUT
ITEF, MAVT, PHYS students will have to learn a lot of new words related to biochemistry, biology and medicine, while
HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.).

Competencies

Subject-specific Competencies
Concepts and Theories
assessed
Techniques and Technologies
assessed

Method-specific Competencies
Analytical Competencies
assessed
Decision-making
assessed
Media and Digital Technologies
fostered
Problem-solving
fostered
Project Management
fostered

Social Competencies
Communication
fostered
Cooperation and Teamwork
fostered
Customer Orientation
fostered
Leadership and Responsibility
fostered
Self-presentation and Social Influence
fostered
Sensitivity to Diversity
fostered
Negotiation
fostered

Personal Competencies
Adaptability and Flexibility
fostered
Creative Thinking
fostered
Critical Thinking
fostered
Integrity and Work Ethics
fostered
Self-awareness and Self-reflection
fostered
Self-direction and Self-management
fostered

Abstract
Image segmentation. Motion extraction and tracking. 3D data extraction. Invariant features. Specific object recognition and object class

Objective
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience
through practical computer and programming exercises.

Content
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep
learning.
The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image
processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is
considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then
turns to image discretization, necessary to process images by computer.
The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear
filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic
information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific
objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based
approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets
are given.

Prerequisites / notice
Prerequisites:
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux.
The course language is English.

Abstract
The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques,
(absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course
discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

Objective
Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with
particular emphasis on biological applications.
Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

<table>
<thead>
<tr>
<th>376-0121-00L</th>
<th>Multiscale Bone Biomechanics</th>
<th>W</th>
<th>6 credits</th>
<th>3S</th>
<th>R. Müller, X.-H. Qin</th>
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</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>The seminar provides state-of-the-art insight to the biomechanical function of bone from molecules, to cells, tissue and up to the organ. Multiscale imaging and simulation allows linking different levels of hierarchy, where systems biology helps understanding the mechanobiological response of bone to loading and injury in scenarios relevant for personalized health and translational medicine. The learning objectives include 1. advanced knowledge of the state-of-the-are in multiscale bone biomechanics; 2. basic understanding of the biological principles governing bone in health, disease and treatment from molecules, to cells, tissue and up to the organ; 3. good understanding of the prevalent biomechanical testing and imaging techniques on the various levels of bone hierarchy; 4. practical implementation of state-of-the-art multiscale simulation techniques; 5. improved programming skills through the use of python; 6. hands on experience in designing solutions for clinical and industrial problems; 7. encouragement of critical thinking and creating an environment for independent and self-directed studying.</td>
<td></td>
<td><strong>Content</strong></td>
<td>Bone is one of the most investigated biological materials due to its primary function of providing skeletal stability. Bone is susceptible to different local stimuli including mechanical forces and has great capabilities in adapting its mechanical properties to the changes in its environment. Nevertheless, aging or hormonal changes can make bone lose its ability to remodel appropriately, with loss of strength and increased fracture risk as a result, leading to devastating diseases such as osteoporosis. To better understand the biomechanical function of bone, one has to understand the hierarchical organization of this fascinating material down from the molecules, to the cells, tissue and up to the organ. Multiscale imaging and simulation allow to link these different levels of hierarchy. Incorporating systems biology approaches, not only biomechanical strength of the material can be assessed but also the mechanobiological response of the bone triggered by loading and injury in scenarios relevant for personalized health. Watching cells working together to build and repair bone in a coordinated fashion is a spectacle, which will need dynamic image content and deep discussions in the lecture room to probe the imagination of the individual student interested in the topic. Lastly, state-of-the-art developments in tissue engineering and regeneration, 3D bioprinting and bio-manufacturing and organoid technology will be highlighted towards personalized health. For the seminar, concepts of video lectures will be used in a flipped classroom setup, where students can study the basic biology, engineering, and mathematical concepts in video tutorials online (TORQUEs). All videos and animations will be incorporated in Moodle and PolyBook allowing studying and interactive course participation online. It is anticipated that the students need to prepare 2x45 minutes for the study of the actual lecture material. The course is structured as a seminar in three parts of 45 minutes with video lectures and a flipped classroom setup. In the first part (TORQUEs: Tiny, Open-with-Restrictions courses focused on QUality and Effectiveness), students study the basic concepts in short, interactive video lectures on the online learning platform Moodle. Students are able to post questions at the end of each video lecture or the Moodle forum that will be addressed in the second part of the lectures using a flipped classroom concept. For the flipped classroom, the lecturers may prepare additional teaching material to answer the posted questions (Q&amp;A). Following the Q&amp;A, the students will have to form small groups to try to solve such problems and to present their solutions for advanced multiscale investigation of bone ranging from basic science to clinical application. Towards the end of the semester, students will have to present self-selected publications associated with the different topics of the lecture identified through PubMed or the Web of Science.</td>
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<td>Techniques and Technologies</td>
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<td><strong>Method-specific Competencies</strong></td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Project Management</td>
<td>assessed</td>
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<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
<td>fostered</td>
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<td><strong>Personal Competencies</strong></td>
<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<td></td>
<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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<table>
<thead>
<tr>
<th>376-1651-00L</th>
<th>Clinical and Movement Biomechanics</th>
<th>W</th>
<th>4 credits</th>
<th>3G</th>
<th>D. K. Ravi, S. H. Hosseini Nasab, R. List, further lecturers</th>
</tr>
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<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Measurement and modeling of the human movement during daily activities and in a clinical environment. The students are able to analyse the human movement from a technical point of view, to process the data and perform modeling with a focus towards clinical application. The course includes study design, measurement techniques, clinical testing, accessing movement data and analysis as well as modeling with regards to human movement.</td>
<td></td>
<td><strong>Objective</strong></td>
<td>This course includes study design, measurement techniques, clinical testing, accessing movement data and analysis as well as modeling with regards to human movement.</td>
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</table>
Objective
Introduction to the basic principles of trauma biomechanics.

Content
This lecture serves as an introduction to the field of trauma biomechanics. Emphasis is placed on the interdisciplinary nature of impact biomechanics, which uses the combination of fundamental engineering principles and advanced medical technologies to develop injury prevention measures. Topics include: accident statistics and accident reconstruction, biomechanical response of the human to impact loading, injury mechanisms and injury criteria, test methods (including crash tests), computer simulations, aspects of vehicle safety. Real world examples mainly from automobile safety are used to augment lecture material.

Lecture notes
Handouts will be made available.

Literature

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

Recommended Elective Courses
These courses are particularly recommended for the Biomechanics track. Please consult your track advisor if you wish to select other subjects.

Number | Title | Type | ECTS | Hours | Lecturers |
--- | --- | --- | --- | --- | --- |
151-0524-00L | Continuum Mechanics I | W | 4 credits | 2V+1U | A. E. Ehret |
Abstract
- The lecture deals with constitutive models that are relevant for the design and analysis of components and structures. These include anisotropic linear elasticity, linear viscoelasticity, plasticity and viscoplasticity. The basic concepts of homogenization and laminate theory are introduced. Theoretical models are complemented by examples of engineering applications and experiments.

Objective
- After successful completion of the course students are able to
  - explain basic theories for solving continuum mechanics problems
  - proficiently apply these theories by solving application-related academic examples
  - relate the theories and examples to real engineering applications and challenges
  - distinguish between different mechanical behaviors of materials
  - systematically select appropriate constitutive theories suitable to analyze and model these materials

Content
- Anisotropic Elasticity
- Linear Elastic and Linear Viscous Material Behavior
- Viscoelasticity
- Micro-Macro Modelling
- Laminate Theory
- Plasticity
- Viscoplasticity
- Examples of Engineering Applications
- Comparison with Experiments

Lecture notes
- yes

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: fostered

151-0604-00L | Microrobotics | W | 4 credits | 3G | B. Nelson |
Abstract
- Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Objective
- The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

Content
- Main topics of the course include:
  - Scaling laws at micro/nano scales
  - Electrostatics
  - Electromagnetism
  - Low Reynolds number flows
  - Observation tools
  - Materials and fabrication methods
  - Applications of biomedical microrobots

Lecture notes
- The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

Prerequisites / notice
- The lecture will be taught in English.

151-0905-00L | Medical Technology Innovation - From Concept to Clinics | W | 4 credits | 3G | I. Herrmann |
Abstract
- Project-oriented learning on how to develop technological solutions to address unmet clinical needs.
Objective
After completing the course, you will be able to effectively collaborate with medical doctors in order to identify important unmet clinical needs. You will be able to ideate and develop appropriate engineering solutions and implementation strategies for real-world clinical problems. This lecture aims to prepare you for typical engineering challenges in the real-world where - in addition to the development of an elegant solution - interdisciplinary team work and effective communication play a key role.

Lecture notes
will be available on the moodle.

Literature
will be available on the moodle.

Prerequisites / notice
On site presence during (most) of the lectures highly encouraged!

Competencies
Subject-specific Competencies
Techniques and Technologies
Concepts and Theories

Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving

Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Abstract
Ultrasound waves are non-ionizing and thus provide a safe means to interrogate and treat biological tissues. Advantages such as real-time operation, low cost, and portability have led to ultrasound systems becoming standard tools in hospitals and research laboratories. Applications in biology and medicine include ultrasound and optoacoustic imaging, thermal therapy, or pulse stimulation.

Objective
The objective of the course is that students are able to understand how to use ultrasound in biology and medicine and generalize this knowledge to applications in other fields.

Content
The course will cover the basic physics of ultrasound (acoustic waves at frequencies higher than the audible range) in biological tissues as well as the instrumentation required to generate and detect these waves. Imaging methods will extensively be described in the course. Specifically, standard and ultra-fast ultrasound imaging approaches will be covered along with new optoacoustic and transmission ultrasound imaging methods. The course will also describe mathematical modelling approaches and numerical methods as well as signal and image processing tools applicable in ultrasound-based imaging. Other topics include ultrasound sensors, laser ultrasound, therapeutic effects, or biomedical applications and contrast agents. The course will conclude with current and future research directions in the field of ultrasound in biomedicine.

Lecture notes
The lecture slides will be made available to the students.

Prerequisites / notice
Basic knowledge in physics. Basic programming skills, preferably in Matlab.

Abstract
This seminar covers advanced topics in digital humans including both seminal research papers as well as the latest research results. A collection of research papers are selected covering topics such as estimating human pose and motion from images, human motion synthesis, learning-based human avatar creation, learning neural implicit representations for humans, modeling, animations, artificial intelligence for digital characters, and others. A collection of research papers is selected.

Objective
The goal is to get an overview of actual research topics in the field of digital humans and to improve presentation and critical analysis skills.

Content
This seminar covers advanced topics in digital humans including both seminal research papers as well as the latest research results. A collection of research papers is selected covering topics such as estimating human pose and motion from images, human motion synthesis, learning-based human avatar creation, learning neural implicit representations for humans, modeling, animations, artificial intelligence for digital characters, and others. Each student presents one paper to the class and leads a discussion about the paper. All students read the papers and participate in the discussion.

Literature
Individual research papers are selected each term. See https://vg.inf.ethz.ch/, https://igl.ethz.ch/, and http://graphics.ethz.ch/ for example papers.

Competencies
Method-specific Competencies
Analytical Competencies
Social Competencies
Communication
Personal Competencies
Critical Thinking

Abstract
Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.

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Objective

Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within manmade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

Content

Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

Lecture notes

All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Workload</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1176-00L</td>
<td>Wearable and Mobile Technologies of the Future - Focus on Sports and Health</td>
<td>3</td>
<td>4</td>
<td>C. Menon, C. Ahmadizadeh, C. Otesteanu</td>
</tr>
<tr>
<td>376-1219-00L</td>
<td>Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions</td>
<td>3</td>
<td>2</td>
<td>R. Rienier, O. Lambercy</td>
</tr>
</tbody>
</table>

Abstract

Wearable and Mobile Technologies of the Future - Focus on Sports and Health

This course provides the scientific background needed to understand the principles that current technologies investigating movement rely on. The latest technological advancements to track parameters of gait and running, improve posture as well as to monitor overall body movement and provide feedback on motion during sport, rehabilitation or at work will be investigated. The focus will be on wearable-related (e.g., textile-based) technologies.

Module 2: Cardiac.

This module focuses on the latest technologies for monitoring the cardiac cycle and blood pressure. The module starts by succinctly providing background information on cardiac physiology and then briefly introduces conventional technologies used in daily practice. This module subsequently focuses on the latest technologies and the latest data analysis techniques to monitor the cardiac cycle for assisting individuals in sport activities or monitoring their health conditions.

Objective

Objective 1:

Acquire knowledge about the latest technological advancements in wearable and unobtrusive technologies for sport and health.

Objective 2:

Acquire skills to design novel non-invasive technologies for sport and health.

Content

The course consists of two modules.

Module 1: Movement.

This module provides the scientific background needed to understand the principles that current technologies investigating movement rely on. The latest technological advancements to track parameters of gait and running, improve posture as well as to monitor overall body movement and provide feedback on motion during sport, rehabilitation or at work will be investigated. The focus will be on wearable-related (e.g., textile-based) technologies.

Module 2: Cardiac.

This module focuses on the latest technologies for monitoring the cardiac cycle and blood pressure. The module starts by succinctly providing background information on cardiac physiology and then briefly introduces conventional technologies used in daily practice. This module subsequently focuses on the latest technologies and the latest data analysis techniques to monitor the cardiac cycle for assisting individuals in sport activities or monitoring their health conditions.

Prerequisites / notice

- Students should be proficient in programming (any language).
- Note: assignments will be in MATLAB. Students are expected to learn MATLAB on their own if not experienced with this programming language.
- Course prerequisites:
  - For Biomedical Engineering Master's: none
  - For ITET Master's: none
  - For D-NAV Master's: none
  - For D-HEST Master's and PhD students:
    - If BSc in electrical/mechanical engineering or computer science: none
    - If any other BSc program: 376-0022-00L (Imaging and Computing in Medicine) or 376-1983-00L (Foundations of Data Science)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>376-1219-00L</td>
<td>Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions</td>
<td>3</td>
<td>2</td>
<td>R. Rienier, O. Lambercy</td>
</tr>
</tbody>
</table>
Introduction, problem definition, overview
Rehabilitation of visual function
- Anatomy and physiology of the visual sense
- Technical aids (glasses, sensor substitution)
- Retina and cortex implants
Rehabilitation of hearing function
- Anatomy and physiology of the auditory sense
- Hearing aids
- Cochlea Implants
Rehabilitation and use of kinesthetic and tactile function
- Anatomy and physiology of the kinesthetic and tactile sense
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
Rehabilitation of vestibular function
- Anatomy and physiology of the vestibular sense
- Rehabilitation strategies and devices (e.g. BrainPort)
Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter
Brain stimulation and recording
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces

Literature

Introductory Books:


Selected Journal Articles and Web Links:

Prerequisites / notice

Target Group:
- Students of higher semesters and PhD students of
- D-MAVT, D-ITET, D-INFK, D-HEST
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich
- Students of other departments, faculties, courses are also welcome
- This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

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### Rehabilitation and Inclusion

#### 376-1220-00L

**W** 3 credits  **2G**  
R. Riener

#### Abstract
This course presents origins and prevention of different physical, sensory, mental impairments, their treatments, and methods of assistance in public and home environments. Rehabilitation is put into a larger context providing insights into healthcare systems, health economy, accessibility, barrier-free architecture, para-sports, legal & regulatory aspects, disability policy, and inclusion.

#### Objective
With this lecture, we want to not only transfer a broad knowledge about rehabilitation and inclusion, but also raise awareness about the challenges and needs of people with impairments, the economy and the overall society. Students should learn about the complex and multi-faceted interaction of care, treatment, assistance, reimbursement, accessibility, legal regulation, and social inclusion. This knowledge and awareness should be presented in a multi-modal way using interactive tools and organizing group/plenary discussions.

#### Content
The course will cover the following topics:
- Introduction: definition of terms, historical and legal background, role of the UNO, WHO, ICRC
- Origins: reasons and origins of physical, sensory and mental impairments; surgical and pharmaceutical treatments
- Therapy: physical therapy, occupational therapy, speech therapy, psychotherapy
- Technological support: Robot-aided therapy, Virtual Reality, muscle stimulation, Brain-Computer Interfaces (BCIs)
- Home therapy: personal assistance, mobile health systems, tele-monitoring, tele-therapy
- Assistive technologies: gait assistance, prosthesis, orthoses, seeing/hearing aids, etc.
- Social inclusion: definition of normality and belongingness, social behaviours, UN-BRK, etc.
- Accessibility: national and international aspects of accessibility
- Health economy in rehabilitation: public and private cost models, health insurance, SUVA, IV
- Barrier-free building and living: environmental obstacles, norms in architecture, inclusive design
- Parasports: history of Olympics and Paralympics, Special Olympics, Deaflympics, Cybathlon
- Policy: health, social, equal opportunity, disability
- Regulatory affairs: ethics committees, Swissmedic, Bundesamt für Gesundheit (BAG), law and disability
- Prevention: primary and secondary prevention, social prevention

### Competencies

#### Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

#### Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

#### Social Competencies
- Communication
- Leadership and Responsibility

#### Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

### Micro/Nanotechnology and Microfluidics for Biomedical Applications

#### 376-1351-00L

**W** 2 credits  **2V**  
E. Delamarche

#### Abstract
This course is an introduction to techniques in micro/nanotechnology and to microfluidics. It reviews how many familiar devices are built and can be used for research and biomedical applications. Transistors for DNA sequencing, beamers for patterning proteins, hard-disk technology for biosensing and microfluidics for point-of-care diagnostics are just a few examples of the covered topics.

#### Objective
The main objective of the course is to introduce micro/nanotechnology and microfluidics to students having any technical background. The course is multi-disciplinary and covers a broad range of techniques. For each lecture, a brief historical perspective is given to illustrate by whom and how the techniques were invented.

The course should familiarize the students with the techniques used in micro/nanotechnology, cleanroom microfabrication, and show them how micro/nanotechnology pervades throughout life sciences. Microfluidics will be emphasized due to their increasing importance in research and for medical applications.

The second objective is to have life sciences students less intimidated by micro/nanotechnology and make them able to link instruments and techniques to specific problems that they might have in their projects/studies. This will also help students getting access to the ETHZ/IBM Nanotech Center infrastructure if needed.
Content

Mostly formal lectures (2 × 45 min), with few specific guest lectures on topics of particular relevance. For example, an introduction to cleanroom and micro/nanotechnology instruments and 3D printing will be provided. Last 3 weeks would be dedicated to the presentation and evaluation of projects by students (2 to 3 students per team). For this, about 12 recent technologies are listed and each team picks a technology and makes a short report and presentation describing how it works, its strengths and weaknesses, and describes what problem it solves.

In terms of technical content, the lectures will cover:
- an overview of the microelectronics industry, Moore’s law, field-effect transistors, next-generation DNA sequencing
- liquid crystal displays, organic light emitting diodes, electrophoretic displays, micromirrors and beamers, photopatterning of proteins and cells, optogenetics, and flexible displays and electronics
- hard disk drives and the giant magnetoresistance effect, magnetic nanoparticles, photons, magnetic sensing and optical biosensing
- cleanroom techniques and instruments, from design to microfabrication of simple devices and microfluidics, examples of DNA microarrays
- the principles of microfluidics, microfluidic functions and fabrication, from microfluidics for research to point-of-care diagnostics, and the (infamous) history of Theranos, as well as some discussions on diagnostics for COVID, R0, and (im)precision of diagnostic devices and why it matters
- 2 × 45 min will be covered by Yuksei Temiz, a master of Arduino programming and do-it-yourself electronics, who will present how to make $20 electronic components that are synergistic to microfluidic devices and that can be controlled using a smartphone

Competencies

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<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td></td>
<td>Concepts and Theories</td>
<td>Communication</td>
<td>Critical Thinking</td>
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<td></td>
<td>Techniques and Technologies</td>
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<td>Integrity and Work Ethics</td>
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<td>assessed</td>
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<td>fostered</td>
</tr>
<tr>
<td>376-1714-00L Biocompatible Materials</td>
<td>W 4 credits</td>
<td>3V K. Maniura, M. Rottmar, M. Zenobi-Wong</td>
<td></td>
</tr>
</tbody>
</table>

Abstract

Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

Objective

The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction into different materials in use for medical applications.

Content

Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated.

Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Lecture notes

Handouts are deposited online (moodle).

Literature


(available online via ETH library)

376-1721-00L Bone Biology: Basics, Research and Clinics

<table>
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<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
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<td></td>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
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<td>Decision-making</td>
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<td>Techniques and Technologies</td>
<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Project Management</td>
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<td>Communication</td>
<td>Cooperation and Teamwork</td>
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<td>Leadership and Responsibility</td>
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<tr>
<td>Personal Competencies</td>
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<td>fostered</td>
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<td>Self-direction and Self-management</td>
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<tr>
<td>376-1720-00L Application of MATLAB in the Human Movement Sciences</td>
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</table>

Does not take place this semester.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 405 of 2653
### Abstract
Students will learn to import, process and graphically present experimental data using the MATLAB computing environment. Both the data and the methods of analysis will be typical for experiments in Human Movement Science (i.e. kinematics, kinetics and electromyography).

### Objective
Students will acquire the ability to independently load, plot, and process kinematic, kinetic and electromyographical data using the MATLAB computing environment.

### Content
- Drawbacks of Excel; Possibilities in MATLAB: Import of several data formats; Plot of one and more signals; Removing of an offset and filtering of data based on self-written functions; Normalisation and parametrisation of data; Reliability; Interpolation, Differentiation and Integration in MATLAB.
- During the lecture, several electronically available MATLAB introductions are indicated. Course-specific scripts will be provided by the lecturer.

### Prerequisites / notice
A Laptop with MATLAB installed (v2009 or higher) and wireless internet access is mandatory. Two students can share a laptop if necessary. A MATLAB student version can be obtained at Stud-IDES for free.

### 2V+1U

#### Biostatistics

**Course Information:**
- **Title:** Biostatistics
- **Type:** W
- **ECTS:** 4
- **Hours:** 2+1U
- **Lecturers:** B. Sick

**Objective:**
- Students will learn to import, process and graphically present experimental data using the MATLAB computing environment. Both the data and the methods of analysis will be typical for experiments in Human Movement Science (i.e. kinematics, kinetics and electromyography).
- Students will acquire the ability to independently load, plot, and process kinematic, kinetic and electromyographical data using the MATLAB computing environment.

**Content:**
- Drawbacks of Excel; Possibilities in MATLAB: Import of several data formats; Plot of one and more signals; Removing of an offset and filtering of data based on self-written functions; Normalisation and parametrisation of data; Reliability; Interpolation, Differentiation and Integration in MATLAB.
- During the lecture, several electronically available MATLAB introductions are indicated. Course-specific scripts will be provided by the lecturer.

**Prerequisites / notice:**
- A Laptop with MATLAB installed (v2009 or higher) and wireless internet access is mandatory. Two students can share a laptop if necessary. A MATLAB student version can be obtained at Stud-IDES for free.

### 376-1974-00L

**Colloquium in Biomechanics**

**Course Information:**
- **Title:** Colloquium in Biomechanics
- **Type:** W
- **ECTS:** 2
- **Hours:** 2K
- **Lecturers:** B. Helgason, B. de Wildt, S. J. Ferguson, J. Kimenai, R. Müller, X.-H. Qin, J. G. Snedeker, W. R. Taylor, M. Zenobi-Wong

**Objective:**
- Current topics in biomechanics presented by speakers from academia and industry.
- Getting insight into actual areas and problems of biomechanics.

### 376-2017-00L

**Biomechanics of Sports Injuries and Rehabilitation**

**Course Information:**
- **Title:** Biomechanics of Sports Injuries and Rehabilitation
- **Type:** W
- **ECTS:** 3
- **Hours:** 2V
- **Lecturers:** K.-U. Schmitt, J. Goldhahn

**Objective:**
- This lecture introduces the basic principles of injury mechanics and rehabilitation focussing on sports injuries.
- This lecture deals with simple quantitative and graphical as well as more complex methods of biostatistics. Contents: Descriptive statistics, comparison of mean values, correlation and causality, measurement of agreement, causality versus association.

**Prerequisites / notice:**
- Handouts will be made available.
- Literature

### 402-0674-00L

**Physics in Medical Research: From Atoms to Cells**

**Course Information:**
- **Title:** Physics in Medical Research: From Atoms to Cells
- **Type:** W
- **ECTS:** 6
- **Hours:** 2V+1U
- **Lecturers:** B. K. R. Müller

**Objective:**
- The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.
- The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure’s shapes, which are based on the strain relieving mechanisms and kinetic growth processes.
- High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.
- Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.
- Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.
- X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue’s anisotropies of biopolymers.

### 465-0953-00L

**Bioscience**

**Course Information:**
- **Title:** Bioscience
- **Type:** W
- **ECTS:** 4
- **Hours:** 2V+1U
- **Lecturers:** B. Sick

**Objective:**
- The course deals with simple quantitative and graphical as well as more complex methods of biosciences. Contents: Descriptive statistics, testing hypotheses, confidence intervals, correlation, simple and multiple linear regression, classification and prediction, diagnostic tests, measurement of agreement, causality versus association.

**Prerequisites / notice:**
- - know the commonly used methods in biosciences
- - perform simple data analysis with R

### Biology Courses

### 227-0399-10L

**Physiology and Anatomy for Biomedical Engineers I**

**Course Information:**
- **Title:** Physiology and Anatomy for Biomedical Engineers I
- **Type:** W
- **ECTS:** 3
- **Hours:** 2G
- **Lecturers:** M. Wyss

**Abstract:**
- To identify and enumerate important anatomical structures to describe basic physiological processes of the human body to use a 3d animation database/software to use ‘anatomical language’ to retrieve anatomical structures to understand basic medical terminology.

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**Data:** 15.06.2024 12:39
**Autumn Semester 2024**
Objective
To understand basic principles and structure of the human body in consideration of the clinical relevance and the medical terminology used in medical work and research.

Content
- The Human Body: nomenclature, orientations, tissues
- Musculoskeletal system, Muscle contraction
- Blood vessels, Heart, Circulation
- Blood, Immune system
- Respiratory system
- Acid-Base-Homeostasis

Lecture notes
Lecture notes and handouts

Literature
- Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008
- Faller A., Schuenke M. The Human Body; Thieme 2004
- Netter F. Atlas of human anatomy; Elsevier 2014

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Medical Physics

Track Core Courses

During the Master programme, a minimum of 12 CP must be obtained from track core courses.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0311-00L</td>
<td>Qubits, Electrons, Photons</td>
<td>W</td>
<td>6 credits</td>
<td>3V+2U</td>
<td>T. Zambelli</td>
</tr>
</tbody>
</table>

Abstract
In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis).

Objective
Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics.

Content
- Lagrangian and Hamiltonian: Symmetries and Poisson Brackets
- Postulates of CM: Hilbert Spaces and Operators
- Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator
- Density Operator
- Spin: Qubits, Bloch Equations, and NMR
- Entanglement
- Symmetries and Corresponding Operators
- Schrödinger's Wave Mechanics: Electrons in a Periodic Potential and Energy Bands
- Harmonic Oscillator: Creation and Annihilation Operators
- Identical Particles: Bosons and Fermions
- Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER
- Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener

Lecture notes
No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

IMPORTANT: "qubits" from the point of view of NMR (and NOT from that of quantum computing!).

In this way, students will work out a robust quantum mechanics (theoretical!!!!) basis which will help them in their advanced studies of the following masters: EEIT (batteries), Biomedical Engineering (NMR, bioelectronics), Quantum Engineering, Micro- and Nanosystems.

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Autumn Semester 2024
The purpose of this course is to impart basic knowledge in radiobiology in order to handle ionizing radiation and to provide a basis for predicting the radiation risk.

By the end of this course the participants will be able to:

a) interpret the 6 Rs of radiation oncology in the context of the hallmarks of cancer
b) understand factors which underpin the differing radiosensitivities of different tumors
c) follow rational strategies for combined treatment modalities of ionizing radiation with targeted and immunological agents
d) understand differences in the radiation response of normal tissue versus tumor tissue
e) understand different treatment responses of the tumor and the normal tissue to differential clinical-related parameters of radiotherapy (dose rate, LET etc.).
Einführung in die Strahlenbiologie ionisierender Strahlen: Allgemeine Grundlagen und Begriffsbildungen; Mechanismen der biologischen Strahlenwirkung: Strahlenwirkung auf Zellen. Gewebe und Organe; Modifikation der biologischen Strahlenwirkung; Strahlenzytogenetik: Chromosomenveränderungen, DNA-Defekte, Reparaturprozesse; Molekulare Strahlenbiologie: Bedeutung inter- und intrazellulärer Signalübermittlungsprozesse, Strahlen-induzierter Zelltod, Zellzyklus-Checkpoints; Radioimmunologie, Strahlentoxikologie; Strahlensyndrome, Krebsinduktion, Mutationstauschung, pränahtale Strahlenwirkung; Strahlenbiologische Grundlagen des Strahlenschutzes; Nutzen-Risiko-Abwägungen bei der medizinischen Strahlenanwendung; Prädiktive strahlenbiologische Methoden zur Optimierung der therapeutischen Strahlenanwendung.

Beilagen mit zusammenfassenden Texten, Tabellen, Bild- und Grafikdarstellungen werden abgegeben.


Basic Clinical Radiobiology, edited by Joiner, van der Kogel, 2018

The former number of this course unit is 465-0951-00L.

Subject-specific Competencies

Concepts and Theories

Analytical Competencies

Methods-specific Competencies

Concepts and Theories

Techniques and Technologies

Physics in Medical Research: From Atoms to Cells

Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

Physics and Mathematics of Radiotherapy Planning (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: PHY471

This lecture will provide a detailed introduction to radiotherapy treatment planning. The course considers the physical interactions of radiation in tissue, the mathematical aspects of treatment planning and additional aspects of central importance for radiotherapy planning.

Objective
Students shall develop a thorough understanding of the foundations of radiotherapy from a physics and mathematics perspective, focusing on algorithmic components. After completing the course students should be able to implement the main components of a radiotherapy treatment planning system.

Content
Radiotherapy is one of the main treatment options against cancer. Today, more than 50% of cancer patients receive radiation as part of their treatment. Modern radiotherapy is a highly technology driven field.

Research and development in medical physics has improved the precision of radiotherapy substantially. Using intensity-modulated radiotherapy (IMRT), radiation can be delivered precisely to tumors while minimizing radiation exposure of healthy organs surrounding the tumor. Thereby, medical physics has provided radiation oncologists with new curative treatment approaches where previously only palliative treatments were possible. This lecture will provide a detailed introduction to radiotherapy treatment planning and will consist of three blocks:

1. The first part of the course considers the physical interactions of radiation in tissue. The physical interactions give rise to dose calculation algorithms, which are used to calculate the absorbed radiation dose based on a CT scan of the patient.

2. The second part considers the mathematical aspects of treatment planning. Mathematical optimization techniques are introduced, which are used in intensity-modulated radiotherapy to determine the external radiation fields that optimally irradiate the tumor while minimizing radiation dose to healthy organs.

3. The third part deals with additional aspects of central importance for radiotherapy planning. This includes biomedical imaging techniques for treatment planning and target delineation as well as image registration algorithms.

The lectures are followed by computational exercises where students implement the main components of a radiotherapy treatment planning systems in two dimensions in Matlab.

Lecture notes
Lecture slides and handouts.

Prerequisites / notice
Basic programming skills in Matlab (or willingness to learn) are needed for the exercises. Basic knowledge of calculus is needed, approximately corresponding to the 3rd year of a bachelor degree in physics, mathematics, computer science, engineering or comparable discipline.

Other Elective Courses
These courses may be suitable for the Medical Physics track. Please consult your track advisor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0447-00L</td>
<td>Image Analysis and Computer Vision</td>
<td>W</td>
<td>6</td>
<td>3V+1U</td>
<td>E. Konukoglu, E. Erdil, F. Yu</td>
</tr>
<tr>
<td>Objective</td>
<td>Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.</td>
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<tr>
<td>Content</td>
<td>This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.</td>
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</tbody>
</table>

Lecture notes
Course material Script, computer demonstrations, exercises and problem solutions

Prerequisites / notice
Prerequisites: Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0965-00L</td>
<td>Micro and Nano-Tomography of Biological Tissues</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>M. Stampanoni, F. Marone Welford, F. Marone Welford</td>
</tr>
<tr>
<td>Abstract</td>
<td>The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.</td>
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<tr>
<td>Objective</td>
<td>Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications</td>
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<tr>
<td>Content</td>
<td>Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples. The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.</td>
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</table>

Lecture notes
Available online

Literature
Will be indicated during the lecture.

Biology Courses

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmss/en/studies/application/deadline s.html
**Lecturers**

4V

**Biocompatible Materials**

K. Maniura

ECTS

Physiology and Anatomy for Biomedical Engineers I

2G

Lecturers

3V

Handouts are deposited online (moodle).

W

**Physics in Medical Research: From Atoms to Cells**

V. Vogel

Students will be able

All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2

Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical

The course covers the following topics:

Physics in Medical Research: From Atoms to Cells

- Introduction to natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the

Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues).

The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

The course covers the following topics:

1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the

Consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential

Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current

Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current

Literature

- Acid-Base-Homeostasis

- Blood vessels, Heart, Circulation
- Blood, Immune system
- Musculoskeletal system, Muscle contraction
- The Human Body; nomenclature, orientations, tissues

- Respiratory system

- Faller A., Schuenke M. The Human Body; Thieme 2004
- Netter F. Atlas of human anatomy; Elsevier 2014
- Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008
- Netter F. Atlas of human anatomy; Elsevier 2014

**Molecular Bioengineering**

**Track Core Courses**

**During the Master programme, a minimum of 12 CP must be obtained from track core courses.**

**Number**

**Title**

**Type**

**ECTS**

**Hours**

**Lecturers**

**Number**

**Title**

**Type**

**ECTS**

**Hours**

**Lecturers**

**Number**

**Title**

**Type**

**ECTS**

**Hours**

**Lecturers**

402-0674-00L

Physics in Medical Research: From Atoms to Cells

W

6 credits

2V+1U

B. K. R. Müller

376-1711-00L

Biocompatible Materials

W

4 credits

3V

K. Maniura, M. Rottmar, M. Zenobi-Wong

376-1103-00L

Frontiers in Nanotechnology

W

4 credits

4V

V. Vogel, further lecturers

376-1103-00L

Frontiers in Nanotechnology

W

4 credits

4V

V. Vogel, further lecturers

227-0399-10L

Physiology and Anatomy for Biomedical Engineers I

W

3 credits

2G

M. Wyss

*Abstract*

Students will be able

to identify and enumerate important anatomical structures

to describe basic physiological processes of the human body

to use a 3d animation database/software

to use ‘anatomical language’

to retrieve anatomical structures

to understand basic medical terminology

**Objective**

To understand basic principles and structure of the human body in consideration of the clinical relevance and the medical terminology used in medical work and research.

**Content**

- The Human Body; nomenclature, orientations, tissues
- Musculoskeletal system, Muscle contraction
- Blood vessels, Heart, Circulation
- Blood, Immune system
- Respiratory system
- Acid-Base-Homeostasis

**Literature**

- Netter F. Atlas of human anatomy; Elsevier 2014
- Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008
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Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

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X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of bioplates.

**Recommended Elective Courses**

These courses are particularly recommended for the Molecular Bioengineering track. Please consult your track advisor if you wish to select other subjects.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0604-00L</td>
<td>Micro robotics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>B. Nelson</td>
</tr>
<tr>
<td>151-0905-00L</td>
<td>Medical Technology Innovation - From Concept to Clinics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>I. Herrmann</td>
</tr>
</tbody>
</table>
Abstract
Project-oriented learning on how to develop technological solutions to address unmet clinical needs.

Objective
After completing the course, you will be able to effectively collaborate with medical doctors in order to identify important unmet clinical needs. You will be able to ideate and develop appropriate engineering solutions and implementation strategies for real-world clinical problems. This lecture aims to prepare you for typical engineering challenges in the real-world where - in addition to the development of an elegant solution - interdisciplinary team work and effective communication play a key role.

Lecture notes will be available on the moodle.

Literature will be available on the moodle.

Prerequisites / notice
On site presence during (most) of the lectures highly encouraged!
Graded innovation project will require on-site presence.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

Prerequisites / notice
On site presence during (most) of the lectures highly encouraged!
Graded innovation project will require on-site presence.

227-0311-00L Qubits, Electrons, Photons W 6 credits 3V+2U T. Zambelli

Content
- Lagrangian and Hamiltonian: Symmetries and Poisson Brackets
- Postulates of QM: Hilbert Spaces and Operators
- Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator
- Density Operator
- Spin: Qubits, Bloch Equations, and NMR
- Entanglement
- Symmetries and Corresponding Operators
- Schrödinger's Wave Mechanics: Electrons in a Periodic Potential and Energy Bands
- Harmonic Oscillator: Creation and Annihilation Operators
- Identical Particles: Bosons and Fermions
- Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER
- Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener

Lecture notes
No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM, while corresponding videos of the previous years are available in Moodle !!!

Literature

Supplementary material will be uploaded in Moodle.

Prerequisites / notice
The course has been intentionally conceived to be self-consistent with respect to QM for those master students not having encountered it in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) QM introduction course like the D-ITET “Physics II”.

A solid base of Analysis I & II as well as of Linear Algebra is really helpful.
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Project Management assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity assessed
Negotiation fostered

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management fostered

227-0385-10L Biomedical Imaging

Abstract
Introduction to diagnostic medical imaging based on electromagnetic and acoustic fields including X-ray planar and tomographic imaging, radio-tracer based nuclear imaging techniques, magnetic resonance imaging and ultrasound-based procedures.

Objective
Upon completion of the course students are able to:
• Explain the physical and mathematical foundations of diagnostic medical imaging systems
• Characterize system performance based on signal-to-noise ratio, contrast-to-noise ratio and transfer function
• Design a basic diagnostic imaging system chain including data acquisition and data reconstruction
• Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications

Content
• Introduction (intro, overview, history)
• Signal theory and processing (foundations, transforms, filtering, signal-to-noise ratio)
• X-rays (production, tissue interaction, contrast, modular transfer function)
• X-rays (resolution, detection, digital subtraction angiography, Radon transform)
• X-rays (filtered back-projection, spiral computed tomography, image quality, dose)
• Nuclear imaging (radioactive tracer, collimation, point spread function, SPECT/PECT)
• Nuclear imaging (detection principles, image reconstruction, kinetic modelling)
• Magnetic Resonance (magnetic moment, spin transitions, excitation, relaxation, detection)
• Magnetic Resonance (plane wave encoding, Fourier reconstruction, pulse sequences)
• Magnetic Resonance (contrast mechanisms, gradient- and spin-echo, applications)
• Ultrasound (mechanical wave generation, propagation in tissue, reflection, transmission)
• Ultrasound (spatial and temporal resolution, phased arrays)
• Ultrasound (Doppler shift, implementations, applications)
• Summary, example exam questions

Lecture notes
Lecture notes and handouts

Literature
Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

Prerequisites / notice
Analysis, Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication assessed
Cooperation and Teamwork assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-direction and Self-management fostered

227-0386-00L Biomedical Engineering

Abstract
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the basic vocabulary of biomedical engineering and getting familiar with concepts that govern common medical instruments and the most important organs from an engineering point of view.

Objective
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs.
In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.
Content

History of BME and the role of biomedical engineers. Ethical issues related to BME.
Biomedical sensors both wearable and also biochemical sensors.
Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices.
Bioinformatics: genomic and proteomic tools, databases and basic calculations.
Equations describing basic reactions and enzyme kinetics.
Medical optics: Optical components and systems used in hospitals.
Basic concepts of tissue engineering and organ printing.
Biomaterials and their medical applications.
Function of the heart and the circulatory system.
Transport and exchange of substances in the human body, compartment modeling.
The respiratory system.
Bioimaging.
Orthopedic biomechanics.

Lecture notes
Introduction to Biomedical Engineering
by Enderle, Banchard, and Bronzino

AND

moodle page of the course

Prerequisites / notice
No specific requirements, BUT
ITET, MAVT, PHYS students will have to learn a lot of new words related to biochemistry, biology and medicine, while
HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.).

Competencies

Subject-specific Competencies
- Concepts and Theories
  - assessed
- Techniques and Technologies
  - assessed

Method-specific Competencies
- Analytical Competencies
  - assessed
- Decision-making
  - assessed
- Media and Digital Technologies
  - fostered
- Problem-solving
  - fostered
- Project Management
  - fostered

Social Competencies
- Communication
  - fostered
- Cooperation and Teamwork
  - fostered
- Customer Orientation
  - fostered
- Leadership and Responsibility
  - fostered
- Self-presentation and Social Influence
  - fostered
- Sensitivity to Diversity
  - fostered
- Negotiation
  - fostered

Personal Competencies
- Adaptability and Flexibility
  - fostered
- Creative Thinking
  - fostered
- Critical Thinking
  - fostered
- Integrity and Work Ethics
  - fostered
- Self-awareness and Self-reflection
  - fostered
- Self-direction and Self-management
  - fostered

Abstract
The course introduces bioelectricity and the sensing concepts that enable obtaining information about neurons and their networks. The sources of electrical fields and currents in the context of biological systems are discussed. The fundamental concepts and challenges of measuring bioelectronic signals and the basic concepts to record optogenetically modified organisms are introduced.

Objective
During this course the students will:
- learn the basic concepts in bioelectronics including the sources of bioelectronic signals and the methods to measure them
- be able to solve typical problems in bioelectronics
- learn about the remaining challenges in this field

Content
Lecture topics:

1. Introduction

Sources of bioelectronic signals
2. Membrane and Transport
3-4. Action potential and Hodgkin-Huxley

Measuring bioelectronic signals
5. Detection and Noise
6. Measuring currents in solutions, nanopore sensing and patch clamp pipettes
7. Measuring potentials in solution and core conductance model
8. Measuring electronic signals with wearable electronics, ECG, EEG
9. Measuring mechanical signals with bioelectronics

In vivo stimulation and recording
10. Functional electric stimulation
11. In vivo electrophysiology

Optical recording and control of neurons (optogenetics)
12. Measuring neurons optically, fundamentals of optical microscopy
13. Fluorescent probes and scanning microscopy, optogenetics, in vivo microscopy

14. Measuring biochemical signals

Lecture notes
A detailed script is provided to each lecture including the exercises and their solutions.

Literature
Plonsey and Barr, Bioelectricity: A Quantitative Approach; (Third edition)

Prerequisites / notice
The course requires an open attitude to the interdisciplinary approach of bioelectronics.
In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).
### 227-0965-00L Micro and Nano-Tomography of Biological Tissues

**W** 4 credits  3G  M. Stampanoni, F. Marone Welford

**Abstract**
The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

**Objective**
The course provides the background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

**Content**
Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

**Lecture notes**
Available online

**Literature**
Will be indicated during the lecture.

### 227-0981-00L Cross-Disciplinary Research and Development in Medicine and Engineering

**W** 4 credits  2V+2A  V. Kurtcuoglu, D. de Julien de Zelicourt, M. Meboldt

**Abstract**
A maximum of 12 medical degree students and 12 (biomedical) engineering degree students can be admitted, their number should be equal.

**IMPORTANT:** Note that a special permission from the lecturers is required to register for this course. Contact the head lecturer to that end.

**Objective**
The main goal of this course is to demonstrate the differences in communication between the fields of medicine and engineering. Since such differences become most evident during actual collaborative work, the course is based on a project in physiology, medical or clinical research that combines medicine and engineering.

For the engineering students, the specific aims of the course are to:
- Identify and precisely define a clinical need;
- Acquire a working understanding of the investigated system;
- Identify the engineering challenges in the project and communicate them to the medical students;
- Develop and implement, together with the medical students, solution strategies for the identified challenges;
- Present the solution concept to a cross-disciplinary audience; Preliminary need and solution validation;

**Content**
Cross-disciplinary collaboration between engineers and medical doctors is indispensable for innovation in health care. This course brings together engineering students from ETH Zurich and medical students from the University of Zurich to experience the rewards and challenges of such interdisciplinary work in a project based learning environment.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

**Lecture notes**
Lecture handouts and relevant material will be provided.

**Prerequisites / notice**
IMPORTANT: Note that a special permission from the lecturers is required to register for this course. Contact the head lecturer to that end.
The course teaches the basics of surface and interface science and technology, including surface modifications and forces. It covers various analytical techniques to study surface and interface properties, and explores phenomena of applied relevance like friction, lubrication, phoresis, and wetting where surfaces play a crucial role.

Objective
Students are able to
- describe the physical and chemical properties of surfaces and interfaces.
- analyze and compare analytical tools for surfaces.
- choose and combine appropriate surface-analytical approaches for solving problems connected to applications.
- understand and explain the importance of surfaces and interfaces in a broad range of phenomena and applications.

Content
- Introduction to surfaces and interfaces
- Structure of surfaces over different length scales: from macroscopic roughness to atomic structure
- Surface modifications
- Adsorption and adsorption models
- Surface forces
- Basic physical concepts
- Thermodynamics of surfaces and interfaces
- Measurement of intermolecular and surface forces
- Dynamics and history effects
- Surface analytics: X-ray Photocorrelation Spectroscopy (XPS) – principles and modern developments
- Surface analytics: Secondary Ion Mass Spectroscopy (SIMS) and IR Spectroscopy – Principles and examples
- Atomic Force Microscopy (AFM): Principles and modes of operation
- Tribology: Adhesion, Friction and Lubrication
- Contact mechanics
- Micro and macroscale friction
- Boundary lubrication
- Wetting
- Contact angles
- Phoretic phenomena
- Electric double layer and electrophoresis
- Electro-osmosis
- Other types of phoresis
- Case studies

Lecture notes
Script Download: https://moodle-app2.let.ethz.ch/course/view.php?id=17455

Literature
Script Download: https://moodle-app2.let.ethz.ch/course/view.php?id=17455

Prerequisites / notice
Chemistry:
General undergraduate chemistry including basic chemical kinetics and thermodynamics

Physics:
General undergraduate physics including basic theory of interatomic and intermolecular forces, atomic and crystalline structure of materials and their mechanical and electronic properties

Competencies
Subject-specific Competencies
Concepts and Theories assessed
 Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
 Decision-making assessed

Personal Competencies
Creative Thinking assessed
 Critical Thinking assessed

327-1101-00L Biomineralization W 2 credits 2V K.-H. Ernst
Abstract
The course addresses undergraduate and graduate students interested in getting introduced into the basic concepts of biomineralization.

Objective
The course aims to introduce the basic concepts of biomineralization and the underlying principles, such as supersaturation, nucleation and growth of minerals, the interaction of biomolecules with mineral surfaces, and cell biology of inorganic materials creation. An important part of this class is the independent study and the presentation of original literature from the field.
### Medical Physics I

Biominerlization is a multidisciplinary field. Topics dealing with biology, molecular and cell biology, solid state physics, mineralogy, crystallography, organic and physical chemistry, biochemistry, dentistry, oceanography, geology, etc. are addressed. The course covers definition and general concepts of biominerlization (BM) / types of biominerals and their function / crystal nucleation and growth / biological induction of BM / control of crystal morphology, habit, shape and orientation by organisms / strategies of compartmentalization / the interface between biomolecules (peptides, polysaccharides) and the mineral phase / biomimetic experimental methods for studying BM phenomena / inter-, intra-, extra- and epicellular BM / organic templates and matrices for BM / structure of bone, teeth (vertebrates and invertebrates) and mollusk shells / calcification / stiffification in diatoms, radiolarians and plants / calcium and iron storage / impact of BM on lithosphere and atmosphere / evolution / taxonomy of organisms.

1. Introduction and overview
2. Biominerals and their functions
3. Chemical control of biomineralization
4. Control of morphology: Organic templates and additives
5. Modern methods of investigation of BM
6. BM in matrices: bone and nacre
7. Vertebrate teeth
8. Invertebrate teeth
9. BM within vesicles: calcite of coccoliths
10. Silica
11. Iron storage and mineralization

### Lecture notes

Script with more than 600 pages with many illustrations will be distributed free of charge.

### Literature


### Prerequisites / notice

No special requirements are needed for attending. Basic knowledge in chemistry and cell biology is expected.
The aim of the course is to learn how to design polymerization reactors and bioreactors to produce polymers and proteins with the specific properties and function of peptides in chemistry and biology. The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This includes the post-treatment of polymer latexes, the downstream processing of proteins and the analysis of their colloidal behavior. The course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines. The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.

### Literature

- C. Leroux.
Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Immunology III

Abstract
This course provides a detailed understanding of:
- development of T and B cells
- the dynamics of an immune response during acute and chronic infection
- mechanisms of immunopathology
- modern vaccination strategies
Key experimental results will be shown to help understanding how immunological textbook knowledge has evolved.

Objective
Obtain a detailed understanding of:
- the development, activation, and differentiation of different types of T cells and their effectormechanisms during immune responses,
- Recognition of pathogenic microorganisms by the host cells and molecular events thereafter,
- events and signals for maturation of naive B cells to antibody producing plasma cells and memory B cells.
- Optimization of B cell responses by intelligent design of new vaccines

Content
- Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg)
- NK T cells and responses to lipid antigens
- Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17
- Overview of cytokines and their effector function
- Co-stimulation (signals 1-3)
- Dendritic cells
- Evolution of the “Danger” concept
- Cells expressing Pattern Recognition Receptors and their downstream signals
- T cell function and dysfunction in acute and chronic viral infections

Literature
Documents of the lectures are available for download at:
https://moodle-app2.let.ethz.ch/course/view.php?id=2581&notifyeditingon=1

Prerequisites / notice
Immunology I and II recommended but not compulsory

Other Elective Courses
These courses may be suitable for the Molecular Bioengineering track. Please consult your track advisor.

Biology Courses

Abstract
Students will be able to identify and enumerate important anatomical structures to describe basic physiological processes of the human body to use 'anatomical language' to retrieve anatomical structures to understand basic medical terminology

Objective
To understand basic principles and structure of the human body in consideration of the clinical relevance and the medical terminology used in medical work and research.
The course during 8 afternoons (13h to 18h) covers basic laboratory skills and safety, cell culture, protein analysis, RNA/DNA Isolation and RT-PCR. Each topic will be introduced, followed by practical work at the bench. Presence during the course is mandatory.

Objective
The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology.

Content
The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology.

Prerequisites / notice
Enrollment is limited and students from the Master's programme in Biomedical Engineering (BME) have priority.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Project Management</td>
<td>fostered</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<tr>
<td></td>
<td>Creative Thinking</td>
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Projects and Laboratory Courses

Semester Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1101-00L</td>
<td>How to Write Scientific Texts</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>U. Koch</td>
</tr>
</tbody>
</table>

Abstract
This four-hour course covers the basics of writing and presenting scientific work. The focus lies on the structure and the main elements of a scientific text. Formatting guidelines, citation rules, good practice of scientific writing and hints to convince the audience are part of the course.

Objective
- You can write scientific texts using the correct structure
- You can convincingly present scientific work
- You can differentiate the scientific style from novels and news
- You can adhere to citation rules and scientific integrity

Content
The block course covers the following topics:
- Structure of Scientific Texts
- Structure of Scientific Presentations
- Formatting of Scientific Elements (figures, equations, tables)
- Citation Rules and Scientific Integrity

The lecture will be given in two parts on two afternoons. Some exercises will be built into the lecture.

Literature
Scientific Integrity, see https://ethz.ch/en/research/ethics-and-animal-welfare/research-integrity.html

Prerequisites / notice
You should be writing either a bachelor/semester/master thesis or a scientific publication in the immediate future.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td>Method-specific Competencies</td>
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<tr>
<td>Social Competencies</td>
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<td>fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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</tbody>
</table>

Additional Projects and Laboratory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1772-10L</td>
<td>Semester Project</td>
<td>O</td>
<td>12</td>
<td>20A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Abstract
The semester project is designed to train the students in solving specific biomedical engineering problems. This project uses the technical and social skills acquired during the master's program. The semester project is advised by a professor.

Objective
see above

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1772-20L</td>
<td>Semester Project 2</td>
<td>W</td>
<td>12</td>
<td>20A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Abstract
Only for Programme Regulations 2020.

Objective
see above

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1760-10L</td>
<td>Research Project (6 credits)</td>
<td>W</td>
<td>6</td>
<td>11A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Abstract
Must be completed before the start of the master's thesis.
Abstract
The five-weeks (full-time) short research project can be done at a research or non-research institution in Switzerland or abroad, but not in a pure industry setting. The project can be done alone or in groups of students, and it is finished with a report and/or prototype. The project must be finished before the start of the Master project.

Objective
see above

227-1760-20L Research Project (12 credits) W 12 credits 26A Supervisors
Must be completed before the start of the Master's thesis

Abstract
The ten-weeks (full-time) research project can be done at a research or non-research institution in Switzerland or abroad, but not in a pure industry setting. The project can be done alone or in groups of students, and it is finished with a report and/or prototype. The project must be finished before the start of the Master project.

Objective
see above

227-1760-30L Research Project (18 credits) W 18 credits 39A Supervisors
Must be completed before the start of the Master's thesis

Abstract
The fifteen-weeks (full-time) research project can be done at a research or non-research institution in Switzerland or abroad, but not in a pure industry setting. The project can be done alone or in groups of students, and it is finished with a report and/or prototype. The project must be finished before the start of the Master project.

Objective
see above

227-1760-00L Research Project (24 credits) W 24 credits 51A Supervisors
Must be completed before the start of the Master's thesis

Abstract
The aim of the long research project is to perform a larger (exploratory) scientific study or a larger development project in a team. The duration of this project is at least four months (full-time) and it is finished with a report and/or prototype.

Objective
see above

227-1750-00L Internship in Industry W 12 credits external organisers
Only for Biomedical Engineering MSc (Programme Regulations 2020).

Abstract
The main objective of the 12-week internship (full-time) is to expose master's students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.

Objective
see above

▼ Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
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<td>227-1101-00L</td>
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<td>E-</td>
<td>0</td>
<td></td>
<td>U. Koch</td>
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</table>

Abstract
This four-hour course covers the basics of writing and presenting scientific work. The focus lies on the structure and the main elements of a scientific text. Formatting guidelines, citation rules, good practice of scientific writing and hints to convince the audience are part of the course.

Objective
- You can write scientific texts using the correct structure
- You can convincingly present scientific work
- You can differentiate the scientific style from novels and news
- You can adhere to citation rules and scientific integrity

Content
The block course covers the following topics:
- Structure of Scientific Texts
- Structure of Scientific Presentations
- Formatting of Scientific Elements (figures, equations, tables)
- Citation Rules and Scientific Integrity

Literature
Scientific Integrity, see https://ethz.ch/en/research/ethics-and-animal-welfare/research-integrity.html

Prerequisites / notice
You should be writing either a bachelor/semester/master thesis or a scientific publication in the immediate future.

Competencies
- Subject-specific Competencies
- Method-specific Competencies
- Social Competencies
- Personal Competencies

227-1700-00L Master's Thesis O 30 credits 40D Supervisors
Admission only if all the following apply:
- a. bachelor program successful completed;
- b. any additional requirements necessary to gain admission to the master program BME have been successfully completed;
- c. both the semester project and (if applicable) the internship successfully completed.

Registration in myStudies required!

Abstract
The masters program culminates in a six months research project which addresses a scientific research questions on one's chosen area of specialization. The masters thesis is supervised by a program-affiliated faculty member and the topic must be approved by the track advisor.

Objective
see above

▼ Science in Perspective

Only courses offered under "GESS Science in Perspective" count in this category. See "Offered in" tab in course view. For more information, please refer to https://gess.ethz.ch/en/studies/science-in-perspective/SiP-FAQs.html

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-
## Generally Accessible Seminars and Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0980-00L</td>
<td>Seminar on Biomedical Magnetic Resonance</td>
<td>Z</td>
<td>0 credits</td>
<td>1S</td>
<td>K. P. Prüssmann, S. Kozerke, M. Weiger Senften</td>
</tr>
</tbody>
</table>

**Abstract**
Current developments and problems of magnetic resonance imaging (MRI)

**Objective**
Getting insight into advanced topics in magnetic resonance imaging

## Biomedical Engineering Master - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

## Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td>Practical/laboratory course</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>Independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>Diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>Revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</tbody>
</table>

## ECTS

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Credit Transfer and Accumulation System</td>
</tr>
<tr>
<td>Special students and auditors need special permission from the lecturers.</td>
</tr>
</tbody>
</table>
Biotechnology Master

▶ Core Courses

▶ Courses

Students need to acquire a total of 6 ECTS in lectures in this category.
The list of core courses is a closed list, no other course can be added to this category.
Students need to pass both lectures offered in this category.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0101-00L</td>
<td>Systems Genomics</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>B. Treutlein, C. Beisel, Z. He</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>This course is an introduction to the wide field of Genomics. It addresses how fundamental questions in biological systems are studied using methods in genomics and how the resulting data is analysed to make quantitative interpretations of biological phenomena.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Objective</strong></td>
<td>The goal of this course is to get detailed insights in how state-of-the-art DNA sequencing technologies can be applied for a qualitative and quantitative description of molecular and cellular processes and function. Students will learn how to analyse RNA-seq / transcriptomics data and make biological interpretations in a quantitative manner.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Content</strong></td>
<td>This course will be a mix of lecture sessions, hands-on computational data analysis using public datasets and seminars discussing own results in the context of the published studies. In the lectures we will introduce current Next-Generation Sequencing technologies and their application to address basically all facets of modern biology and biomedical research. We will cover the major sample processing methods used for investigating functional genomic aspects like transcriptome and chromatin profiling, review recent advances in (cancer) genome sequencing and give an overview of public big data sequencing projects (ENCOD, GTEx, TCGA, ...). For the computational data analysis we will focus on different gene expression profiling (RNA-seq) experiments that have been selected from fascinating published biological studies. Data analysis based on R will follow a detailed tutorial describing all required steps of sequence read processing and will be conducted in small groups to enable every student hands-on experience.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>The PowerPoint presentations of the lectures as well as other course material relevant for an active participation will be made available online.</td>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This course provides an overview of modern concepts of bioengineering across different levels of complexity, from single molecules to systems, microscaled reactors to production environments, and across different fields of applications</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Students will be able to recognize major developments in bioengineering across different organisms and levels of complexity and be able to relate it to major technological and conceptual advances in the underlying sciences.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Molecular and cellular engineering: Synthetic biology; Engineering strategies in biology; from single molecules to systems; downscaling bioengineering; Bioengineering in chemistry, pharmaceutical sciences, and diagnostics, personalized medicine.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Handouts during class</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Literature</strong></td>
<td>Will be announced during the course</td>
<td></td>
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<tr>
<td><strong>Competencies</strong></td>
<td>Subject-specific Competencies</td>
<td></td>
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<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Concepts and Theories</td>
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<td></td>
<td>Techniques and Technologies</td>
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<td>assessed</td>
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<td></td>
<td>Personal Competencies</td>
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<td>assessed</td>
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<td></td>
<td>Critical Thinking</td>
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</table>

▶ Research Project and Industry Internship

Students can choose between Research Project OR Industry Internship. Duration: 12 weeks full-time min. Must be carried out in a different research group/company than the master’s thesis.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0805-00L</td>
<td>Research Project</td>
<td>W</td>
<td>16</td>
<td>34A</td>
<td>Supervisors</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student. Research Project duration: 12 weeks, completed with a written report.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Students get acquainted with scientific working methods and deepen their knowledge in a particular research area</td>
<td></td>
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</tr>
<tr>
<td>636-0806-00L</td>
<td>Industry Internship</td>
<td>W</td>
<td>16</td>
<td>34A</td>
<td>Supervisors</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Industry internship of at least 12 weeks, completed with a written report.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Students gain experience in an industrial environment and an overview of different research areas by applying concepts taught in the courses.</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>The students look for a placement themselves.</td>
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</table>

▶ Master’s Thesis

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>636-0900-10L</td>
<td>Master’s Thesis</td>
<td>O</td>
<td>44</td>
<td>91D</td>
<td>Supervisors</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is carried out under the supervision of a professor in a research group of the D-BSSE, usually at the D-BSSE. Students are free to choose the area.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>In the Master thesis students prove their ability to independent, structured and scientific working.</td>
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</table>

▶ Master’s Thesis (ONLY for Programme Regulations 2017)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
</table>

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### Practical Training

Students need to acquire a total of 16 ECTS in lab courses. All listed lab courses are mandatory.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0201-00L</td>
<td>Lab Course: Methods in Cell Analysis and Laboratory Automation</td>
<td>O</td>
<td>3</td>
<td>6P</td>
<td>T. Horn</td>
</tr>
<tr>
<td></td>
<td>The lab course is open for MSc Biotechnology students only.</td>
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</tbody>
</table>

**Abstract**
The course Methods in Cell Analysis and Laboratory Automation introduces students to high-end cell analysis and sample preparation methods including image analysis. Students will be taught theoretical aspects and skills in Flow Cytometry, Light Microscopy, Image Analysis, and the use of Laboratory Automation.

**Objective**
- to understand the technical and physical principles of light microscopes and flow cytometers
- to have hands-on experience in the use of these technologies to analyze/image real samples
- to be able to run a basic analysis of the data and images obtained with flow cytometers and microscopes
- to get introduced to liquid handling (pipetting) robotics and learn how to implement a basic workflow

**Content**
The practical course will have five units at 2 days each (total 10 days):

1. Flow Cytometry:
   a. Introduction to Flow Cytometry
   b. Practical demonstration on flow cytometry analyzers and flow cytometry cell sorters
   c. Flow cytometry sample preparation
   d. Learn how to use flow cytometry equipment to analyze and sort fluorescence-labeled cells
2. Light microscopy
   a. Learn how to build a microscope and understand the underlying physical principles
   b. Learn how to use a modern automated wide field fluorescence microscope
3. Use this microscope to automatically acquire images of a cell culture assay to analyze the dose-dependent effect of a drug treatment
4. Image Analysis
   a. Introduction to the fundamentals of image analysis
   b. Learn the basics of the image analysis software Fiji/ImageJ
   c. Use Fiji/ImageJ to analyze the images acquired during the microscopy exercise
5. Laboratory Automation
   a. Introduction to the basics of automated liquid handling/ lab robotics
   b. See examples on using lab automation for plasmid library generation and cell cultivation
   c. Learn how to program and execute a basic pipetting workflow including liquid handling and labware transfers on Tecan and Hamilton robotic systems
6. Presentations
   a. Each student will be assigned to an individual topic of the course and will have to prepare a presentation on it.
   b. Presentations and discussion in form of a Colloquium

**Lecture notes**
You will find further information on the practical course and the equipment at:
https://www.bsse.ethz.ch/scf
https://www.bsse.ethz.ch/laf

**Literature**
- Microscopy: Murphy and Davidson, Fundamentals of Light Microscopy and Electronic Imaging, John Wiley & Sons, 2012
- Flow Cytometry: Shapiro, Practical Flow Cytometry, John Wiley & Sons, 2005

**Prerequisites / notice**
The following knowledge is required for the course:
- basic laboratory methods
- basic physics of optics (properties of light, refraction, lenses, fluorescence)
- basic biology of cells (cell anatomy and physiology)

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>636-0203-00L</td>
<td>Lab Course: Microsystems and Microfluidics in Biotechnology</td>
<td>O</td>
<td>3</td>
<td>5P</td>
<td>P. S. Dittrich, A. Hiertemann</td>
</tr>
<tr>
<td></td>
<td>The lab course is open for MSc Biotechnology students only.</td>
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</tbody>
</table>

**Abstract**
This practical course is an introduction to microsystems technology and microfluidics for the life sciences. It includes basic concepts of microsystem design, fabrication, and assembly into an experimental setup. Biological applications include a variety of measurements of cellular and tissue signals and subsequent analysis.

**Objective**
The students are introduced to the basic principles of microsystems technology. They get acquainted with practical scientific work and learn the entire workflow of (a) understanding the theoretical concept, (b) planning the experiment, (c) engineering of the needed device, (d) execution of the experiment and data acquisition, (e) data evaluation and analysis, and (f) reporting and discussion of the results.

**Content**
The practical course will consist of a set of 4 experiments.

**Lecture notes**
Notes and guidelines will be provided at the beginning of the course.

**Literature**

**Prerequisites / notice**
The practical course will consist of a set of 4 experiments. For each experiment, the student will be required to:
- understand the theoretical concept behind the experiment
- plan the experiment
- engineer the devices
- execute the experiments and acquire data
- evaluate and analyze the data
- report and discuss the results
A good quality of the final report will be expected and be an important criterion.
Lab Course: Microbial Biotechnology

The lab course is open for MSc Biotechnology students only.

**Objective**

Students will learn the foundations of monoseptic working practice and create and screen microbial libraries for identification of strains expressing different fluorescent protein (XFP) levels.

**Content**

- Block A: Handling and preparation of microbial libraries
  - D1: Introduction to microbiological cultures and monoseptic working techniques.
  - D2: Plasmid-based expression systems and variation of XFP synthesis levels via site-directed RBS mutagenesis.
- Block B: Library screening
  - D3: In vivo screening for XFP expression levels.
  - D4: Analysis of XFP levels via SDS-PAGE analysis. RBS-sequencing.
- Block C: Hit recovery and validation
  - D5: In silico analysis of RBS variants.
  - D6: Cellular XFP content for selected variants at different culture conditions.
- Block D: Data analysis and presentation
  - D7: Protein expression analysis. Q&A for reports and presentations.
  - D8: Final presentations and wrap-up.

**Lecture notes**

Material will be provided during the course.

**Literature**


**Advanced Courses**

Students need to acquire a minimum of 22 ECTS in this category (MSc Biotechnology Study Programme Regulations 2021).

The list of advanced courses is a closed list, no other course can be added to this category.

**Biomolecular-Orientated**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0103-00L</td>
<td>Microtechnology</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>A. Hierlemann</td>
</tr>
</tbody>
</table>

**Abstract**

Students are introduced to the basics of microtechnology, cleanroom, semiconductor and silicon process technologies. They will get to know the fabrication of mostly silicon-based microdevices and -systems and all related microfabrication processes.

**Objective**

Students are introduced to the basics of microtechnology, cleanroom, semiconductor and silicon process technologies. They will get to know the different fabrication methods for various microdevices and systems.

**Content**

- Fundamentals of semiconductors and band model
- Fundamentals of devices: transistor and diode.
- Silicon processing and fabrication steps
- Silicon crystal structure and manufacturing
- Thermal oxidation
- Doping via diffusion and ion implantation
- Photolithography
- Thin film deposition: dielectrics and metals
- Wet etching & bulk micromachining
- Dry etching & surface micromachining
- Microtechnological processing and fabrication sequence
- Optional: Packaging

**Lecture notes**

Handouts in English

**Literature**


**Prerequisites / notice**

Fundamentals in physics and physicochemistry (orbital models etc.) are required, a repetitorium of fundamental physics and quantum theory at the semester beginning can be offered.

**Competencies**

- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies
- Social Competencies: Communication
- Personal Competencies: Critical Thinking
The students will learn basic and advanced knowledge in applying biophysical methods to address problems and overcome challenges in biotechnology, cell biology and life sciences in general. The biological and physical possibilities and limitations of the methods will be discussed and critically evaluated. By the end of the course the students will have assimilated knowledge on a portfolio of biophysical tools widening their research capabilities and aptitude.

The biophysical methods to be taught will include:
- Light microscopy: Resolution limit of light microscopy, fluorescence, GFP, fluorescence microscopy, DIC, phase contrast, difference between wide-field and confocal microscopy
- Electron microscopy: Scanning electron microscopy, transmission electron microscopy, electron tomography, cryo-electron microscopy, single particle analysis and averaging, tomography, sectioning, negative stain
- X-ray, electron and neutron diffraction
- MRI Imaging
- Scanning tunnelling microscopy and atomic force microscopy
- Patch clamp technologies: Principles of patch clamp analysis and application. Various patch clamp approaches used in research and industry
- Surface plasmon resonance-based biosensors
- Molecular pore-based sensors and sequencing devices
- Mechanical molecular and cellular assembly devices
- Optical and magnetic tweezers
- CD spectroscopy
- Optogenetics
- Molecular dynamics simulations

Literature
- Methods in Molecular Biophysics (5th edition), Serdyuk et al., Cambridge University Press

Prerequisites / Notice
The module is composed of 3 SWS (3 hours/week): 2-hour lecture, 1-hour seminar. For the seminar, students will prepare oral presentations on specific in-depth subjects with/under the guidance of the teacher.

Lecture notes
Hand out will be given to students at lecture.

Literature
- Methods in Molecular Biophysics (5th edition), Serdyuk et al., Cambridge University Press

Prerequisites / Notice
The module is composed of 3 SWS (3 hours/week): 2-hour lecture, 1-hour seminar. For the seminar, students will prepare oral presentations on specific in-depth subjects with/under the guidance of the teacher.

Lecture notes
Hand out will be given to students at lecture.
Literature

Representative literature:

1. Alberts, Molecular Biology (Ch.2 Cellular chemistry).
2. Ratner, Biomaterials Science (Ch. 2.3, 2.4 Polymers & hydrogels).
3. Walsh, Protein Biochemistry, (Ch. 2, Protein Structure).

636-0117-00L Mathematical Modelling for Bioengineering and Systems Biology

Objective

The course enables students to formulate, analyse, and simulate mathematical models of biochemical networks. To this end, the course covers basic mathematical concepts and tools to explore biochemical reaction dynamics as well as basic concepts from dynamical systems theory. The exercises serve to deepen the understanding of the presented concepts and the mathematical methods, and to train students to numerically solve and simulate mathematical models.

Content

Biochemical Reaction Modelling


Compétences

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Problem-solving

Personal Competencies

Creative Thinking

Critical Thinking

636-0118-00L Introduction to Dynamical Systems with Applications to Biology

Objective

The goal of this course is to introduce the student to dynamical systems and to develop a solid understanding of their fundamental properties. The theory will be developed systematically, focusing on analytical methods for low dimensional systems, geometric intuition, and application examples from biology. Computer simulations using matlab will be used to demonstrate various concepts.

Content

A dynamical view of the world; the importance of nonlinearity; solutions of differential equations; solving equations on the computer; the phase plane; fixed points and stability; linear stability analysis; classifications of linear systems; Liapunov functions and nonlinear stability; cycles and oscillations; bifurcations and bifurcation diagrams. Many biological examples will be used through the course to demonstrate the concepts.

Prerequisites / notice

Prerequisites: Calculus; a first course in differential equations; basic linear algebra (eigenvalues and eigenvectors). Matlab programming.

636-0109-00L Stem Cells: Biology and Therapeutic Manipulation

Objective

Understanding of current knowledge, and lack thereof, in stem cell biology, regenerative medicine and required technologies relevant for stem cell research and therapy will be discussed.

Content

We will use different diseases to discuss how to potentially model, diagnose or heal them by stem cell based therapies. This will be used as a guiding framework to discuss relevant concepts and technologies in cell and molecular biology, engineering, imaging, bioinformatics, tissue engineering, that are required to manipulate stem cells for therapeutic application.

Topics will include:

- Embryonic and adult stem cells and their niches
- Induced stem cells by directed reprogramming
- Relevant basic cell biology and developmental biology
- Relevant molecular biology
- Cell culture systems
- Cell fates and their molecular control by transcription factors and signalling pathways
- Cell reprogramming
- Disease Modelling
- Tissue engineering
- Bioimaging, Bioinformatics
- Single cell technologies

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 428 of 2653
Students are introduced to the basics of microtechnology, cleanroom, semiconductor and silicon process technologies. They will get to know the fabrication of mostly silicon-based microdevices and -systems and all related microfabrication processes.

The students will learn basic and advanced knowledge in applying biophysical methods to address problems and overcome challenges in biotechnology, cell biology and life sciences in general. The biological and physical possibilities and limitations of the methods will be discussed and critically evaluated. By the end of the course the students will have assimilated knowledge on a portfolio of biophysical tools widening their research capabilities and aptitude.

The biophysical methods to be taught will include:
- Light microscopy: Resolution limit of light microscopy, fluorescence, GFP, fluorescence microscopy, DIC, phase contrast, difference between wide-field and confocal microscopy
- Super resolution optical microscopy: STED, PALM, STORM, other variations
- Electron microscopy: Scanning electron microscopy, transmission electron microscopy, electron tomography, cryo-electron microscopy, single particle analysis and averaging, tommography, sectioning, negative stain
- X-ray, electron and neutron diffraction
- MRI imaging
- Scanning tunnelling microscopy and atomic force microscopy
- Patch clamp techniques: Principles of patch clamp analysis and application. Various patch clamp approaches used in research and industry
- Surface plasmon resonance-based biosensors
- Molecular pore-based sensors and sequencing devices
- Mechanical molecular and cellular assembly devices
- Optical and magnetic tweezers
- CD spectroscopy
- Optogenetics
- Molecular dynamics simulations

The information on the web can be updated until the beginning of the semester.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Social Competencies</td>
<td>Analytical Competencies</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Personal Competencies</td>
<td>Communication</td>
<td>fostered</td>
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<td></td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<td>Self-presentation and Social Influence</td>
<td>fostered</td>
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<td>Critical Thinking</td>
<td>fostered</td>
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<td></td>
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<td>Integrity and Work Ethics</td>
<td>fostered</td>
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</tbody>
</table>

The biophysical methods to be taught will include:
- Light microscopy: Resolution limit of light microscopy, fluorescence, GFP, fluorescence microscopy, DIC, phase contrast, difference between wide-field and confocal microscopy
- Super resolution optical microscopy: STED, PALM, STORM, other variations
- Electron microscopy: Scanning electron microscopy, transmission electron microscopy, electron tomography, cryo-electron microscopy, single particle analysis and averaging, tommography, sectioning, negative stain
- X-ray, electron and neutron diffraction
- MRI imaging
- Scanning tunnelling microscopy and atomic force microscopy
- Patch clamp techniques: Principles of patch clamp analysis and application. Various patch clamp approaches used in research and industry
- Surface plasmon resonance-based biosensors
- Molecular pore-based sensors and sequencing devices
- Mechanical molecular and cellular assembly devices
- Optical and magnetic tweezers
- CD spectroscopy
- Optogenetics
- Molecular dynamics simulations

Hand out will be given to students at lecture.
### 636-0108-00L Biological Engineering and Biotechnology

**Abstract**

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

**Objective**

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

**Content**


**Literature**

- Methods in Molecular Biophysics (5th edition), Serdyuk et al., Cambridge University Press
- Methods in Molecular Biophysics (5th edition), Serdyuk et al., Cambridge University Press

**Prerequisites / notice**

The module is composed of 3 SWS (3 hours/week): 2-hour lecture, 1-hour seminar. For the seminar, students will prepare oral presentations on specific in-depth subjects with/under the guidance of the teacher.

### 636-0117-00L Mathematical Modelling for Bioengineering and Systems Biology

**Abstract**

Basic concepts and mathematical tools to explore biochemical reaction kinetics and biological network dynamics.

**Objective**

The course enables students to formulate, analyse, and simulate mathematical models of biochemical networks. To this end, the course covers basic mathematical concepts and tools to explore biochemical reaction dynamics as well as basic concepts from dynamical systems theory. The exercises serve to deepen the understanding of the presented concepts and the mathematical methods, and to train students to numerically solve and simulate mathematical models.

**Content**

- Biochemical Reaction Modelling
- Basic Concepts from Linear Algebra & Differential Equations Mathematical Methods: Linear Stability Analysis, Phase Plane Analysis, Bifurcation Analysis
- Dynamical Systems: Switches, Oscillators, Adaptation Signal Propagation in Signalling Networks Parameter Estimation

**Competencies**

- Subject-specific Competencies: Concepts and Theories assessed
- Method-specific Competencies: Analytical Competencies assessed
- Personal Competencies: Creative Thinking fostered

**Literature**

- A Primer in Mathematical Models in Biology (Vol. 129). SIAM.
- Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering. CRC Press.
- Methods in Molecular Biophysics (5th edition), Serdyuk et al., Cambridge University Press

**Prerequisites / notice**

Does not take place this semester.

### 636-0118-00L Introduction to Dynamical Systems with Applications to Biology

**Abstract**

Many physical systems are dynamic and are characterized by internal variables that change with time. Describing the quantitative and qualitative features of this change is the topic of dynamical systems theory. Dynamical systems arise naturally in virtually all scientific disciplines including physics, biology, chemistry and engineering. This course is a broad introduction to the topic dynamical systems and their application to biology. Computer simulations using matlab will be used to demonstrate various concepts.

**Objective**

The goal of this course is to introduce the student to dynamical systems and to develop a solid understanding of their fundamental properties. The theory will be developed systematically, focusing on analytical methods for low dimensional systems, geometric intuition, and application examples from biology. Computer simulations using matlab will be used to demonstrate various concepts.

**Content**

A dynamical view of the world; the importance of nonlinearity; solutions of differential equations; solving equations on the computer; the phase plane; fixed points and stability; linear stability analysis; classifications of linear systems; Liapunov functions and nonlinear stability; cycles and oscillations; bifurcations and bifurcation diagrams. Many biological examples will be used through the course to demonstrate the concepts.

**Literature**

- Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering. CRC Press.
- A Primer in Mathematical Models in Biology (Vol. 129). SIAM.

**Prerequisites / notice**

- Calculus; a first course in differential equations; basic linear algebra (eigenvectors). Matlab programming.

### 636-0109-00L Stem Cells: Biology and Therapeutic Manipulation

**Abstract**

Stem cells are central in tissue regeneration and repair, and hold great potential for therapy. We will discuss the role of stem cells in health and disease, and possibilities to manipulate their behavior for therapeutic application. Basic molecular and cell biology, engineering and novel technologies relevant for stem cell research and therapy will be discussed.

**Objective**

Understanding of current knowledge, and lack thereof, in stem cell biology, regenerative medicine and required technologies. Theoretical preparation for practical laboratory experimentation with stem cells.
We will use different diseases to discuss how to potentially model, diagnose or heal them by stem cell based therapies. This will be used as a guiding framework to discuss relevant concepts and technologies in cell and molecular biology, engineering, imaging, bioinformatics, tissue engineering, that are required to manipulate stem cells for therapeutic application.

Topics will include:
- Embryonic and adult stem cells and their niches
- Induced stem cells by directed reprogramming
- Relevant basic cell biology and developmental biology
- Relevant molecular biology
- Cell culture systems
- Cell fates and their molecular control by transcription factors and signalling pathways
- Cell reprogramming
- Disease modelling
- Tissue engineering
- Bioimaging, Bioinformatics
- Single cell technologies

<table>
<thead>
<tr>
<th>Content</th>
<th>Lecturers fostered</th>
<th>ECTS</th>
<th>Type</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>Topics will include:</td>
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<tr>
<td>- Embryonic and adult stem cells and their niches</td>
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<tr>
<td>- Induced stem cells by directed reprogramming</td>
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<tr>
<td>- Relevant basic cell biology and developmental biology</td>
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<td>- Relevant molecular biology</td>
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<td>- Cell culture systems</td>
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<td>- Cell fates and their molecular control by transcription factors and signalling pathways</td>
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<tr>
<td>- Cell reprogramming</td>
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<td>- Disease modelling</td>
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<tr>
<td>- Tissue engineering</td>
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<tr>
<td>- Bioimaging, Bioinformatics</td>
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<td>- Single cell technologies</td>
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<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Assessed</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
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<tr>
<td>Techniques and Technologies</td>
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<tr>
<td>Analytical Competencies</td>
<td>Assessed</td>
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<tr>
<td>Media and Digital Technologies</td>
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<tr>
<td>Communication</td>
<td>Fostered</td>
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<tr>
<td>Cooperation and Teamwork</td>
<td>Fostered</td>
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<tr>
<td>Self-presentation and Social Influence</td>
<td>Fostered</td>
<td></td>
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<tr>
<td>Critical Thinking</td>
<td>Fostered</td>
<td></td>
</tr>
<tr>
<td>Integrity and Work Ethics</td>
<td>Fostered</td>
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</table>

| Electives | The electives list in the ETH course catalogue is an open list, and the courses listed in the ETH course catalogue provide just examples for possible elective courses, e.g. a selection of eligible courses. Students are expected to look for relevant courses in the ETH and University of Basel course catalogue and ask their mentor for approval. Courses from the advanced course category may also be taken as electives. We particularly recommend browsing the University of Basel course catalogue for elective courses of relevant master's degree programs (using the filter "programme structure" on the course catalogue website), such as for example: Biomedical Engineering, Chemistry, Drug Sciences, Epidemiology, Infection Biology, Molecular Biology, Nanosciences. |

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>636-0015-00L</td>
<td>An Introduction to Probability Theory and Stochastic Processes with Applications to Biology</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td></td>
</tr>
</tbody>
</table>

Does not take place this semester.

| Abstract | Biology is becoming increasingly quantitative and mathematical modeling is now an integral part of biological research. In many biological processes, ranging from gene-expression to evolution, randomness plays an important role that can only be understood using stochastic models. This course will provide the students with a theoretical foundation for developing such stochastic models and analyzing and simulating their behavior. |

| Objective | The aim of this course is to introduce certain topics in Probability Theory and Stochastic Processes that have been specifically selected with an eye on biological applications. This course will teach students the tools and techniques for modeling and analyzing random phenomena. Throughout the course, several biological applications will be discussed and students will be encouraged to do additional reading based on their research interests. |

| Content | The first half of the course will cover the basics of Probability Theory while the second half will delve into the theory of Stochastic Processes. Below is the list of topics that will be covered in the course. |


3. Convolvulation of Random Variables: Modes of convergences, Laws of large numbers, the central limit theorem, the law of the iterated logarithm, Applications to the analysis of cell population data. |


| Prerequisites / notice | The course will involve a healthy balance between mathematical rigor (theorem proving) and biological applications. Students are expected to have a good grasp of Linear Algebra and Multivariable Calculus. Basic knowledge of set theory will also be needed. Students should be prepared for abstract reasoning. |

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>636-0017-00L</td>
<td>Computational Biology</td>
<td>W</td>
<td>6 credits</td>
<td>3G+2A</td>
<td>T. Vaughan, C. Magnus, T. Stadler</td>
</tr>
</tbody>
</table>

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.
Objective

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

* stochastic models in molecular evolution
* phylogenetic & phylodynamic inference
* maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

* epidemiology
* pathogen evolution
* macroevolution of species

Content

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS.

Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes

Lecture slides will be available on moodle.

Literature

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

* Yang, Z. 2006. Computational Molecular Evolution.
* Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.

Prerequisites / notice

Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place in Basel before the start of the semester.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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</table>

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<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
<th>ECTS</th>
<th>Type</th>
<th>Target Group</th>
<th>Course Details</th>
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<tbody>
<tr>
<td>636-0511-00L</td>
<td>Developmental Neuroscience (University of Basel)</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>external organisers</td>
<td></td>
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</tbody>
</table>

Does not take place this semester.
The course must be registered for directly at Uni Basel.
Uni Basel course number: 14467-01

Mind the enrolment deadlines at Uni Basel:
https://www.unibas.ch/en/Studies/Mobility/Mobility-Switzerland/Students-Registering-From-Other-Swiss-Universities.html

Abstract

Development of cerebral cortex, hippocampus, motor system, olfactory system, visual system, auditory system, somatosensory system, navigation and memory systems, developmental disorders (autism, stem cells in the developing, adult and diseased brain).

<table>
<thead>
<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
<th>ECTS</th>
<th>Type</th>
<th>Target Group</th>
<th>Course Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0515-00L</td>
<td>Molecular Medicine I (University of Basel)</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>external organisers</td>
<td></td>
</tr>
</tbody>
</table>

The course must be registered for directly at Uni Basel.
Uni Basel course number: 22831-01

Mind the enrolment deadlines at Uni Basel:
https://www.unibas.ch/en/Studies/Mobility/Mobility-Switzerland/Students-Registering-From-Other-Swiss-Universities.html

Abstract

This lecture series will introduce biologists to the mechanisms that cause human diseases. Emphasis will be on the genetic and environmental factors that lead to diseases, and how this knowledge can be used to develop diagnostic and therapeutic procedures.

<table>
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<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
<th>ECTS</th>
<th>Type</th>
<th>Target Group</th>
<th>Course Details</th>
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</thead>
<tbody>
<tr>
<td>636-0706-00L</td>
<td>Spatio-Temporal Modelling in Biology</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>D. Iber</td>
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</tbody>
</table>

This course focuses on modeling spatio-temporal problems in biology, in particular on the cell and tissue level. The main focus is on mechanisms and concepts, but mathematical and numerical techniques are introduced as required. Biological examples discussed in the course provide an introduction to key concepts in developmental biology.

Objective

Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides an introduction to dynamical system, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

Content

1. Introduction to Modelling in Biology
2. Bioimage Analysis
3. Morphogen Gradients
4. Precision & Robustness of Patterning
5. Mathematical Description of Growing Biological Systems
6. Travelling Waves & Wave Pinning
7. Turing Patterns
8. Chemotaxis
9. Epithelial Organisation
10. Tissue Simulation Frameworks
11. Tissue Mechanics & Fluid Dynamics
12. Growth Control
13. Image-Based Modelling
14. Summary

Lecture notes

All lecture material will be made available online via Moodle.
The course is structured in four main pillars:

- Basics of protein structure
- Metals in Biology (University of Basel)
- Supramolecular Chemistry (University of Basel)
- Data analysis is fundamental for arriving at scientific conclusions and testing different hypotheses. This course offers a hands-on approach to data analysis techniques such as exploratory data analysis, testing differences in populations, p-values, power calculations, multiple testing, confounding, linear regression, maximum likelihood, model selection, and logistic regression; along with the fundamentals of R programming including markdown and data handling with the tidyverse.

**Prerequisites / notice**

The course is self-contained. The course assumes no background in biology but a good foundation regarding mathematical and computational techniques.

---

**636-0119-00L Introduction to Statistics and R**

**Objective**

To acquire the statistical understanding to design an appropriate analysis and the practical skills to implement the analysis in R and present the results.

**Content**

Data analysis is fundamental for arriving at scientific conclusions and testing different hypotheses. This course offers a hands-on introduction to statistical analyses including: exploratory data analysis, testing differences in populations, p-values, power calculations, multiple testing, confounding, linear regression, maximum likelihood, model selection, and logistic regression; along with the fundamentals of R programming including markdown and data handling with the tidyverse.

**Lecture notes**

Lecture slides will be available

**Prerequisites / notice**

Access to Rstudio with some markdown and tidyverse packages installed.

---

**636-0120-00L Introduction to Programming**

**Objective**

The goal of this course is to give students, who have no prior programming background, a solid introduction to algorithm development and its successive implementation in a programming language. For students with previously acquired programming skills, the course will serve as a reinforcement of key aspects of structured programming in addition to providing a well-rounded introduction to MATLAB, R and Python.

**Content**

The course is structured in four main pillars:

- Logical thinking: Translating a problem into a conceptual sequence of computational steps. For example:
  - Problem: What is the GC content of a given DNA string?
  - Logical steps:
    i) Iterate through all nucleotides in the DNA string, one by one
    ii) Count the Cs or Gs
    iii) Divide the count of Cs or Gs by the length of the DNA string
    iv) Report the result.
- Writing code: Full introduction to the MATLAB programming languages (R and Python will also be covered). Solutions to all exercises will be provided in MATLAB, R and Python. Creation of programming projects with an integrated development environment (IDE).
- Primer of Unix commands: Command-line examples on how to access servers and computing resources at the D-BSSE. Submission of jobs to the EULER cluster.

**Lecture notes**

Available on course website (Moodle)

**Literature**

Publicly available material (links will be posted on the course website)

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**636-0552-00L Metals in Biology (University of Basel)**

**Objective**

Identify key features of metalloenzymes and enzyme mimics

Deduce and draw reasonable reaction mechanisms catalyzed by metalloenzymes

Understand the role of metalloenzymes in solving energy-related grand challenges

Design functional enzyme mimics

Critically analyze the structure and function of metalloproteins

**Abstract**

Metal co-factors and their interactions with proteins

Analysis of key metalloenzymes including: Hydrolases, Oxygenases, Oxidases, Hydrogenases, Nitrogenase, Redox-proteins, Oxygen evolving complex, Photosystem II, Metal trafficking in cells, Metal homeostasis, DNA-binding proteins, Biomimetic chemistry, Artificial Metalloenzymes etc.

Metals in medicine

**Literature**

Mind the enrolment deadlines at Uni Basel:
https://www.unibas.ch/en/Studies/Mobility-Mobility-Switzerland/Students-Registering-From-Other-Swiss-Universities.html

- Murray, Mathematical Biology, Springer
- Forgacs and Newman, Biological Physics of the Developing Embryo, CUP
- Keener and Sneyd, Mathematical Physiology, Springer
- Fall et al, Computational Cell Biology, Springer
- Szallasi et al, System Modeling in Cellular Biology, MIT Press
- Wolkenhauer, Systems Biology
- Kreyszig, Engineering Mathematics, Wiley

---

**636-0553-00L Chemical Biology (University of Basel)**

**Objective**

The modern tools of chemical biology will be discussed and contextualized with a discussion of practical applications with those tools.

**Abstract**

The course must be registered for directly at Uni Basel.

**Prerequisites / notice**

The course must be registered for directly at Uni Basel.

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**636-0551-00L Supramolecular Chemistry (University of Basel)**

**Objective**

- Identify key features of metalloenzymes and enzyme mimics
- Deduce and draw reasonable reaction mechanisms catalyzed by metalloenzymes
- Understand the role of metalloenzymes in solving energy-related grand challenges
- Design functional enzyme mimics
- Critically analyze the structure and function of metalloproteins

**Abstract**

The modern tools of chemical biology will be discussed and contextualized with a discussion of practical applications with those tools.

**Prerequisites / notice**

The course must be registered for directly at Uni Basel.

**Literature**

- Mind the enrolment deadlines at Uni Basel:
  https://www.unibas.ch/en/Studies/Mobility-Mobility-Switzerland/Students-Registering-From-Other-Swiss-Universities.html
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- Kreyszig, Engineering Mathematics, Wiley
Mind the enrolment deadlines at Uni Basel: 
https://www.unibas.ch/en/Studies/Mobility/Mobility-Switzerland/Students/ 
Registering-From-Other-Swiss-Universities.html

Abstract
This course provides an introduction to supramolecular chemistry. Prior knowledge in supramolecular chemistry is not a prerequisite for this course.

Objective
After this course, the student is expected to understand and be able to apply the basics of supramolecular chemistry: host-guest interactions, host design, self-assembly and simple enzyme mimetics.

Content
This course provides an introduction to supramolecular chemistry. Prior knowledge in supramolecular chemistry is not a prerequisite for this course. We will first cover the basic concepts of supramolecular chemistry: non-covalent interactions, host-guest chemistry, binding constant determination and binding strength. Subsequently, we will take a closer look at how to bind different species: cations, anions and neutral organic molecules. Towards the end of the semester, we will cover self-assembly processes and applications of supramolecular structures as simple enzyme mimetics.

Lecture notes
The lecture slides are provided online via ADAM. No additional literature is required. If additional information is desired, the book “Supramolecular Chemistry” by Jonathan W. Steed and Jerry L. Atwood (John Wiley & Sons) is recommended.

636-0554-00L Modelling and Simulation in Drug Development

W 2 credits 3V H.-M. Kaltenbach

Abstract
This course introduces how Modelling and Simulation (=mathematical modelling) is applied today for the development of novel drugs in the pharmaceutical industry. Background lectures are combined with hands-on exercises on real-world examples.

Objective
The goal of this course is to provide students with a general understanding of drug development and pharmacology and how Modelling and Simulation is used to develop new drugs. Together with the application, the course will provide the background in the statistical methodologies used to model multivariate and time-dependent data with several levels of statistical variability.

Content
Understanding the pharmacology, pharmacokinetics and pharmacodynamics (PK/PD) of novel drugs is key for a successful drug development process. Modelling and Simulation of these data is at the core to gain this understanding. Focusing on the application using real-world examples, this course will introduce the statistical methodologies that have been developed to describe complex biological and pharmacological data with several levels of statistical variability.

The course will cover the basics of drug development and pharmacology with a focus on the principles of drug absorption, distribution, metabolism and excretion (ADME) and drug pharmacokinetics and pharmacodynamics (PK/PD). The different drug formats (small molecules, biologics, cell-based therapies, gene therapies and oligonucleotide formats) and their pharmacological properties will be introduced. The translation from animal to human to inform first-in-human dose selections will be discussed.

The methodology part will cover compartmental PK/PD modelling, the practical aspects of numerical solutions of ordinary differential equation (ODEs) and the theory on non-linear mixed effects (NLME) modelling, which has become the de-facto standard methodology in the pharmaceutical industry. Practical problems of Modelling and Simulations will be discussed including parameter identifiability, model development and model evaluation and the application (or not) of the Occam’s Razor.

The course will focus on hands-on exercises using contemporary real-world examples from the pharmaceutical industry and provide necessary theoretical and methodological background in accompanying lectures.

The course is organized jointly by D-BSSE and LYO-X, a Quantitative Systems Pharmacology consulting company situated in Basel.

Prerequisites / notice
Basics of dynamic systems (e.g., BSSE courses by Iber or Kammash, or CSB course by Stelling).
Basics of statistics and R (e.g., BSSE courses by Kuipers or Kaltenbach).

Science in Perspective

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-BSSE

Biotechnology Master - Key for Type

<table>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Key for Hours

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<tr>
<th>V</th>
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<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Module 3 we leave behind the negative images from the early days of automation. A gloomy and misanthropic image of automation - both a

A. Paulus

O

2G

Eligible for credits

S. Menz

Scripts, documents, studies, dates and addresses are stored on the server of the program and accessible to students on the Miro Board.

Module 2: Collaboration

Key terms: “Behaviour for Collaboration” - Structural questions on collaboration and the patterns of behaviour.

Module 3: Foundation of Automation

Key terms: Managed data, semantics and file formats

Module 4: Foundation of Value Creation

Key terms: Added value of digital transformation, distributed data management, digital twin, logistics and robotics.

Module 5: New Business Models

Key terms: Business models, cultural change, disruption, evolution, lean methods

Highway to hell or highway to haven” - the question of a clear and simple roadmap is always at the heart of a digital transformation. “Value

The module offers the opportunity to prepare for the voluntary buildingSMART Professional Certification.

What does it take to be able to work together in a digitally networked environment? How many “techie genes” are needed to work efficiently

CAS ARC Digital

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Module 1: Foundations of Digitalisation</th>
<th>Type</th>
<th>ECTS</th>
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<tr>
<td>072-0101-00L</td>
<td>Key terms: Digital transformation is more than digitisation of existing processes and information</td>
<td>O</td>
<td>1 credit</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
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<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>072-0102-00L</td>
<td>Key terms: “Behaviour for Collaboration” - Structural questions on collaboration and the patterns of behaviour.</td>
<td>O</td>
<td>1 credit</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
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<table>
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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>072-0103-00L</td>
<td>Key terms: Managed data, semantics and file formats</td>
<td>O</td>
<td>1 credit</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Module 4: Foundation of Value Creation</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>072-0104-00L</td>
<td>Key terms: Added value of digital transformation, distributed data management, digital twin, logistics and robotics.</td>
<td>O</td>
<td>1 credit</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Module 5: New Business Models</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>072-0105-00L</td>
<td>Key terms: Business models, cultural change, disruption, evolution, lean methods</td>
<td>O</td>
<td>1 credit</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
</tr>
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The Term Paper

The Term Paper is offered in spring semesters only.

CAS ARC Digital - Key for Type

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<tr>
<th>Type</th>
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<th>Courses outside the curriculum</th>
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### Key for Hours

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<th>Code</th>
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<td>lecture</td>
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<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<td>R</td>
<td>revision course / private study</td>
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**ECTS**
- European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>072-0201-00L</td>
<td>Module 1: Understanding of Roles</td>
<td>O</td>
<td>1</td>
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<td>A. Paulus, S. Menz</td>
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<td>Abstract</td>
<td>Our advanced studies’ lectures are given in German. Please find an English written abstract and/or keywords in the field ‘objective’.</td>
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<tr>
<td>Objective</td>
<td>The students are able to understand the following terminologies, processes and competences. They are able to put them into practice.</td>
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<tr>
<td>- Profession</td>
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<td>- Ethos and ethic</td>
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<td>- Organisational forms</td>
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<td>- Role and tasks</td>
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<td>- Attitude and practice</td>
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<tr>
<td>Lecture notes</td>
<td>Please find the teaching material, the further readings and Information on our server.</td>
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<tr>
<td>Literature</td>
<td><a href="http://www.map.arch.ethz.ch/en">www.map.arch.ethz.ch/en</a></td>
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</table>

| 072-0202-00L | Module 2: Collaboration | O    | 1    | 2G    | A. Paulus, S. Menz |
| Abstract | Our advanced studies’ lectures are given in German. Please find an English written abstract and/or keywords in the field ‘objective’. |
| Objective | The students are able to understand the following terminologies, processes and competences. They are able to put them into practice. |
| - Organisation charts |
| - Project knowledge and process understanding |
| - Structure of the project |
| - Agile project management |
| - Socio-economic viewpoint |
| - Perception of demand |
| Content | Our advanced studies’ lectures are given in German. Please find an English written abstract and/or keywords in the field ‘objective’. |
| Lecture notes | Please find the teaching material, the further readings and Information on our server. |
| Literature | www.map.arch.ethz.ch/en |

| 072-0203-00L | Module 3: Services | O    | 1    | 2G    | A. Paulus, S. Menz |
| Abstract | Our advanced studies’ lectures are given in German. Please find an English written abstract and/or keywords in the field ‘objective’. |
| Objective | The students are able to understand the following terminologies, processes and competences. They are able to put them into practice. |
| - Phases and services |
| - Due diligence and duty of loyalty |
| - Duties and tasks, liability |
| - Working packages |
| - Management and coordination |
| Content | Our advanced studies’ lectures are given in German. Please find an English written abstract and/or keywords in the field ‘objective’. |
| Lecture notes | Please find the teaching material, the further readings and Information on our server. |
| Literature | www.map.arch.ethz.ch/en |

| 072-0204-00L | Module 4: Guiding/Steering/Leading | O    | 1    | 2G    | A. Paulus, S. Menz |
| Abstract | Our advanced studies’ lectures are given in German. Please find an English written abstract and/or keywords in the field ‘objective’. |
| Objective | The students are able to understand the following terminologies, processes and competences. They are able to put them into practice. |
| - Management and administration |
| - Leadership |
| - Team performance |
| - Motivation and conflict resolution |
| Content | Our advanced studies’ lectures are given in German. Please find an English written abstract and/or keywords in the field ‘objective’. |
| Lecture notes | Please find the teaching material, the further readings and Information on our server. |
| Literature | www.map.arch.ethz.ch/en |

| 072-0205-00L | Module 5: Project | O    | 1    | 2G    | A. Paulus, S. Menz |
| Abstract | Our advanced studies’ lectures are given in German. Please find an English written abstract and/or keywords in the field ‘objective’. |
| Objective | The students are able to understand the following terminologies, processes and competences. They are able to put them into practice. |
| - Management of unknowns |
| - Decision making |
| - Future perspectives |
| - Micro and macro environment |
| - Strength and flexibility |
| Content | Our advanced studies’ lectures are given in German. Please find an English written abstract and/or keywords in the field ‘objective’. |
| Lecture notes | Please find the teaching material, the further readings and Information on our server. |
| Literature | www.map.arch.ethz.ch/en |

#### Term Paper

Offered in the Spring Semester.

<table>
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<tr>
<th>CAS ARC in Project Leadership - Key for Type</th>
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<th>W+</th>
<th>W</th>
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<td>E-</td>
<td>Z</td>
<td>Dr</td>
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<td>Eligible for credits and recommended</td>
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**Recommended, not eligible for credits**

**Courses outside the curriculum**

**Suitable for doctorate**
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<th>Key for Hours</th>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**
- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
The participants understand a property in the context of a life cycle.

Introductory module «Enterprise» considers the role of organizations in the economic network of markets and their identity. It presents the peculiarities of planning offices as a service provider, shows different types of companies and discusses the business cycle from founding to succession planning. In addition, the branch-specific development of leadership and organizational models as well as the problem of access to international markets are examined. Accompanying the basics of a general business model for service companies are taught and key criteria defined.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Module 2: State of the Art

Key words: Markt, Neubau, Wiederverwendung, Energieumwandlung, Entsorgung

Knowledge about type, extent and change of the building Switzerland and the main questions.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Module 3: Economic Interest

Key words: Bildungsvermögen, Anschaffungskosten, Nutzungswert, Erneuerungswert, Erneuerung, Entsorgungswert, Abbruch, Wiederverwendung

The structure and nomenclature of the interventions in the stock are presented and models for the registration and calculation of the costs can exceed the cost of construction after just a few years. In this module, a systematic consideration of the phases and processes in the life cycle of a property takes place. Study I explores various aspects of life-cycle planning and construction.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Module 4: Course of Action

Key words: Erhaltung, Wiederverwendung, Entsorgung

Preservation of value, increase in value, destruction of value and replacement construction.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Module 5: Life Cycle and Resources

Key words: Bauwerk Schweiz, Neubau und Sanierung, Wiederverwendbarkeit, Energiefloss, Schadstoffe

The structure and nomenclature of the interventions in the stock are presented and models for the registration and calculation of the materials. Implications for selective decommissioning, disposal, landfilling, recycling and reuse, as well as the importance of the gray matter energy of demolished and more than 60 million t of raw materials are used in new buildings. This module examines the cycle principle and its implications for selective decommissioning, disposal, landfilling, recycling and reuse, as well as the importance of the gray matter energy of materials.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Term Paper
The term paper is offered in spring semester only.

CAS ARC in Real Estate Strategies urban-peri-urban - Key for Type

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<th>Number</th>
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<td>072-0301-00L</td>
<td>Module 1: Perception of Demand</td>
<td>O</td>
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<td>2G</td>
<td>A. Paulus, S. Menz</td>
</tr>
<tr>
<td></td>
<td>Key words: Construction and real estate market, micro and macro environment</td>
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<tr>
<td></td>
<td>In Module 1, by interpreting the snapshot of one's own enterprise and opportunities and dangers to appreciate.</td>
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<td></td>
<td>Introductory module «Enterprise» considers the role of organizations in the economic network of markets and their identity. It presents the peculiarities of planning offices as a service provider, shows different types of companies and discusses the business cycle from founding to succession planning. In addition, the branch-specific development of leadership and organizational models as well as the problem of access to international markets are examined. Accompanying the basics of a general business model for service companies are taught and key criteria defined.</td>
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<td>Scripts, documents, studies, dates and addresses are stored on the server of the program.</td>
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<td>072-0302-00L</td>
<td>Module 2: State of the Art</td>
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<td>1 credit</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
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<tr>
<td></td>
<td>Key words: Bauwerk Schweiz, new construction and renovation, economy Change in value, demolition / replacement, potential for compression</td>
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<td></td>
<td>Knowledge about type, extent and change of the building Switzerland and the main questions.</td>
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<td></td>
<td>With more than CHF 3.585 billion (excluding land), Switzerland is the largest national capital. It grows by around 4.7 per cent each year, but its value is under-invested. Is there a risk of slippage? Should more be invested in maintenance / repair or more canceled and replaced? How big is the compaction potential in the stock? Excursus on civil engineering and infrastructure construction</td>
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<td>Module 3: Economic Interest</td>
<td>O</td>
<td>1 credit</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
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<tr>
<td></td>
<td>Key words: intention development, realization operation</td>
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<td></td>
<td>The participants understand a property in the context of a life cycle</td>
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<td>The importance of a life-cycle-oriented approach has arrived in the Swiss construction and real estate sector. Cumulative management costs can exceed the cost of construction after just a few years. In this module, a systematic consideration of the phases and processes in the life cycle of a property takes place. Study I explores various aspects of life-cycle planning and construction.</td>
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<tr>
<td>072-0304-00L</td>
<td>Module 4: Course of Action</td>
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<td>1 credit</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
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<td>Key words: maintenance, change, replacement</td>
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<td></td>
<td>Preservation of value, increase in value, destruction of value and replacement construction</td>
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<td></td>
<td>The various depths of intervention in dealing with a existing property and their effects are known.</td>
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<td></td>
<td>The structure and nomenclature of the interventions in the stock are presented and models for the registration and calculation of the</td>
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<td>structural interventions are presented. It focuses specifically on ongoing maintenance, the periodic repair and planning of renewal cycles, as well as on structural interventions and value-enhancing measures. Based on the study II, the learning content is applied and various options for action in dealing with the building stock are evaluated.</td>
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<td>Literature recommendations at <a href="http://www.bauprozess.arch.ethz.ch">www.bauprozess.arch.ethz.ch</a> and <a href="http://www.kompetenz.arch.ethz.ch">www.kompetenz.arch.ethz.ch</a></td>
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<tr>
<td>072-0305-00L</td>
<td>Module 5: Life Cycle and Resources</td>
<td>O</td>
<td>1 credit</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
</tr>
<tr>
<td></td>
<td>Key words: building fabric, material cycle Production and disposal / reusability of building fabric, energy flows, pollutants</td>
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<tr>
<td></td>
<td>Building and breaking off is understood as an energy and material flow.</td>
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<td></td>
<td>The total weight of all properties in Switzerland is estimated at around 1 billion tonnes. Every year around 10 million m³ of buildings are demolished and more than 80 million t of raw materials are used in new buildings. This module examines the cycle principle and its implications for selective decommissioning, disposal, landfilling, recycling and reuse, as well as the importance of the gray matter energy of materials. Continuation, reuse, demolition / new construction - stakeholders, goals and conflicting goals</td>
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<tr>
<td></td>
<td>Literature</td>
<td>Scripts, documents, studies, dates and addresses are stored on the server of the program.</td>
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<tr>
<td></td>
<td>Literature</td>
<td>Literature recommendations at <a href="http://www.bauprozess.arch.ethz.ch">www.bauprozess.arch.ethz.ch</a> and <a href="http://www.kompetenz.arch.ethz.ch">www.kompetenz.arch.ethz.ch</a></td>
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</tbody>
</table>
Module 1: Market, purpose and business model

Key terms: Market, purpose and business model

The aim is to use a snapshot in time to interpret one's own company and become able to assess opportunities and risks.

Content

The “company” module considers the role of organisations within the economic network of the markets and the nature of their identity. It presents the special aspects of planning offices as service providers, illustrates various types of company, and discusses companies’ lifecycle as they move from their founding to the period of planning for the succession. Both sector-specific development of management and organizational models and also the problems of obtaining access to international markets are also investigated. Alongside this, the foundations of a generally valid business model for service companies are described and key criteria are defined.

Literature

Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Module 2: Acquisition

Key terms: Competence, communication and network

The aim is to become able to analyse and implement the processes and instruments used for acquisition in one's own company.

Content

Acquisition represents a separate project in entrepreneurial activity, since all the activities involved in obtaining a commission fall under this term. The “acquisition” module focuses on imparting basic knowledge of networking and professional dialogue. Both of these tools require an assessment of one’s own situation with regard to competence, resources and customer relations. The conversation is a direct interaction; everyone involved is both an addressee and also basically an equal interlocutor. Networking can be learned: situational “small talk,” social competence and a healthy ability to communicate can be learned.

Literature

Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Module 3: Marketing

Key terms: Planning, positioning and identity

The aim is to become familiar with the tools used in marketing and able to use them in specific situations.

Content

Marketing means orienting company activities towards market demands. Communication between suppliers, clients and the competition plays the decisive role here. The “marketing” module illustrates the foundations of marketing planning for architects and engineers. The essential definitions are provided and the core tasks involved in marketing are described. On this basis, the way in which a marketing plan is developed is explained and strategic and operational marketing planning is described in detail. The topics of branding and the opportunities represented by press and public relations work for architects and planners round out the “marketing” module.

Literature

Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Module 4: Financial Management

Key terms: Cost accounting, budgeting and controlling

The aim is to become able to analyse one's own company's financial resources in detail, interpret key parameters for the current situation and test them.

Content

Financial management means achieving the target company output with costs that are as low as possible, and in the longer term to create secure asset and capital structures. The tasks involved in financial management in a planning office include establishing a well-structured accounting department, careful cost accounting, sound budgeting and an effective controlling system. On the basis of a practical financial structure for architecture and engineering offices, the “financial management” module presents the information needed to carry these tasks out in a professional and responsible way.

Literature

Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Module 5: Digitalisation

Key terms: Strategy, potentials and digital planning

The aim is to become familiar with the current practical work involved in IT in planning companies and be able both to analyze the specific challenges it implies and also to infer one’s own prospects for development in this context. In addition, thought needs to be given to the way in which the value creation provided by digitalisation influences one’s own company.

Content

IT refers on the one hand to information and data processing in a company, and on the other to the hardware and software components needed for the purpose. This “information technology” module focuses on potential strategies for company management in the IT field. The focus is not on the use of any individual programme, but on taking conscious decisions for or against IT components in one’s own company in order to obtain helpful support in one’s everyday work. The strengths, weaknesses, opportunities and risk of this strategy suggest possible potentials.

The participants will present their own theses on entrepreneurship and open them up for discussion in the plenary session.

Literature

Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Term Paper

Offered in the Spring Semester.

CAS ARC in Unternehmensführung - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
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<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
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<td>Dr</td>
<td>Suitable for doctorate</td>
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Data: 15.06.2024 12:39   Autumn Semester 2024   Page 440 of 2653
### Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
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<td>seminar</td>
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<td>R</td>
<td>revision course / private study</td>
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**ECTS**  
- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
### CAS in Advanced Materials and Processes

#### Module

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tr>
<td>Abstract</td>
<td>CAS AMaP participants are offered a MaP professor as a mentor together with whom they design their study plan along an individually-specified focus area in Advanced Materials and Processes. Building on the individual expertise, interests and needs of the participants, the customised CAS AMaP module consists of the elements: (i) research project, (ii) courses and lectures, (iii) knowledge transfer.</td>
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<tr>
<td>Objective</td>
<td>The CAS AMaP module is fully customisable, building on the expertise of technical specialist professionals and aims at: - training skills at the frontiers of the current state of research in Advanced Materials and Processes, - deepening technical know-how and state-of-the-art knowledge in the specified focus area, and - advancing practical competencies in the impart of expertise and knowledge transfer across disciplines and educational levels.</td>
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<tr>
<td>Content</td>
<td>Depending on individual interests and needs of the technical specialist professionals, the CAS AMaP module consists of the elements: I. conducting a research project in the mentor’s group, addressing fundamental, development or applied problems, considering theoretical and/or experimental aspects, II. individual schedule of courses and lectures with state-of-the-art knowledge, and III. sharing of know-how in, e.g. seminars and interactive formats, thereby enhancing bidirectional knowledge transfer.</td>
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#### CAS in Advanced Materials and Processes - Key for Type

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#### Key for Hours

<table>
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<th>lecture</th>
<th>P</th>
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<tr>
<td>K</td>
<td>colloquium</td>
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#### ECTS

- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.

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CAS in Applied Earth Sciences

Modules Geo-Resources

The Module Geo-Resources runs over two semesters (FS and HS) and is offered every three years.

Takes place in FS25 + HS25

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>669-0102-00L</td>
<td>Autumn Course: Geothermal Usage of the Subsurface</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>M. O. Saar</td>
</tr>
</tbody>
</table>

Abstract
The block course focuses on shallow groundwater wells and ground heat exchangers, but also expands the spectrum to include geothermal energy and geostorage potential in Switzerland. The contributions address, among other things, the question of how, with increased use of geothermal resources, conflicts of use due to the growing number of uses can be dealt with.

Objective
The aim of the course is for participants to be able to describe the basic processes of geothermal use and to understand the regulatory framework. They will be able to assess the mutual influence of the uses and know possibilities to take these into account in strategic planning.

Modules Geo-Constructions

The Module Geo-Constructions runs over two semesters (FS and HS) and is offered every three years.

Takes place in FS23 + HS23

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>669-0202-00L</td>
<td>Fall Course: Characterisation of Rock and Rock Mass Behaviour for Underground Excavations</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>J. Aaron</td>
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</tbody>
</table>

Abstract
The course focuses on the characterization of rock as a basis for describing rock mass behaviour with the help of hazard scenarios that are used in the planning and construction of underground excavations.

Objective
Participants learn the geological, geomechanical and hydrogeological factors necessary for the assessment and are able to estimate the influence of geological conditions on underground excavations.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: fostered

Social Competencies
- Cooperation and Teamwork: fostered

Personal Competencies
- Critical Thinking: fostered

Modules Geo-Risks

The Module Geo-Risks runs over two semesters (FS and HS) and is offered every three years.

Takes place in FS24 + HS24

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>669-0302-00L</td>
<td>Autumn Course: Landslide Process and Hazards</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>J. Aaron, A. Manconi</td>
</tr>
</tbody>
</table>

Abstract
The autumn course provides current and new knowledge needed for classification, determination of the relevant processes and estimation of the temporal behaviour of geological mass movements.

Objective
The participants learn which investigations and measurements can be used to improve the hazard analysis in a targeted manner, especially for more complex slope instabilities.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

Personal Competencies
- Critical Thinking: fostered

CAS in Applied Earth Sciences - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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Key for Hours

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ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
# CAS in Applied Statistics

## Compulsory Courses

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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>447-0649-01L</td>
<td>Applied Statistical Regression I</td>
<td>O</td>
<td>4</td>
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<tr>
<td></td>
<td>Does not take place this semester.</td>
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<tr>
<td>Abstract</td>
<td>Simple and multiple regression models, with emphasis on practical aspects and interpretation of results, analysis of residuals and model selection.</td>
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<tr>
<td>447-0625-01L</td>
<td>Applied Analysis of Variance and Experimental Design I</td>
<td>O</td>
<td>3</td>
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<tr>
<td>Abstract</td>
<td>Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs.</td>
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<tr>
<td>Objective</td>
<td>Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.</td>
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<tr>
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<td>Methods-specific Competencies: Decision-making</td>
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<tr>
<td>Personal Competencies</td>
<td>Methods-specific Competencies: Critical Thinking</td>
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## Further Courses

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<th>Lecturers</th>
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<td>447-0649-02L</td>
<td>Applied Statistical Regression II</td>
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<tr>
<td>Abstract</td>
<td>Generalized linear models (GLMs) and basic ideas of more advanced regression models.</td>
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<tr>
<td>Objective</td>
<td>Understanding the concept and flexibility of generalized linear models and correct interpretation of the corresponding model outputs.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies: Concepts and Theories</td>
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<tr>
<td></td>
<td>Methods-specific Competencies: Decision-making</td>
<td>assessed</td>
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<tr>
<td>Personal Competencies</td>
<td>Methods-specific Competencies: Critical Thinking</td>
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</table>

### Literature

### Further Courses

- **Nonparametric Regression**
  - **Number**: 447-6221-00L
  - **Title**: Nonparametric Regression
  - **Type**: W
  - **ECTS**: 1
  - **Hours**: 1G
  - **Lecturers**: M. Mächler
  - **Abstract**: This course focuses on nonparametric estimation of probability densities and regression functions. These recent methods allow modelling without restrictive assumptions such as 'linear function'. These smoothing methods require a weight function and a smoothing parameter. Focus is on one dimension, higher dimensions and samples of curves are treated briefly. Exercises at the computer.
  - **Competencies**: Subject-specific Competencies: Concepts and Theories. Method-specific Competencies: Analytical Competencies. Personal Competencies: Creative Thinking

- **Repeated Measures**
  - **Number**: 447-6257-00L
  - **Title**: Repeated Measures
  - **Type**: W
  - **ECTS**: 1
  - **Hours**: 1G
  - **Lecturers**: M. L. Spohn
  - **Competencies**: Subject-specific Competencies: Concepts and Theories. Method-specific Competencies: Analytical Competencies. Personal Competencies: Creative Thinking

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The elements of a sample survey are explained. The most important classical sample designs (simple random sampling and stratified random sampling) with their estimation procedures and the use of auxiliary information including the Horvitz-Thompson estimator are introduced. Data preparation, non-response and its treatment, variance estimation and analysis of survey data is discussed.

Knowledge of the Elements and the process of a sample survey. Understanding of the paradigm of random samples. Knowledge of simple random sampling and stratified random sampling and capability to apply the corresponding methods. Knowledge of further methods of sampling and estimation as well as data preparation and analysis.

Introduction to the statistical methods of survey research.

Nonparametric and Resampling Methods

- understanding basics of Bayesian inference
- use R packages to run MCMC algorithms
- fit and understand Bayesian linear models
- introduction to hierarchical Bayesian models

We will learn how to describe business/scientific problems as probabilistic models, apply Bayes rules to draw inference from data, and use the probabilistic programming language STAN to obtain samples from posterior distributions. We will learn how to build, fit and validate Bayesian models of increasing complexity. There will be examples of applications from various fields: insurance, meteorology, marketing, etc.

Applied Bayesian Statistics

Introduction to Bayesian statistics: basics of inference, computation with MCMC, linear regression, Bayesian hierarchical models. Focus on applications and hands-on programming.

Statistical Analysis of Financial Data


Getting to know the typical properties of financial data and appropriate statistical models, incl. the corresponding functions in R.
Analysis of High-Dimensional Data

Abstract
Block course on analysis of high-dimensional data with a focus on prediction and feature assessment.

Objective
The goal of this course is to gain a good understanding of the concepts discussed during the lecture and to apply the new methods on real data examples using the software "R". The topics covered in the lecture are:

Part 1: Linear regression in the high-dimensional context; Overfitting, prediction and the bias-variance tradeoff; Model selection; Ridge and Lasso regularization

Part 2: Logistic regression and regularization; Classification based on decision trees, Random Forest and AdaBoost; Multiple testing; P-value adjustment and variance shrinkage

Content
Course on Analysis of High-Dimensional Data with focus on Prediction and Feature Assessment.

Part 1: Linear regression in the high-dimensional context; Overfitting, prediction and the bias-variance tradeoff; Model selection; Ridge and Lasso regularization

Part 2: Logistic regression and regularization; Classification based on decision trees, Random Forest and AdaBoost; Multiple testing; P-value adjustment and variance shrinkage

Lecture notes
The block course is based on lecture notes (https://bookdown.org/staedler_n/highdimstats/).

Literature

Prerequisites / notice
The exercises are done exclusively with the (free, open source) software "R" (http://www.r-project.org). A final exam will also happen at the computers, using R (and your brains!).

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Spatial Statistics

Abstract
In many research fields, spatially referenced data are collected. When analysing such data the focus is either on exploring their structure (dependence on explanatory variables, autocorrelation) and/or on spatial prediction. The course provides an introduction to geostatistical methods that are useful for such purposes.

Objective
The course will provide an overview of the basic concepts and stochastic models that are commonly used to model geostatistical data sets. In addition, the participants will learn a number of geostatistical techniques and acquire some familiarity with software that is useful for analysing spatial data.

Content
After an introductory discussion of the types of problems and the kind of data that arise in environmental research, an introduction into linear geostatistics (models: stationary random processes, modelling large-scale spatial patterns by regression, modelling autocorrelation by variogram; kriging: mean-square prediction of spatial data) will be taught. The lectures will be complemented by data analyses that the participants have to do themselves.

Lecture notes
Slides, descriptions of the problems for the data analyses and worked-out solutions to them will be provided.

Literature
### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### CAS in Applied Statistics - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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<tbody>
<tr>
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### Key for Hours

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<td>revision course / private study</td>
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### ECTS

- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
### Module

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<tr>
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<td>265-0100-00L</td>
<td>Foundations of Programming</td>
<td>O</td>
<td>2</td>
<td>2A</td>
<td>L. E. Fässler</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>The initial module offers a practical introduction to some basic concepts and techniques for information processing as well as practical applications of them. The programming language are Python and SQL.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Participants learn...</td>
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<tr>
<td></td>
<td>- how to encode a problem into a program, test the program, and correct errors.</td>
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<td></td>
<td>- to understand and improve existing code.</td>
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<td>- deal with the complexity of real data.</td>
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<td>- store data in a suitable data structure.</td>
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<td></td>
<td>- query databases and understand and evaluate the corresponding database model.</td>
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<tr>
<td><strong>Content</strong></td>
<td>The following programming concepts are introduced during this module:</td>
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<td>1. Variables, data types</td>
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<td>2. Condition check, loops, logics</td>
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<td>3. Sequential data types</td>
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<td></td>
<td>4. Functions and Modules</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>No prior knowledge is required for this course. It is based on application-oriented learning. The students spend most of their time working through programming projects and discussing their results with teaching assistants. To learn the programming basics there are electronic tutorials available.</td>
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<thead>
<tr>
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<th>Concepts and Theories</th>
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<table>
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<tr>
<th>265-0101-00L</th>
<th>Data Science: From Analytics to Learning</th>
<th>O</th>
<th>4</th>
<th>3V</th>
<th>O. Akkus Ispir, E. Konukoglu</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>In this module, basic paradigms and techniques in working with data will be discussed, especially towards data security, managing data decentrally, and learning from data.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Participants will understand some of the concepts in detail and see the mathematics behind them.</td>
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<tr>
<td><strong>Content</strong></td>
<td>The module in particular covers cryptography and digital signatures, networking and distributed algorithms, distributed ledger technology, as well as machine learning (supervised and unsupervised learning). For each topic, there will be a hands-on and in-depth introduction that allows participants to gain a technical understanding of key ideas. This is supported by simple and concrete examples as well as programming assignments.</td>
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<tr>
<th>265-0102-00L</th>
<th>Computer Vision Basics</th>
<th>O</th>
<th>2</th>
<th>2V</th>
<th>E. Konukoglu</th>
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<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This module will cover basic theoretical knowledge on visual recognition systems of the last two decades, mostly focusing on the most recent advancements in deep learning and convolutional neural networks.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Participants understand basic concepts of visual recognition and human-computer interaction systems.</td>
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<tr>
<td><strong>Content</strong></td>
<td>The content starts with an introduction to neural networks and then focuses on how they are used for computer vision tasks. The theoretical knowledge will be supported with a practical session that will allow participants to gain hands-on experience with most commonly used tools and deepen their understanding of the key concepts with examples.</td>
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| 265-0104-00L | Reinforcement Learning Basics | O    | 2    | 2V    | B. Grewe |

| 265-0105-00L | Ethics, Leadership & Communication in Data-Science | O    | 2    | 2V    | O. Akkus Ispir |

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<thead>
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**ECTS** European Credit Transfer and Accumulation System
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In this module, participants will understand the diverse aspects of these phases and the impact on the organization and governance. The inner working of the R&D organization by exploring roles and processes is investigated.

The module will be based on a self-study Polybook.

### Course Details

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<th>Lecturers</th>
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<tr>
<td>247-0200-00L</td>
<td>Fundamentals of R&amp;D and Innovation</td>
<td>O</td>
<td>4</td>
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<td>U. Grossner, C. Ganz</td>
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<tr>
<td>Abstract</td>
<td>This course provides an introduction to research &amp; development, both as a general activity and as a dedicated function within a corporation. Participants will learn how to organize, conduct and manage individual R&amp;D projects as well as groups of projects. Special emphasis will be given to scientific and technical reporting.</td>
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<tr>
<td>Objective</td>
<td>The course provides the framework of organization, managing and reporting of R&amp;D projects and innovation initiatives.</td>
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<td>Lecture notes</td>
<td>The module will be based on a self-study Polybook.</td>
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<td>247-0201-00L</td>
<td>Innovation – What Is and to What Purpose Do We Need It?</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>U. Grossner, C. Ganz</td>
</tr>
<tr>
<td>Abstract</td>
<td>Innovation is more than a good idea; it involves bringing the idea to the market, resulting in a highly differentiating market position. Not only product, also ideas have a lifecycle, from conception through launch, scaling, maintenance, to phase out, and replacement by a new innovation. Each phase is facing particular challenges that will be explored.</td>
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<td>Objective</td>
<td>In this module, participants will understand the diverse aspects of these phases and the impact on the organization and governance.</td>
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<td>R&amp;D: The Engine of Innovation</td>
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<tr>
<td>Abstract</td>
<td>The inner working of the R&amp;D organization by exploring roles and processes is investigated.</td>
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<tr>
<td>Objective</td>
<td>The aim of this course is to develop the participants’ ability to articulate a coherent plan for R&amp;D activities linked to the business needs of a corporation, and to set the environment to enable an efficient R&amp;D organization.</td>
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<tr>
<td>Content</td>
<td>In most organizations, the R&amp;D organization is the one that delivers the innovation to be brought to the market. In this module, we investigate the inner working of the R&amp;D organization by exploring roles and processes. Since R&amp;D almost always starts with significant uncertainties and unsolved technical problems, governing R&amp;D has to account for these unknowns. As R&amp;D processes take time in which the market environment may change in ways other than predicted at the beginning of a project, external influences have to be continuously monitored as well to enable market success.</td>
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<td>247-0203-00L</td>
<td>The Innovation Ecosystem</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>U. Grossner, C. Ganz</td>
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<tr>
<td>Abstract</td>
<td>This module wraps up the various aspects of innovation beyond the own organization.</td>
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<tr>
<td>Objective</td>
<td>The goal of this module is to complete the R&amp;D and innovation framework and make the key points available in the context of the organizations’ environment.</td>
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<tr>
<td>Content</td>
<td>Successful innovation builds on a whole ecosystem of contributors: customer co-creation, university collaboration, strategic partnerships, or start-up investments are just a few examples of activities where other players may expedite the innovation process. Other aspects of the environment of innovation covers intellectual property strategy, or standardization and certification. In addition to successfully operating in the existing business ecosystem, innovation may transform it, or even create new ecosystems, with innovative business models.</td>
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# CAS in Applied Technology: R&D and Innovation - Key for Type

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**ECTS**  
European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
### Modules

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>268-0101-00L</td>
<td>Introduction to Information Security</td>
<td>O</td>
<td>5 credits</td>
<td>4G</td>
<td>P. Schaller, S. Matetic</td>
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</table>

**Abstract**
In this course, the goal is to introduce the fundamentals of information/cyber security from a technical point of view. Along with theory, hands-on experiments are an important building block of the course and help to deepen the students' understanding of the theory parts.

**Objective**
Graduates of the course know the technical foundations of information security and understand the difficulty and complexity involved when trying to build secure systems.

**Content**
In this new course, the goal is to introduce the fundamentals of information/cyber security from a technical point of view. Along with theory, hands-on experiments are an important building block of the course and help to deepen the students' understanding of the theory parts.

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: fostered
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: fostered

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<tr>
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<th>Lecturers</th>
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</table>

**Abstract**
Participants of the seminar are assigned a recent topic in cyber security. They are expected to become acquainted with the assigned issue and to prepare a corresponding presentation in the context of the seminar.

**Objective**
Participants have understood and presented a publication or report on a present topic in information security. By attending other participants presentations students get further introduced to additional current information security related topics/incidents.

**Content**
Participants of the seminar are assigned a recent topic in cyber security. They are expected to become acquainted with the assigned issue and to prepare a corresponding presentation in the context of the seminar.

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>268-0202-00L</td>
<td>Contemporary Topics in Cyber Security</td>
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</table>

**Abstract**
This course is composed of various sub-modules related to Cyber Security taught by experts on the relevant fields.

**Objective**
Students are expected to see behind the curtain of current research and engineering activities related to Cyber Security. At the same time students are introduced to contemporary challenges in cyber security by renowned experts.

**Content**
The lectures cover contemporary aspects and challenges in Cyber Security. The goal is to present current fields of research/engineering and the latest results. By way of example, Cyber Security Policy is one of sub-modules presented by researchers of the Center for Security Studies at ETH. Besides faculty members of the computer science department, there will be guest lecturers from industry presenting Cyber Security related challenges in their field of activity.

**Literature**
Will be announced during the course.

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**CAS in Cyber Security - Key for Type**

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
<th>Notes</th>
</tr>
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<tbody>
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**Key for Hours**

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### CAS in Data and Machine Learning

#### Modules

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<th>Lecturers</th>
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<tr>
<td>275-0001-00L</td>
<td>Introduction to Programming</td>
<td>O</td>
<td>3 credits</td>
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<td>L. E. Fässler</td>
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</table>

**Abstract**

This module offers a practical introduction to some basic concepts and techniques for information processing and their practical applications. The programming languages are Python and SQL.

**Objective**

- how to encode a problem into a program, test the program, and correct errors.
- to understand and improve existing code.
- deal with the complexity of real data.
- store data in a suitable data structure.
- query databases and understand and evaluate the corresponding database model.
- to implement mathematical models as a simulation.

**Content**

The following programming concepts are introduced during this module:

1. Variables, data types
2. Condition check, loops, logics
3. Sequential data types
4. Functions and Modules
5. Data management (SQL)

In the practical part of the course, students work on small programming projects with a context from natural sciences. Electronic tutorials are available as preparation.

**Prerequisites / notice**

No prior knowledge is required for this course. It is based on application-oriented learning. The students spend most of their time working through programming projects and discussing their results with teaching assistants. To learn the programming basics there are electronic tutorials available.

**Competencies**

### Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed

### Method-specific Competencies

- Analytical Competencies assessed
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

### Social Competencies

Communication assessed

### Personal Competencies

- Adaptability and Flexibility fostered
- Creative Thinking assessed
- Critical Thinking assessed
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

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<td>Information, Data &amp; Computers</td>
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<tr>
<td>275-0003-00L</td>
<td>Data Science &amp; Machine Learning</td>
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<td>4 credits</td>
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</table>

**Abstract**

This course provides a fundamental training in the areas of data science and machine learning. It is intended for managers and leaders who want to understand the typical workflow, fundamental techniques and key challenges of data science and machine learning to drive successful implementations.

**Objective**

- have a good understanding of the basic methods of data science and machine learning
- know the typical data science workflow and can understand and assess the role and importance of each individual step
- understand the importance of quantifying and communicating uncertainty in the data
- know the importance and basic techniques of cleaning and organizing data and can perform simple data cleaning tasks in pandas.
- can identify suitable algorithms and select the best-suited one for a given task
- can apply machine learning methods as implemented in scikit-learn on tabular data
- understand the basic ideas behind modern deep learning methods and can implement simple deep learning models in tensorflow
- understand some key applications such as natural language processing or computer vision.
- are able to apply the learned methods to practical problems in data science.

**Content**

We will cover the following topics:

- The typical data science workflow
- Cleaning, organizing and preparing data for further analysis
- Exploratory data analysis: Gaining an understanding through visualizing and summarizing data
- Basics of statistical inference and uncertainty quantification
- Correlations and regression.
- Basics of Machine learning, including supervised and unsupervised learning, model evaluation and model selection
- Standard algorithms such as linear regression, decision trees, k-nearest neighbors, k-means, principal component analysis
- Identification of the best-suited algorithm and models for a given dataset and machine learning task
- Foundations of Deep Learning
- Challenges & Considerations: Potential pitfalls, threats, and ethical considerations.

The theoretical parts will be complemented by practical exercises using python, pandas, numpy, matplotlib, scikit-learn, and tensorflow.
Participants learn how new information technologies such as machine learning and AI change different aspects of a business, and learn how to evaluate specific risks, costs, and benefits of new technologies. It addresses success factors and pitfalls for technology initiatives, and equips participants to contribute to technology-related decisions.

Participants understand how technology impacts business strategy. They are able to assess benefits, costs, and risks of new technology use, and to contribute to decisions balancing these aspects. They understand the long-term impact of today's technology decisions and can use it to help companies make better technology investment decisions.

Participants are able to confidently participate in discussions with technical experts and to ensure technology is evaluated from the perspective of the commissioning business.

Participants understand how AI projects differ from traditional IT projects. They are able to shape respective projects in their companies and to help make them successful.

This integration module links the newly acquired understanding of technology with technology's impact on business strategy. Participants will explore how new information technologies such as machine learning and AI change different aspects of a business, and learn how to evaluate specific risks, costs, and benefits of new technologies. The module will shed light on success factors and common pitfalls when implementing new technologies and respective business changes, and it will specifically address the communication between technical experts and business management. The module provides insights into how participants can contribute to technology-related decisions and help shape the use of IT for business benefit. It teaches concepts regarding IT cost, IT risk, IT complexity, and IT lifecycle management, software architecture and project methodologies, including how machine-learning projects differ from traditional IT projects, and applies them to a number of current business/IT topics such as cloud computing, use of AI for software development, and Internet of Things.

<table>
<thead>
<tr>
<th>Course Code</th>
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<th>Lectures</th>
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<tbody>
<tr>
<td>275-0004-00L</td>
<td>AI and IT in Industry</td>
<td>3</td>
<td>2</td>
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</tbody>
</table>

Key for Hours

- V: lecture
- G: lecture with exercise
- U: exercise
- S: seminar
- K: colloquium
- P: practical/laboratory course
- A: independent project
- D: diploma thesis
- R: revision course / private study

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Special students and auditors need special permission from the lecturers.
The widespread use of mobile technologies (e.g., wearable sensors, mobile applications, social media, and location-tracking technologies) can meet the health monitoring needs of the world's aging population and the ever-growing number of chronic patients. However, this premise is based on applying information and communication technologies that allow us to monitor patient data in many different ways. In this course, we will analyze systematic ways to collect data, review the most appropriate methods and applications in healthcare, discuss the main challenges, and apply the newly gained knowledge in a project.

The course has four learning objectives, i.e., to

1. understand the concept of digital biomarkers in general
2. understand the various application areas of digital biomarkers
3. to critically reflect and assess existing digital biomarkers
4. to understand how to design a digital biomarker

The course will cover the following topics:

1. Introduction to digital biomarkers
2. Design of digital biomarker studies
3. Exploration and assessment of digital biomarker candidates
4. Digital biomarker project and critical reflection

Prerequisites / notice

This module is assessed based on the participant’s pass/fail status of the group project (including a presentation). The group project is ungraded.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<td>Analytical Competencies</td>
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<td>Adaptability and Flexibility</td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
<td>Leadership and Responsibility</td>
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<td>Project Management</td>
<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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Methods

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<tr>
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<th>Type</th>
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<td>375-0003-00L</td>
<td>Designing a Digital Biomarker (Group Project 2)</td>
<td>O</td>
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<td>M. Jovanova, T. Kowatsch</td>
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<td>375-0004-00L</td>
<td>Designing a Just-in-time Adaptive Intervention (Group Project 3)</td>
<td>O</td>
<td>4 credits</td>
<td>2G</td>
<td>M. K. Nißen, T. Kowatsch</td>
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</table>

Abstract

Today, we face the challenge of chronic conditions. Personal coaching approaches are neither scalable nor financially sustainable. The question arises therefore to which degree Digital Health Interventions (DHIs) are appropriate to address this challenge. In this CAS module, students will design, implement and evaluate a DHI, esp. a just-in-time adaptive intervention.
After this module, participants will be able to…

1. understand the importance of just-in-time adaptive interventions (JITAIs), esp. for the prevention of NCDs
2. understand the design, implementation and evaluation of smartphone-based and chatbot-delivered JITAIs
3. discuss opportunities and challenges of JITAIs

What are the implications and rationale behind the recent developments in the field of digital health?

Digital Health is the use of information and communication technology for the prevention and treatment of diseases in the everyday life of individuals. It is thus linked to topics such as digital health interventions, digital biomarkers, digital coaches and healthcare chatbots, telemedicine, mobile and wearable computing, self-tracking, personalized medicine, connected health, smart homes, or smart cars.

In the 20th century, healthcare systems specialized in acute care. In the 21st century, we now face the challenge of dealing with the specific characteristics of non-communicable diseases (NCDs). NCDs are now responsible for around 70% of all deaths worldwide and 85% of all deaths in Europe and are associated with an estimated economic loss of $7 trillion between 2011 and 2025. NCDs are characterized in particular by the fact that they require an intervention paradigm that focuses on prevention and lifestyle change. Lifestyle (e.g., diet, physical activity, tobacco, or alcohol consumption) can reduce the risk of suffering from a chronic condition or, if already present, can reduce its burden. A corresponding change in lifestyle is, however, only implemented by a fraction of those affected, partly because of missing or inadequate interventions or health literacy, partly due to socio-cultural influences. Individual personal coaching of these individuals is neither scalable nor financially sustainable.

To this end, the question arises on how to develop evidence-based digital health interventions (DHIs) that allow medical doctors and other caregivers to scale and tailor long-term treatments to individuals in need at sustainable costs. At the intersection of health economics, behavioral medicine, information systems research, and computer science, this CAS module has the objective to help participants interested in the multi-disciplinary field of digital health to better understand the need, design, implementation, and assessment of DHIs, esp. just-in-time adaptive interventions (JITAIs).

After this module, participants will be able to…

1. understand the importance of JITAIs, esp. for the prevention of NCDs
2. understand the design, implementation and evaluation of smartphone-based and chatbot-delivered JITAIs
3. discuss opportunities and challenges of JITAIs

The CAS module is structured in two parts and follows the concept of a blended treatment consisting of live sessions and complementary online material. In the live sessions, participants will learn relevant topics. Complementary learning material (e.g., video clips), multiple-choice questions, and exercises are provided via the online learning platform.

In the second part, participants work in teams and will use their knowledge from the first part of the module to develop a smartphone-based and chatbot-delivered JITAI with MobileCoach (www.mobile-coach.eu), an open-source software platform for the development of digital biomarker and digital health interventions. Each team will then present and discuss the resulting JITAI and evaluation results with their colleagues who will provide peer reviews. Additional live coaching sessions are offered to support the teams with the design and evaluation of their JITAI, and with the preparation of the final group project presentations.

**Literature**

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories assessed
- Techniques and Technologies assessed

**Method-specific Competencies**
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management assessed

**Social Competencies**
- Communication assessed
- Cooperation and Teamwork assessed
- Customer Orientation assessed
- Leadership and Responsibility assessed
- Self-presentation and Social Influence assessed
- Sensitivity to Diversity assessed
- Negotiation assessed

**Personal Competencies**
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

**CAS in Digital Health - Key for Type**

<table>
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<th>Code</th>
<th>Description</th>
<th>Suitable for Doctorate</th>
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**Key for Hours**

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## CAS in Digital Clinical Trials

### Modules

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<th>Number</th>
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<tr>
<td>395-0100-01L</td>
<td>The Power of Study Design</td>
<td>O</td>
<td>3</td>
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<td>S. Goldhahn, A. Burden, D. Stekhoven, to be announced</td>
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<tr>
<td>395-0103-00L</td>
<td>Precision Medicine and AI</td>
<td>O</td>
<td>2</td>
<td>3G</td>
<td>A. Fontecedro-Curioni, A. Ghosh, S. Modica</td>
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</table>

**Abstract**

Precision Medicine is a new approach in health care aiming to deliver personalized prevention and treatment for human diseases, by taking into account individual differences in lifestyle, environment, and biology.

**Objective**

After taking this course, participants will be able
- to describe the goal of precision medicine;
- to explain different next-generation sequencing technologies;
- to illustrate how to make good use of public biological/clinical repositories;
- to demonstrate basic concepts of big data and machine learning;
- to explain how to genotype biological samples for a genetic disease;
- to describe examples of complicated ethical or clinical situations in personalized medicine.

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<td>Digital Measures</td>
<td>O</td>
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<td>J. Goldhahn, I. Clay</td>
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**Abstract**

Participants will learn all necessary steps to establish new digital measures for their own clinical research. They will get a comprehensive understanding of this new emerging field, will discuss the newest guidelines with authors from international societies, will have a chance to interact with digital pioneers, and will be enabled to develop a concept for their individual digital measure.

**Objective**

The course enables participants to...

1. describe why new methods are needed to generate evidence.
2. describe how new (digital) methods for generating evidence are established.
3. explain how the concept of patient-centredness is applied in the development of new methods for evidence generation.
4. analyse sources of bias in basic research.
5. analyse the conditions for the development and validation of new evidence generation tools.
6. understand the framework for the development of new methods for evidence generation and to analyse the advantages and disadvantages of different approaches.
7. develop their own concept for a new digital measure.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management

- **Method-specific Competencies**
  - Communication
  - Cooperation and Teamwork

- **Social Competencies**
  - Creative Thinking
  - Critical Thinking

**CAS in Digital Clinical Trials - Key for Type**

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European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
This module focuses on the development needs of participants' business skills and competencies. In this module, experienced business coaches and mentors will interact regularly with participants, offer guidance on how to strategize and implement business cases. They will give feedback on challenges and activities and help participants strengthen their abilities to garner needed resources for their undertakings.

Objective
This module enables participants:
- To identify key unknowns and important progress measures for their respective business case and implement effective means and tools to further develop their business case
- To understand the view of potential customers and implement their feedback to improve the business case
- To effectively communicate and enroll other important venture constituents (mentors, advisors, employees, investors, etc.) in the venture.

Content
This module focuses on the development needs of participants' business skills and competencies. In this module, experienced business coaches and startup mentors will interact regularly with the participants, offer guidance on how to strategize and implement compelling business cases, feedback on specific challenges, and participants' activities with the goal to strengthen the ability of the participant to garner needed resources for their undertakings.

Lecture notes
See Online Platform

Literature
See Online Platform

Prerequisites / notice
This module is only for CAS ELTV participants.
Abstract
This module focuses on the development needs for participants' leadership competencies. In this module, experienced leadership coaches will interact regularly with the participants, coach along a personal development plan, and feedback on specific challenges and participants' activities with the goal to strengthen the participants' leader capability and people skills.

Objective
This module enables participants:
- To identify current gaps in the personal management skills and competencies and develop meaningful goals and plans to fill those gaps
- To implement effective exercises and practices to improve the participants' leadership capacity
- To effectively communicate and manage key constituents, notably employees and key advisors in a venture project.

Content
This module focuses on the development needs of participants' leadership competencies. In this module, experienced leadership coaches will interact regularly with the participants, coach them along a personal development plan, and feedback participants on specific challenges and activities with the goal to strengthen the participants' leadership capability and people skills.

Lecture notes
See Online Platform

Literature
See Online Platform

Prerequisites / notice
This module is only for CAS ELTV participants.

CAS in Entrepreneurial Leadership in Technology Ventures - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
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<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
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Key for Hours

| V  | lecture                          | P   | practical/laboratory course          |
| G  | lecture with exercise            | A   | independent project                  |
| U  | exercise                         | D   | diploma thesis                       |
| S  | seminar                          | R   | revision course / private study       |
| K  | colloquium                       |     |                                      |

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### CAS in Global Cooperation and Sustainable Development

Take place each spring semester and every second autumn semester (odd years).

#### Module

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<td>W</td>
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<td>ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.</td>
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<td>Registration only through the NADEL administration office.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>The course aims at strengthening the capacity in portfolio management for VET, skills development and active labor market policies. It deals with basic issues and challenges of Vocational Education and Training (VET) in Developing Countries. In view of the many of school leavers VET has to place itself between the contradicting intentions of quality education and short-term training interventions.</td>
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<tr>
<td>Objective</td>
<td>The participants are able to</td>
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<tr>
<td></td>
<td>- Assess project proposals and ongoing project regarding their relevance and suitability in the specific country context</td>
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<tr>
<td></td>
<td>- Explain strengths and weaknesses of the opposing approaches &quot;dual apprenticeship&quot; and &quot;competency based training&quot; as well as synergies and incompatibilities between the two</td>
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<td></td>
<td>- Describe the competent use of tools currently applied in VET</td>
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</tr>
<tr>
<td>Content</td>
<td>• Basic concepts and terms</td>
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</tr>
<tr>
<td></td>
<td>• Differences and commonalities between VET and neighboring systems</td>
<td></td>
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<tr>
<td></td>
<td>• Planning, assessment of VET interventions with different objectives: economic development, poverty alleviation, creation of self-employment or systems development</td>
<td></td>
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<tr>
<td></td>
<td>• VET as a cooperation system of stakeholders with different duties, interests and competencies</td>
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<tr>
<td></td>
<td>• Background, potential use and limitations of (national) qualification frameworks</td>
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<tr>
<td></td>
<td>• Half-day visit to important actors of the Swiss VET landscape</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Students of the course must fulfill requirements specified on the homepage of NADEL.</td>
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<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decision-making</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Problem-solving</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Project Management</td>
<td>fostered</td>
</tr>
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<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
<td></td>
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<tr>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
<td></td>
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<tr>
<td></td>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Negotiation</td>
<td>fostered</td>
<td></td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
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</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
<td></td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
<td></td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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</table>

<table>
<thead>
<tr>
<th>865-0000-01L</th>
<th>Planning and Monitoring of Projects</th>
<th>O</th>
<th>2 credits</th>
<th>3G</th>
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<td></td>
<td>Does not take place this semester.</td>
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<tr>
<td></td>
<td>Only for CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.</td>
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<tr>
<td></td>
<td>ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>The course provides a deeper understanding of the methodological foundations of results-oriented planning and steering of development projects. Together with the participants, we reflect on the situation-specific application of instruments for project planning and the development of a monitoring system, which makes it possible to adapt and steer projects.</td>
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<tr>
<td>Objective</td>
<td>The course participants are able to describe the processes and concepts of project planning and monitoring using the correct technical terminology, to initiate an analysis of the initial situation, to elaborate a monitoring system, and to adaptively steer the implementation of projects.</td>
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<tr>
<td>Content</td>
<td>- Basic concepts of result-oriented project management</td>
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<td></td>
<td>- Instruments and resources for project planning, including the elaboration of a &quot;logframe matrix&quot; and results chain</td>
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<td></td>
<td>- 24 months of resources for project monitoring, and for the development of a monitoring system, including indicators to assess objectives achievement and steer the Project</td>
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<tr>
<td></td>
<td>- 'Write' and structure results-oriented Project reports</td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>Students of the course must fulfill requirements specified on the homepage of NADEL.</td>
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<table>
<thead>
<tr>
<th>865-0024-00L</th>
<th>The SDGs in an Urbanising World</th>
<th>W</th>
<th>1 credit</th>
<th>2G</th>
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<tbody>
<tr>
<td></td>
<td>Does not take place this semester.</td>
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<td></td>
<td></td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>Registration only through the NADEL administration office.</td>
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</tbody>
</table>
This course draws out good practices in promoting sustainability development at the city and local level. Participants gain insights on designing urban-focused development interventions.

### Abstract

Historically, cities have been hubs of innovation, economic activity and rising prosperity. However, the unprecedented speed and scale at which cities are growing today is a huge challenge. As epicenters of migration, environmental degradation, health hazards and unemployment, urban areas are especially vulnerable to disasters, social conflict and inequality. Despite this, some of the most promising initiatives to achieve the SDGs have been implemented by cities. What strategies and processes do successful city-based initiatives pursue? How can development organisations support mainstreaming the SDGs at the local level? What can be learnt from experiences so far? This course draws out good practices in promoting sustainability and equity at the city and local level. Participants gain insights on designing urban-focused development interventions.

### Prerequisites / Notice

Students of the course must fulfill requirements specified on the homepage of NADEL. Electronic registration may be done only after registration with the NADEL secretariat.

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Analytical Competencies</th>
<th>Critical Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Personal Competencies</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Registration

Registration only through the NADEL administration office.

### Prerequisites / Notice

Students of the course must fulfill requirements specified on the homepage of NADEL. Electronic registration may be done only after registration with the NADEL secretariat.

### Competencies

- **Qualitative and Participatory Research Methods for Development Practitioners**
  - Does not take place this semester.
  - Only for MAS/CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.

### Prerequisites / Notice

Targeting students doing a CAS in Development and Cooperation.

### Registration

Registration only through the NADEL administration office.

### Prerequisites / Notice

Students of the course must fulfill requirements specified on the homepage of NADEL. Electronic registration may be done only after registration with the NADEL secretariat.

### Competencies

- **Migration and Development**
  - Does not take place this semester.
  - Only for MAS/CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.
24 months of practical experience in international cooperation.

ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

ETH MA/MSc students apply with a letter of motivation to the NADEL administration office.

Registration only through the NADEL administration office.

Abstract
Globally, over 280 million people live outside their countries of origin. While the concept of migration has negative connotations for some, migration can bring significant benefits — to both countries of origin and destination, if the right policies and initiatives are in place. The course explores the role that international cooperation can play in promoting the positive aspects of migration.

Objective
Course participants have improved understanding of the following issues:
- Definition of migration concepts and terms
- International legal frameworks related to migration
- The geography of migration flows
- Major drivers of migration
- The evolving concept of "migration and development"
- International cooperation organisations and their strategies and activities in terms of migration and development.

Content
Globally, over 280 million people are currently living outside their countries of origin, voluntarily and involuntarily; and a further 60 million people live in internal displacement settings within their countries of origin. Migration is multifaceted, and driven by various, often interlinked factors including conflict and violence, economic, social and political factors, as well as environmental and climate related events. While the concept of migration has negative connotations for some, migration can bring significant benefits — to both countries of origin and destination, if the right policies and initiatives are in place.

The course explores the role that international cooperation can play in promoting the positive aspects of migration and in reducing the potential negative consequences.

This course covers:
- Important terms and concepts related to migration;
- International legal frameworks related to migration;
- The geography of migration flows;
- Major drivers of migration;
- The evolving concept of migration and development;
- Actions, strategies and initiatives of international cooperation actors when it comes to migration and development.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Methods-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<td>Concepts and Theories</td>
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<td>Cooperation and Teamwork</td>
<td>Critical Thinking</td>
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<td>assessed</td>
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</table>

865-0020-00L Social Entrepreneurship – Driving Sustainability in Business

Does not take place this semester.

Only for MAS/CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.

ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

Registration only through the NADEL administration office.

Abstract
This course introduces the concept of social entrepreneurship, understanding in which situations and under which conditions the concept can be applied, and the basics of developing a business strategy for a social enterprise.

Objective
This course introduces the concept of social entrepreneurship over three different blocks. The first part is dedicated to the definition, history, context and the successes and blockers of social entrepreneurship, including some real-world examples. In the second part the participants will learn to transform a social business idea into a concrete social business plan. The last block of the course is dedicated to the power of storytelling, where participants learn how to pitch their business ideas convincingly.

Content
- Definitions of "social entrepreneurship" and the difference with "entrepreneurship"
- Get inspired by concrete examples of successful social ventures
- Formulate a social business plan using the business canvas methodology
- Learning to think and act like a social entrepreneur
- The art and power of storytelling in an entrepreneurial context

Competencies

<table>
<thead>
<tr>
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<th>Methods-specific Competencies</th>
<th>Social Competencies</th>
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<td>Analytical Competencies</td>
<td>Cooperation and Teamwork</td>
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<td>assessed</td>
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</table>

865-0059-00L Storytelling for Systems Change

Only for CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.

ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

Registration only through the NADEL administration office.
Abstract

This course provides a foundation in the principles, techniques, and strategies for storytelling in the context of systems change. Key topics include:

- Psychology of Stories
- Key Elements and Techniques of Storytelling
- Ethics & Authenticity
- Using Stories in Project Cycle Management

Objective

By the end of this course, participants will be able to apply and adapt the fundamentals of storytelling to support their work as development practitioners and as proponents of systems change. They will be able to integrate storytelling techniques into activities such as reporting, fundraising, and context analysis. They will be better equipped to construct stories that are engaging and illustrative of the complexity of systems change.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<td>Concepts and Theories</td>
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<td>Self-presentation and Social Influence</td>
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<td>fostered</td>
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<tr>
<td>Creative Thinking</td>
<td>Critical Thinking</td>
<td>Integrity and Work Ethics</td>
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<tr>
<td>assessed</td>
<td>assessed</td>
<td>fostered</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
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<td>fostered</td>
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</table>

865-0049-00L AI for Global Development Organisations

Only for CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.

ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

Registration only through the NADEL administration office.

865-0012-00L Gender and Economics

Only for MAS/CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.

ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

ETH MA/MSc students apply with a letter of motivation to the NADEL administration office.

Abstract

This course on gender and economics is intended to provide basic- and intermediate-level training to development practitioners and policy and program staff in international development agencies. The overall objective of the course is to strengthen the capacity of technical advisors and program staff on the importance of gender-responsive economic policy. The course conveys basic knowledge about gender aspects in economics. Key elements are:

- Feminist approaches to macroeconomics, microeconomics and international economics
- Critical analysis of global and regional economic trends, including those related to economic crises
- Gender-responsive economic policy for program implementation, policymaking, and advocacy

Content

Economic inequalities between men and women persist in many countries. For example, in many countries, men earn more money and are more likely to own land and control productive assets than women. This course on gender and economics is intended to provide basic- and intermediate-level training to development practitioners and policy and program staff in international development agencies. The overall objective of the course is to strengthen the capacity of technical advisors and program staff on the importance of gender-responsive economic policy. The course is taught in cooperation with SDC and UN women.

CAS in Global Cooperation and Sustainable Development - Key for Type

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>O</th>
<th>W+</th>
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<tbody>
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<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</table>

Key for Hours

| V | lecture |
| G | lecture with exercise |
| U | exercise |
| S | seminar |
| K | colloquium |
| P | practical/laboratory course |
| A | independent project |
| D | diploma thesis |
| R | revision course / private study |

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Adaptability and Flexibility

The past two decades witnessed significant advances in the areas of computational design and digital fabrication in architecture. These developments have fostered a new type of architectural thinking, which is characterized by flexibility, adaptability, and the ability to respond to changing conditions and user needs. Through various exercises, participants will learn to critically question current approaches to existing buildings, which are all too often characterized by rigid and inflexible designs.

The students of this seminar will gain insight into different evaluation criteria and value systems within the larger field of preservation. The past two decades have seen a shift in the way we think about historic buildings and sites. While buildings protected as monuments are widely recognized as cultural heritage, the large building stock of the second half of the 20th century is often considered unattractive and its maintenance or upgrading a costly imposition. However, it is precisely this stock that holds great potential, as it generally allows more possibilities for use and change than protected objects. In case of demolition, individual components of these buildings can possibly be reused.

The discussion about values, protection and preservation of the existing building stock is complex and must be conducted on different levels. In addition to classic protection criteria, ecological and economic considerations, too, must be taken into account.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Content</th>
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<tbody>
<tr>
<td>Social Competencies</td>
<td>Negotiation fostered</td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Decision-making fostered, Problem-solving fostered</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication fostered</td>
</tr>
<tr>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories fostered</td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies fostered, Media and Digital Technologies fostered</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Cooperation and Teamwork fostered</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility fostered, Creative Thinking fostered</td>
</tr>
</tbody>
</table>

Digital Heritage

This course focuses on recent constructions built using innovative computational design and fabrication technologies, and the challenges associated with their repair, maintenance, and preservation.

With the help of input lectures and excursions in and around Zurich, participants will explore new types of materials, structural designs, construction processes and methods associated with recently completed buildings built using computational methods. They will learn to critically observe existing theories and methods of preservation and discuss in groups the relationship between today’s digitally fabricated objects and future challenges in the discipline of preservation.

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<tr>
<td>Method-specific Competencies</td>
<td>Decision-making fostered, Problem-solving fostered</td>
</tr>
<tr>
<td>Social Competencies</td>
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Preservation in Switzerland

Historic buildings and sites are not per se significant parts of cultural heritage. They only become so when certain values are associated with them. Monument values are as dynamic as the society that produces them. The lecture traces the historical development of monument recognition and preservation in Switzerland since 1798.

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<th>Competencies</th>
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<tr>
<td>Social Competencies</td>
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<td>079-0200-00L</td>
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<td>O</td>
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<tr>
<td>079-0250-00L</td>
<td>Preservation in Switzerland</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>S. Langenberg</td>
</tr>
</tbody>
</table>
Objective

Students will be able to name the most important actors in Swiss heritage conservation and describe developments in the field. They know methodological approaches and can place them in their historical context. They can identify the necessary principles and instruments in different situations and use them in their professional environment.

Content

In the 20th century, the most important impulses for the theory and practice of restoration came from the Federal Commission for the Preservation of Monuments, whose theoretical discourse and work are traced in detail. However, the activities of the cantons, private-law organisations and universities are also examined within the course. The institutionalisation of monument preservation is analysed in the context of social developments, whereby the evolution of its self-image from a patriotic civic duty in the age of industrialisation to monument preservation as environmental protection in the sustainability discourse of the 21st century is also examined. In the second half of the semester, the theoretical foundations, actors and instruments that are relevant in Switzerland today will be presented and their interaction explained.

Central questions will be examined in greater depth using concrete case studies. Among others, the following will be discussed: the restoration of Chillon Castle from 1897; the mountain village restoration of Vrin in 1944; the restoration of the Augustinian Church in Zurich in 1958; the controversy surrounding the reconstruction of the Predigerchor in Zurich in 1987; the extension of the Stadtcasino Basel (2016-2020); the struggle for the preservation of medieval wooden buildings in the canton of Schwyz (2000-2021).

Competencies

Subject-specific Competencies

Concepts and Theories

Development of the Existing Building Stock

079-0252-00L Does not take place this semester.

Abstract

The course deals with the densification strategy of the city of Zurich and the resulting handling of existing building stock (mostly demolition and new construction). Insights into real estate evaluation and specific examples are used to show possible alternatives.

Objective

The course discusses the topic of densification and the future of the existing building stock. By dealing with the qualities of existing buildings within the areas to be densified, students are invited to discuss whether these objects are to be preserved, transformed, and supplemented or whether they have to be demolished.

Content

The city of Zurich introduced the densification strategy in the revised spatial planning law, focusing on the existing building stock. As a rule, densification is achieved today through demolitions and replacement. This includes buildings which are still in a good condition. The course thus aims to explore possible alternatives.

Brief general introduction to the real estate market and real estate valuation; introduction to the topic of "densification", well and badly realised examples; discussion of current densification projects and alternative solutions within the framework of two to three workshops.

Competencies

Subject-specific Competencies

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Brief general introduction to the real estate market and real estate valuation; introduction to the topic of "densification", well and badly realised examples; discussion of current densification projects and alternative solutions within the framework of two to three workshops.

Key for Hours

V lecture
G lecture with exercise
U exercise
S seminar
K colloquium
P practical/laboratory course
A independent project
D diploma thesis
R revision course / private study

ECTS European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
# Modules

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<tr>
<th>Number</th>
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<th>Hours</th>
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<tr>
<td>148-0001-00L</td>
<td>GIS-basics and -principles</td>
<td>O</td>
<td>3 credits</td>
<td>4G</td>
<td>L. Hurni, M. Raubal</td>
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**Abstract**
A Geographic Information System (GIS) is a system for collecting, managing, analyzing and visualizing spatial data (geodata). This module teaches the fundamental concepts and principles necessary for a comprehensive understanding and effective application of GIS technologies.

**Objective**
After completion of this module, students will be able to understand the fundamentals of Geographic Information Systems (GIS) and be able to retrieve and apply them appropriately in practice. They will be able to describe and apply the essential components and principles of GIS.

**Competencies**

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<td>O</td>
<td>4 credits</td>
<td>7G</td>
<td>L. Hurni, M. Raubal</td>
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</table>

**Abstract**
GIS methods and processes represent the basic strategies and processing steps used within a GIS workflow to model, capture, manage, analyze, and visualize geodata. The GIS workflow is a systematic approach that ensures that geospatial data is used effectively to solve problems in various application domains.

**Objective**
The aim of this module is to provide students with a comprehensive understanding and diverse skills in the use of GIS methods and processes. The entire sequence of geodata processing from acquisition to application is to be covered. The goal is to provide students with a structured and systematic approach to effectively process and use geospatial data in a meaningful way.

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**Project**

*Offered in the spring semester*

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**CAS in Geoinformation Systems and Analysis - Key for Type**

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<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
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<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
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**Key for Hours**

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<tr>
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<th>lecture</th>
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<td>diploma thesis</td>
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<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
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<td>K</td>
<td>colloquium</td>
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**ECTS**
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Wireless Networking and Mobile Computing

252-0237-00L

Concepts of Object-Oriented Programming

- **Type**: W
- **ECTS**: 8 credits
- **Hours**: 3V+2U+2A
- **Lecturers**: P. Müller

**Abstract**

A course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object, and class initialization, program correctness, reflection, and the state of art for Wi-Fi 802.11, Cellular 5G, and Internet-of-Things.

**Objective**

After this course, students will:

- Have a deep understanding of advanced concepts of object-oriented programming and their support through various language features.
- Be able to understand language concepts on a semantic level and be able to compare and evaluate language designs.
- Be able to learn new languages more rapidly.
- Be aware of many subtle problems of object-oriented programming and know how to avoid them.

**Content**

The main goal of this course is to convey a deep understanding of the key concepts of sequential object-oriented programming and their support in different languages. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.

The topics discussed in the course include among others:

- The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing)
- The key problems of single and multiple inheritance and how different languages address them
- Generic type systems, in particular, Java generics, C# generics, and C++ templates
- The situations in which object-oriented programming does not provide encapsulation, and how to avoid them
- The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing
- How to maintain the consistency of data structures

**Literature**

Will be announced in the lecture.

**Prerequisites / notice**

Prerequisites:

- Mastering at least one object-oriented programming language (this course will NOT provide an introduction to object-oriented programming); programming experience

252-0293-00L

Wireless Networking and Mobile Computing

- **Type**: W
- **ECTS**: 4 credits
- **Hours**: 2V+1U
- **Lecturers**: S. Mangold

**Abstract**

This course gives an overview about wireless standards and summarizes the state of art for Wi-Fi 802.11, Cellular 5G, and Internet-of-Things, contact tracing with Bluetooth, audio communication, visible light communications, medical technology. The course combines lectures with a set of assignments in which students are asked to work with a JAVA simulation tool, and Arduino boards.

**Objective**

The objective of the course is to learn about the general principles of wireless communications, including physics, frequency spectrum regulation, and standards. Further, the most up-to-date standards and protocols used for wireless LAN IEEE 802.11, Wi-Fi, Internet-of-Things, sensor networks, cellular networks, visible light communication, and cognitive radios, are analyzed and evaluated. Students develop their own add-on mobile computing algorithms to improve the behavior of the systems, using a Java-based event-driven simulator. We also hand out embedded systems that can be used for experiments for optical communication. Throughout the course, insights from telecommunications, toy industry, and medical technology industry are shared.

**Content**

Wireless Communication, Wi-Fi, Contact Tracing, Bluetooth, Internet-of-Things, 5G, Standards, Regulation, Algorithms, Radio Spectrum, Cognitive Radio, Mesh Networks, Optical Communication, Visible Light Communication. We will address contact tracing, radio link budget, location distance measurements, and Bluetooth in more depth. MedTech basics are also provided.

Chapters:

1. Introduction
2. Wireless Communication Basics
3. IEEE 802.11 Wireless LAN (Wi-Fi)
4. IEEE 802.15 Wireless PAN (ZigBee & Bluetooth)
5. Mobile Computing Algorithm Basics: Control and Game Theory
6. Visible Light Communication
7. Audio Communication
9. Mobile Computing for Automated Medicine Delivery

**Lecture notes / Literature**

The course material will be made available by the lecturer.

1. The course webpage (look for Stefan Mangold's site)
2. The Java 802 protocol emulator "JEmula802" from https://bitbucket.org/lfield/jemula802

**Prerequisites / notice**

Students should have interest in wireless communication, and should be familiar with Java programming. Experience with GNU Octave or Matlab will help too (not required).
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252-0463-00L Security Engineering W 7 credits 2V+2U+2A D. Basin, S. Krstic

Abstract
Subject of the class are engineering techniques for developing secure systems. We examine concepts, methods and tools, applied within the different activities of the SW development process to improve security of the system. Topics: security requirements&risk analysis, system modeling&model-based development methods, implementation-level security, and evaluation criteria for secure systems.

Objective
Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software. Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems.
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Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems

Modules taught:

1. Introduction
   - Introduction of Infsec group and speakers
   - Security meets SW engineering: an introduction
   - The activities of SW engineering, and where security fits in
   - Overview of this class
2. Requirements Engineering: Security Requirements and some Analysis
   - Overview: functional and non-functional requirements
   - Use cases, misuse cases, sequence diagrams
   - Safety and security
3. Modeling in the design activities
   - Structure, behavior, and data flow
   - Class diagrams, statecharts
4. Model-driven security for access control (Part I)
   - SecureUML as a language for access control
   - Combining Design Modeling Languages with SecureUML
5. Model-driven security (Part II)
   - Continuation of above topics
6. Security patterns (design and implementation)
7. Implementation-level security
   - Buffer overflows
   - Input checking
   - Injection attacks
8. Code scanning
   - Static code analysis basics
   - Theoretical and practical challenges
   - Analysis algorithms
   - Common bug pattern search and specification
   - Dataflow analysis
9. Testing
   - Overview and basics
   - Model-based testing
   - Testing security properties
10. Risk analysis and management
    - "Risk": assets, threats, vulnerabilities, risk
    - Risk assessment: quantitative and qualitative
    - Safeguards
    - Generic risk analysis procedure
    - The OCTAVE approach
    - Example of qualitative risk assessment
11. Threat modeling
    - Overview
    - Safety engineering basics: FMEA and FTA
    - Security impact analysis in the design phase
    - Modeling security threats: attack trees
    - Examples and experience
12. Evaluation criteria
    - NIST special papers
    - ISO/IEC 27000
    - Common criteria
    - BSI baseline protection
13. Guest lecture
    - TBA

Literature

- Further relevant books and journal/conference articles will be announced in the lecture.

Prerequisites / notice

Prerequisite: Class on Information Security
Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensible to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real-world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
what is data?
Bayesian Learning
Computational learning theory

Supervised learning:
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks

Unsupervised learning:
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation
Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature

Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
252-0546-00L Physically-Based Simulation in Computer Graphics W 5 credits 2V+1U+1A S. Coros, B. Thomaszewski

Abstract
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Objective
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Content
The lecture covers topics in physically-based modeling, such as particle systems, mass-spring models, finite difference and finite element methods. These approaches are used to represent and simulate deformable objects or fluids with applications in animated movies, 3D games and medical systems. Furthermore, the lecture covers topics such as rigid body dynamics, collision detection, and character animation.

Prerequisites / notice
Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++. Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

252-1411-00L Security of Wireless Networks W 6 credits 2V+1U+2A S. Capkun, K. Kostiainen

Abstract
This course discusses physical layer aspects of wireless communication and a wide range of security-related topics in the domain of wireless technologies. It mainly targets computer science students. Though useful, a background in signal processing or physical layer concepts is not required. A basic understanding of security (e.g. as taught in 252-0211.00L Information Security) is recommended.

Objective
After this course, students should be able to describe and classify security goals of and attacks on various wireless networks and technologies, with an emphasis on physical layer aspects.

Content
- Introduction to wireless communication
- Physical layer security schemes
- Spreading techniques and their application in jamming-resistant communication and Global Navigation Satellite Systems (GNSSs)
- Secure ranging with Ultra-Wide Band (UWB)
- Security aspects of cellular networks, WiFi, and Bluetooth Low Energy (BLE)

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Social Competencies
- Cooperation and Teamwork

Personal Competencies
- Critical Thinking

252-1414-00L System Security W 7 credits 2V+2U+2A S. Capkun, S. Shinde

Abstract
The first part of the course covers general security concepts and hardware-based support for security. In the second part, the focus is on system design and methodologies for building secure systems.

Objective
In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

Content
The first part of the course covers general security concepts. Topics include the concept of physical and software-based side channel attacks on hardware resources, architectural support for security (e.g., memory management and permissions, disk encryption), and trusted execution environments (Intel SGX, ARM TrustZone, AMD SEV, and RISC-V Keystone).

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: common software faults (e.g., buffer overflows, etc.), bug-detection, writing secure software (design, architecture, QA, testing), compiler-supported security (e.g., control-flow integrity), and language-supported security (e.g., memory safety).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking

252-1425-00L Geometry: Combinatorics and Algorithms W 8 credits 3V+2U+2A B. Gärtner, M. Hoffmann, P. Schnider

Abstract
Geometric structures are useful in many areas, and there is a need to understand their structural properties, and to work with them algorithmically. The lecture addresses theoretical foundations concerning geometric structures. Central objects of interest are triangulations. We study combinatorial (Does a certain object exist?) and algorithmic questions (Can we find a certain object efficiently?) of triangulations. We study combinatorial and algorithmic geometry, so as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains. In particular, we want to prepare students for conducting independent research, for instance, within the scope of a thesis project.

Objective
The goal is to make students familiar with fundamental concepts, techniques and results in combinatorial and computational geometry, so as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains.

Content
Planar and geometric graphs, embeddings and their representation (Whitney's Theorem, canonical orderings, DCEL), polygon triangulations and the art gallery theorem, convexity in R^d, planar convex hull algorithms (Jarvis Wrap, Graham Scan, Chan's Algorithm), point set triangulations, Delaunay triangulations (Lawson flips, lifting map, randomized incremental construction). Voronoi diagrams, the Crossing Lemma and incidence bounds, line arrangements (duality, Zone Theorem, ham-sandwich cuts), 3-SUM hardness, counting planar triangulations.

Lecture notes
Yes

Literature

Prerequisites / notice
Prerequisites: The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH.

Outlook
Outlook: In the following spring semester there is a seminar "Geometry: Combinatorics and Algorithms" that builds on this course. There are ample possibilities for Semester-, Bachelor- and Master Thesis projects in the area.

252-3005-00L Natural Language Processing W 7 credits 3V+3U+1A R. Cotterell

Abstract
This lecture provides an introduction to natural language processing and computational linguistics. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Objective
This lecture provides an introduction to natural language processing and computational linguistics. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Content
The lecture covers topics in physically-based modeling, such as particle systems, mass-spring models, finite difference and finite element methods. These approaches are used to represent and simulate deformable objects or fluids with applications in animated movies, 3D games and medical systems. Furthermore, the lecture covers topics such as rigid body dynamics, collision detection, and character animation.

Prerequisites / notice
Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++. Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.
This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

**227-2210-00L**

**Computer Architecture**

W 8 credits 6G+1A S. Sadrosadati, O. Mutlu

**Abstract**

Computer architecture is the science & art of designing and optimizing hardware components and the hardware/software interface to create a computer that meets design goals. This course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.

**Objective**

We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), new paradigms like processing-in-memory, parallel computing systems (including multicore processors, coherence and consistency, GPUs), heterogeneous computing, interconnection networks, specialized systems for major data-intensive workloads (e.g. graph analytics, bioinformatics, machine learning), etc. We will focus on fundamentals as well as cutting-edge research. Significant attention will be given to real-life examples and tradeoffs, as well as critical analysis of modern computing systems.

**Content**

The principles presented in the lecture are reinforced in the laboratory through 1) the design and implementation of a cycle-accurate simulator, where we will explore different components of a modern computing system (e.g., pipeline, memory hierarchy, branch prediction, prefetching, caches, multithreading), and 2) the extension of state-of-the-art research simulators (e.g., Ramulator) for more in-depth understanding of specific system components (e.g., memory scheduling, prefetching).

See the course website for detailed and complete content of past incarnations of the course: https://safari.ethz.ch/architecture

**Lecture notes**

All the materials (including lecture slides) will be provided on the course website: https://safari.ethz.ch/architecture/

The video recordings of the lectures are expected to be made available after lectures.

See https://safari.ethz.ch/architecture for past examples.

**Literature**

We will provide required and recommended readings in every lecture. They will mainly consist of research papers presented in major Computer Architecture and related conferences and journals.

See https://safari.ethz.ch/architecture for past examples.

**Prerequisites / notice**


**Competencies**

Subject-specific Competencies

- Concepts and Theories  assessed
- Techniques and Technologies  assessed

Method-specific Competencies

- Analytical Competencies  assessed
- Problem-solving  assessed

Social Competencies

- Communication  assessed
- Leadership and Responsibility  assessed

Personal Competencies

- Adaptability and Flexibility  assessed
- Critical Thinking  assessed
- Self-direction and Self-management  assessed

263-2400-00L

**Reliable and Trustworthy Artificial Intelligence**

W 6 credits 2V+2U+1A M. Vechev

**Abstract**

Creating reliable, secure, robust, and fair machine learning models is a core challenge in artificial intelligence and one of fundamental importance. The goal of the course is to teach both the mathematical foundations of this new and emerging area as well as to introduce students to the latest and most exciting research in the space.

**Objective**

Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of engineering and research problems. To facilitate deeper understanding, the course includes a group coding project where students will build a system based on the learned material.
The course is split into 4 parts:

1. **Robustness of Machine Learning**
   - Adversarial attacks and defenses on deep learning models.
   - Certified training of deep neural networks (combining symbolic and continuous methods).

2. **Privacy of Machine Learning**
   - Threat models (e.g., stealing data, poisoning, membership inference, etc.).
   - Attacking federated machine learning (across vision, natural language and tabular data).
   - Differential privacy for defending machine learning.
   - AI Regulations and checking model compliance.

3. **Fairness of Machine Learning**
   - Introduction to fairness (motivation, definitions).
   - Enforcing individual fairness (for both vision and tabular data).
   - Enforcing group fairness (e.g., demographic parity, equalized odds).

4. **Robustness, Privacy and Fairness of Foundation Models**
   - We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).


Prerequisites / notice

While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in "Intro to ML" classes at most institutions (e.g., "Introduction to Machine Learning" at ETH).

Competencies

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<tr>
<th>Prerequisites / notice</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Personal Competencies</th>
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263-2520-00L Formal Foundations of Programming Languages

Abstract

The course covers topics in the theory of programming languages, types, and program verification, and how to construct and validate that theory with machine-checked proofs in the Coq proof assistant.

Objective

Students will learn how to develop machine-checked proofs, how to rigorously define the semantics of a programming language and its type system, and how to analyze and formally establish the guarantees of well-typed programs.

Content

The course will proceed in two parallel tracks:

- The theory track (2V) will introduce operational semantics, type systems, and type soundness proofs, starting with the simply-typed lambda calculus and then continuing with increasingly expressive languages.

- The Coq track (2G) will begin with an introduction to machine-checked proofs and the Coq proof assistant. Afterwards we will mechanize the theory developed in the first track. This is the hands-on part of the course; students will carry out these proofs in Coq themselves with instructions from the lecturer.

263-2800-00L Design of Parallel and High-Performance Computing

Abstract

Advanced topics in parallel and high-performance computing.

Objective

Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

Content

We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

Prerequisites / notice

This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

263-3010-00L Big Data

Abstract

This course will provide an introduction to big data processing and analytics, focusing on the Apache Hadoop ecosystem. Students will learn about the core components of Hadoop, such as the Hadoop Distributed File System (HDFS) and the MapReduce framework. They will also gain hands-on experience with tools like Pig and Hive for data processing, and Spark for real-time analytics.

Objective

1. Understand the architecture and key components of Hadoop.
2. Master the basics of data processing using Hadoop and Pig/Hive.
3. Gain proficiency in real-time data processing with Apache Spark.

Content

- Data Storage and Processing with HDFS and Hadoop.
- Data Processing with Pig and Hive: SQL-like language for data processing.
- Real-time Data Processing with Apache Spark.
- Integration with Other Tools: Explore integration with other big data tools and ecosystems.

Prerequisites / notice

Students should have a basic understanding of programming concepts, experience with programming in one or more languages, and familiarity with data processing concepts. Knowledge of the Python language is beneficial but not mandatory.

Assessment

The course evaluation will include:

1. Homework assignments to reinforce concepts learned in class.
2. Project work: Students will work on a real-world big data project, applying the skills and knowledge gained in the course.
3. Midterm exam: Comprehensive assessment of the material covered in the first half of the course.
4. Final exam: Comprehensive assessment of the material covered in the entire course.

Credit Distribution

- Homework: 10 credits
- Project: 10 credits
- Midterm Exam: 10 credits
- Final Exam: 10 credits

Total: 40 credits

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Abstract
The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations.

Objective
Do you want to be able to query your own data productively and efficiently in your future semester projects, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This courses teaches you how to do so as well as the dos and don'ts.

“Big Data” refers to the case when the amount of data is very large (100 GB and more), or when the data is not completely structured (or messy). The Big Data revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the “fourth paradigm”.

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it are needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each one of your projects efficiently and consistently.

Content
This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage(S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Large scale analytics and machine learning are outside of the scope of this course.

Prerequisites / notice
The lecture is hybrid, meaning you can attend with us in the lecture hall, or on Zoom, or watch the recordings on YouTube later. Exercise sessions are in presence.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departmentes interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2023

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

Literature
Course textbook: https://ghislainfourny.github.io/big-data-textbook/

Papers from scientific conferences and journals. References will be given as part of the course material during the semester.
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations. In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology. The participation in the course is subject to the following condition: - Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://ml2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/ss19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18

The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud. The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in-depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.

The course will cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. This list of papers will be provided at the beginning of the course.

This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it may also be accessible to last-year bachelor students.

This course familiarizes the students with some of the main tools and techniques in modern subareas of algorithm design. The lectures will cover modern topics in algorithm design and analysis, including the following: graph sparsifications while preserving cuts or distances, various approximation algorithms techniques and concepts, metric algorithms, multiplicative weight updates, streaming algorithms, sketching algorithms. This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations. E.g., having passed the course Algorithms, Probability, and Computing (APC) is recommended, though not required formally. If you are not sure whether you’re ready for this class or not, please consult the instructor.
Privacy is a fundamental human right! And yet, technological advances (in particular in computer science) can often undermine privacy. In this course, we will see how to formalize various notions of privacy and how to build systems that preserve privacy, by combining techniques from cryptography and statistics.

The course will cover topics spanning four broad themes with a focus on the first two themes:

1. Network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. Network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. Analysis and inference topics such as traffic monitoring and network forensics; and

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

This course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

Basic knowledge in cryptography, probability and machine learning is recommended but not required.

References to relevant research papers will be provided.

Literature
Boneh & Shoup - A Graduate Course in Applied Cryptography

Prerequisites
Basic knowledge in cryptography, probability and machine learning is recommended but not required.
Lecture slides will be made available at the course Web site.

No textbook is required, but there will be regularly assigned readings from research literature, linked to the course website.

There are no prerequisites for this class. However, it will help if the student has taken an undergraduate or graduate level class in statistics, data science or machine learning. This class is appropriate for advanced undergraduates and master students in Computer Science as well as PhD students in other departments.

**263-5056-00L Applications of Deep Learning on Graphs**

W 4 credits 2G+1A G. Rätzsch

*Abstract*

Graphs are an incredibly versatile abstraction to represent arbitrary structures such as molecules, relational knowledge or social and traffic networks. This course provides a practical overview of deep (representation) learning on graphs and their applications.

*Objective*

Many established deep learning methods require dense input data with a well-defined structure (e.g. an image, a sequence of word embeddings). However, many practical applications deal with sparsely connected and complex data structures, such as molecules, knowledge graphs or social networks. Graph Neural Networks (GNNs) and general representation learning on graphs have recently experienced a surge in popularity because it addresses the challenge to effectively learn representations over said structures. In this course, we aim to understand the fundamental principles of deep (representation) learning on graphs, the similarities and differences to other concepts in deep learning, as well as the unique challenges from a practical point of view. Finally, we provide an overview of recent applications of graph neural networks.

*Content*

Introduction to GNN concepts: 1) problem-solving on graphs (node-, edge-, graph-level objectives), structural priors (inductive biases) of graph data, applications for graph learning, 2) Graph Neural Networks: convolutional, attentional, message passing, overview on the zoo of published operators. Relations to Transformers and DeepSets. 3) Expressivity of GNNs. 4) Scalability of Graph Neural Networks: Subsampling, Clustering (Pooling), 5) Augmentations and self-supervised learning on Graphs Application: Drug Discovery, Knowledge graphs. Temporal GNNs, Geometric GNNs, Deep Generative Models for Graphs.

*Prerequisites / notice*

263-3210-00 Depp Learning or 263-0008-00 Computational Intelligence Lab; 252-0220-00 Introduction to Machine Learning; Statistics/Probability; Programming in Python; Unix Command Line.

**263-5210-00L Probabilistic Artificial Intelligence**

W 8 credits 3V+2U+2A A. Krause

*Abstract*

This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

*Objective*

How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit “intelligent” behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

*Content*

Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

*Prerequisites / notice*

Solid basic knowledge in statistics, algorithms and programming.

*Competencies*

The material covered in the course “Introduction to Machine Learning” is considered as a prerequisite.

**263-5351-00L Machine Learning for Genomics**

W 6 credits 2V+2U+1A V. Boeva

*Abstract*

The course reviews solutions provided by machine learning to the most challenging questions in human genomics.

*Objective*

Over the last few years, the parallel development of machine learning methods and molecular profiling technologies for human cells, such as sequencing, created an extremely powerful tool to get insights into the cellular mechanisms in healthy and diseased contexts. In this course, we will discuss the state-of-the-art machine learning methodology solving or attempting to solve common problems in human genomics. At the end of the course, you will be familiar with (1) classical and advanced machine learning architectures used in genomics, (2) bioinformatics analysis of human genomic and transcriptomic data, and (3) data types used in this field.

*Content*

- Short introduction to major concepts of molecular biology: DNA, genes, genome, central dogma, transcription factors, epigenetic code, DNA methylation, signaling pathways
- Prediction of transcription factor binding sites, open chromatin, histone marks, promoters, nucleosome positioning (convolutional neural networks, position weight matrices)
- Prediction of variant effects and gene expression (hidden Markov models, topic models)
- Deconvolution of mixed signal (NMF, ICA)
- DNA, RNA and protein folding (RN, LSTM, transformers)
- Data imputation for single-cell RNA-seq data, clustering and annotation (diffusion and methods on graphs)
- Batch correction (autoencoders, optimal transport)
- Survival analysis (Cox proportional hazard model, regularization penalties, multi-omics, multi-tasking)

*Prerequisites / notice*


*Competencies*

The course covers major concepts of molecular biology: DNA, genes, genome, central dogma, transcription factors, epigenetic code, DNA methylation, signaling pathways

**263-5902-00L Computer Vision**

W 8 credits 3V+1U+3A M. Pollefeys, S. Tang, F. Yu

*Abstract*

The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.
The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

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<th>Number</th>
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<td>Case Studies from Practice Seminar</td>
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<td>4 credits</td>
<td>2S</td>
<td>M. Brandis</td>
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</table>

The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human interaction, as well as gaming technology.

The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including: Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introduction to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course are student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/graphics/VR research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Computer Graphics“ which takes place in Basel before the start of the semester.

Lecture slides will be available on moodle.

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:
- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:
- epidemiology
- pathogen evolution
- macroevolution of species

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including: Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introduction to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course are student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/graphics/VR research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

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Lecture slides will be available on moodle.

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:
* Yang, Z. 2006. Computational Molecular Evolution.
* Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.
Content
Participants learn how to systematically approach an IT problem in practice. They work in groups of three to solve a case from a participating company in depth, studying provided materials, searching for additional information, analyzing all in depth, interviewing members from the company or discussing findings with them to obtain further insights, and presenting and defending their conclusion to company representatives, the lecturer, and all other participants of the seminar. Participants also learn how to challenge presentations from other teams, and obtain an overview of learnings from the cases other teams worked on.

Lecture notes
Methodologies to analyze the cases and create final presentations. Short overview of each case.

Prerequisites / notice
Successful completion of Lecture "Information Technology in Practice".

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Self-presentation and Social Influence</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td></td>
<td>Critical Thinking</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
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<td></td>
<td>Self-direction and Self-management</td>
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252-4601-00L Current Topics in Information Security
The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
The seminar covers various topics in information security: security protocols (models, specification & verification), trust management, access control, non-interference, side-channel attacks, identity-based cryptography, host-based attack detection, anomaly detection in backbone networks, key-management for sensor networks.

Objective
The main goals of the seminar are the independent study of scientific literature and assessment of its contributions as well as learning and practicing presentation techniques.

Content
The seminar covers various topics in information security, including network security, cryptography and security protocols. The participants are expected to read a scientific paper and present it in a 35-40 min talk. At the beginning of the semester a short introduction to presentation techniques will be given.

Selected Topics
- security protocols: models, specification & verification
- trust management, access control and non-interference
- side-channel attacks
- identity-based cryptography
- host-based attack detection
- anomaly detection in backbone networks
- key-management for sensor networks

Literature
The reading list will be published on the course web site.

252-5051-00L Advanced Topics in Machine Learning
The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
In this seminar, recent papers of the pattern recognition and machine learning literature are presented and discussed. Possible topics cover statistical models in computer vision, graphical models and machine learning.

Objective
The seminar "Advanced Topics in Machine Learning" familiarizes students with recent developments in pattern recognition and machine learning. Original articles have to be presented and critically reviewed. The students will learn how to structure a scientific presentation in English which covers the key ideas of a scientific paper. An important goal of the seminar presentation is to summarize the essential ideas of the paper in sufficient depth while omitting details which are not essential for the understanding of the work. The presentation style will play an important role and should reach the level of professional scientific presentations.

Content
The seminar will cover a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from computer vision or bioinformatics - two fields, which relies more and more on machine learning methodology and statistical models.

Literature
The papers will be presented in the first session of the seminar.

252-5701-00L Seminar in Advanced Topics in Vision
The deadline for deregistering expires at the end of the third week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
This seminar covers advanced topics in computer vision, such as 3D reconstruction, image understanding, object detection, people tracking, motion prediction, and other related topics. Each time the course is offered, a collection of research papers is selected and each student presents one paper to the class and leads a discussion about the paper and related topics.

Objective
The goal is to get an in-depth understanding of actual problems and research topics in the field of computer vision as well as improve presentations and critical analysis skills.
The goal of this course is for students to gain a comprehensive understanding of state-of-the-art HCI research on user-centered programming interfaces.

All students read the papers and participate in the discussion.

Research Topics in Software Engineering

**Objective**
Each student will be assessed on their understanding of the course material through participation in discussions and completing assignments.

**Content**
The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

**Prerequisites / notice**
Students taking this seminar should have the necessary background in systems and low level programming.

Hardware Acceleration for Data Processing

**Objective**
Each student will be assessed on their understanding of the course material through participation in discussions and completing assignments.

**Content**
The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

**Prerequisites / notice**
Students taking this seminar should have the necessary background in systems and low level programming.

Advanced Topics in Human-Centric Computer Vision

**Objective**
Each student will be assessed on their understanding of the course material through participation in discussions and completing assignments.

**Content**
The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

**Prerequisites / notice**
Students taking this seminar should have the necessary background in systems and low level programming.

Seminar on User-Centered Programming Interfaces

**Objective**
Each student will be assessed on their understanding of the course material through participation in discussions and completing assignments.

**Content**
The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

**Prerequisites / notice**
Students taking this seminar should have the necessary background in systems and low level programming.
### 263-5100-00L  Topics in Medical Machine Learning

**Abstract**
This seminar discusses recent relevant contributions to the fields of medical machine learning and related areas. Each participant will hold a presentation and lead the subsequent discussion.

**Objective**
Preparing and holding a scientific presentation in front of peers is a central part of working in the scientific domain. In this seminar, the participants will learn how to efficiently summarize the relevant parts of a scientific publication, critically reflect its contents, and summarize it for presentation to an audience. The necessary skills to successfully present the key points of existing research work are the same as those needed to communicate own research ideas. In addition to holding a presentation, each student will contribute to and lead the discussion session on the topics presented in the class.

**Content**
The topics covered in the seminar are related to recent computational challenges that arise in the medical field, including but not limited to clinical data analysis, interpretable machine learning, privacy considerations, statistical frameworks, etc. Both recently published works contributing novel ideas to the areas mentioned above as well as seminal contributions from the past are on the list of selected papers.

**Prerequisites / notice**
Knowledge of machine learning and interest in applications in medicine. ML4H is beneficial as a prior course.

### 263-5702-00L  Seminar on Digital Humans

**Abstract**
This seminar covers advanced topics in digital humans with a focus on the latest research results. Topics include estimating human pose and motion from images, human motion synthesis, learning-based human avatar creation, learning neural implicit representations for humans, modeling, animations, artificial intelligence for digital characters, and others. A collection of research papers is selected.

**Objective**
The goal is to get an overview of actual research topics in the field of digital humans and to improve presentation and critical analysis skills.

**Content**
This seminar covers advanced topics in digital humans including both seminal research papers as well as the latest research results. A collection of research papers are selected covering topics such as estimating human pose and motion from images, human motion synthesis, learning-based human avatar creation, learning neural implicit representations for humans, modeling, animations, artificial intelligence for digital characters, and others. Each student presents one paper to the class and leads a discussion about the paper. All students read the papers and participate in the discussion.

**Literature**

### Competencies

<table>
<thead>
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### CAS in Computer Science - Key for Type

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<td>Compulsory</td>
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<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<th>CAS</th>
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<td>E-</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<td>Dr</td>
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### Key for Hours

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<tr>
<td>V</td>
<td>lecture</td>
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<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<th>Symbol</th>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

### ECTS

- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
CAS in Machine Learning in Finance and Insurance

- Compulsory Modules
- Elective Modules
- Project Work

<table>
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<th>Key for Hours</th>
<th>ECTS</th>
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ECTS: European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
CAS in Future Transport Systems: New Business Models

The "CAS in Future Transport Systems: New Business Models" takes place every 1.5 years according to the program website.

Course duration: Six months part time


Major Courses

The "CAS in Future Transport Systems: New Business Models" takes place every 1.5 years according to the program website.

Takes place in the autumn semester 2023

Start of the next course: Spring Semester 2025

Course duration: Six months part time


<table>
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<tr>
<th>Number</th>
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<tr>
<td>166-0300-00L</td>
<td>Framework Conditions and Transport Behaviour ■</td>
<td>O</td>
<td>3.5 credits</td>
<td>3G</td>
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<td></td>
<td>Does not take place this semester.</td>
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<tr>
<td>Abstract</td>
<td>This module addresses the demand for new business models for future transport systems. Why and in what way do people wish to be mobile? What are the economic, social and legal framework conditions, and how will these develop? What approaches leading to new value propositions will follow?</td>
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<td>Objective</td>
<td>Participants</td>
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<td></td>
<td>• can tell the difference between drivers of mobility which cannot really change and those which can change;</td>
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<td>• are able to identify the effects of path dependence on transport systems and future transport systems;</td>
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<td>• are familiar with the socio-psychological factors involved in transport vehicle acquisition and transport behaviour, and can apply them in ideas for new business models;</td>
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<td>• are able to judge the significance of travel time, driving time and fixed costs and use this knowledge to identify new business models;</td>
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<td>• are able to design incentives which will trigger maximum changes in behaviour and/or facilitate cooperative behaviour;</td>
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<td>• are able to embed electric mobility conceptually such that its potential is realised and the associated risks are minimised;</td>
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<td>• are familiar with the framework conditions and efficient drivers required to replace overland transport with air transport;</td>
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<td>• are able to assemble combinations of political and market instruments on the basis of their efficiency profiles and side-effects in order to realise efficiency potentials and changes in behaviour;</td>
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<td>• are able to design policy and market measures in such a way that they minimise rebound effects (including those in connection with automatic and fully autonomous vehicles);</td>
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<td>• are able to recognise the properties of automatic and fully autonomous vehicles which are particularly suitable for new business models.</td>
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<td></td>
<td>• Why are people mobile? What resources (time, money, space) do they invest in mobility?</td>
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<td></td>
<td>• What are the various qualities of transport services (comfort/stress, risk/safety, plannability, multifunctionality)?</td>
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<td>• What are the various resource and quality profiles of current transport services, and what mutual dependencies are there?</td>
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<td></td>
<td>• What current mobility demands are unsated? Why are they unsated? What future key technologies might change this?</td>
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<td>• What current forms of mobility might be substituted by other transport services? If they were substituted, how would the necessary resources and transport service qualities change?</td>
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<td>Methods</td>
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<td></td>
<td>• Group work (groups of four and groups of two)</td>
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<td></td>
<td>• Creative methods for generating value propositions</td>
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<td>• Tasks in preparation for the fourth course day: design, implementation and analysis of a small survey of potential target clients regarding a not-yet-existing business model</td>
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<td>Case studies</td>
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<td>• Reciprocal presentation of personally compiled case studies</td>
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</table>

166-0301-00L New Business Models for Future Transport Systems ■ O 3 credits 2G

Does not take place this semester.

Abstract

This module addresses the implementation of (digital) strategies and innovative business models of the future and elucidates the drivers, inhibitors and challenges of business model innovation. Using suitable methods and procedures, participants in the module develop, evaluate and refine prototypes of sustainable future business models.

Objective

Participants

• are able to understand and explain the core issues, concepts and strategies of business model innovation;
• are able to describe the relevance and the process of business model development;
• are able to translate a personally developed business case into a sustainable business model;
• are able to apply suitable design strategies to optimise a personally developed business model;
• are able to appropriately embed new business models into a corporate or business segment strategy;
• are able to assess the strengths, weaknesses, opportunities and risks of a business model;
• are able to convincingly present their own business case / business model in a structured manner to relevant stakeholder groups (investors, board members, clients, partners);
• are able to engage with and develop various points of view to assess business models;
• are able to shape a modelling process for themselves and reflect on it.

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 484 of 2653
Content

Business model innovation:
• Conceptual foundations of business model innovation
• Drivers, inhibitors and challenges of business model innovation
• Business model innovation in established organisations and structures
• Case study and mini cases in the context of transport system / mobility business model innovation

Business modelling (essentials):
• Business model thinking and modelling
• The Business Model Canvas as a conceptual and methodological tool
  o Customer benefits / value propositions
  o Demand side
  o Supply side
• Business model patterns

Business modelling (application)
• Creation of a real business case for business modelling
• Business model prototyping (basis: Business Model Canvas)
• Evaluation and review/re-prototyping of participants' own business cases / business models

Incorporating new business models into corporate / business segment strategies
• Fit with strategic analysis
• Compliance with corporate or business segment strategy
• Contribution to strategy implementation

Presenting business models convincingly (basics/application)
• Basics of business model presentation
• Development of participants' own storylines and presentation structure (business value concept)
• Pitching of own business case / business model

Lecture notes
Distributed at start of module.

Literature
Distributed at start of module.

Prerequisites / notice
Announced to students of the of the MAS | CAS at the beginning of the term.

166-0302-00L Implementing New Strategies and Business Models for Future Transport Systems  O  3 credits  2G
Does not take place this semester.

Abstract
In order to be successful, new strategies / innovative business models have to be implemented in the market as well as in the company itself. This requires proactively managed transition processes. This module deals with such transition processes on three levels: change management theory – best-practice examples – one's own practice.

Objective
Participants...
• know and understand selected classic and current theories regarding change (management) in systems
• know how to design and initiate participative transition processes
• are familiar with / know how to apply selected tools of change management
• have discussed best-practice cases with responsible managers within the mobility/transportation sector
• have reflected theory and best-practice cases in regard to their own practice
• have developed management options and approaches for their own practice

Content
• Classic and current change management approaches
• Communication in transition processes
• Participation: integration of stakeholders
• Dealing with resistances
• Discussions with guests from practice regarding the management of transition processes related to the implementation of new strategies / business models

Methods
• Selected change management methods and tools

Case studies
• Various good/best practice cases within the mobility sector
• Change cases of students

Lecture notes
Distributed at start of module.

Literature
Distributed at start of module.

Prerequisites / notice
Announced to students of the of the MAS | CAS at the beginning of the term.
Abstract
For companies it is essential to realise products quickly, economically and in a customer-oriented way. In this context approaches to agile and user-centred product development such as Scrum and Design Thinking are increasing in importance. Compared to traditional product development methods, agile methods promise higher quality and customer satisfaction coupled with reduced expenditure.

Objective
Design and realisation of product development projects for future transport systems: Participants are familiar with the methods and procedures of agile and user-centred product development and are able to apply them profitably in their enterprises.

Content
Participants define an innovation theme themselves in groups, and a selection of topics is then drawn from this theme for module group work. The module takes participants through the whole process, from the analysis of target groups and their requirements through project conception and planning to implementation in example form. The course is practical and uses concrete examples. At the end of the module participants will have deployed the methods of agile and user-centred product development to work very practically through a theme they have developed themselves, and will have become familiar with the typical application scenarios, advantages and hurdles associated with these methods.

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the MAS/CAS at the beginning of the term

Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: assessed
- Problem-solving: fostered
- Project Management: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: assessed
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Critical Thinking: assessed
- Negotiation: fostered

**CAS Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>166-0390-00L</td>
<td>CAS Project: New Business Models</td>
<td>O</td>
<td>3</td>
<td>5D</td>
<td>C. Onder</td>
</tr>
</tbody>
</table>

Abstract
The participants, in heterogeneous teams, deal with a current problem from the topics of the CAS New Business Models. They must be able to work interdisciplinarily and across sectors, where appropriate together with relevant other parties. The participants communicate the results appropriately.

Objective
- Deal with a specific problem from the CAS New Business Models subject area.
- Be able to work interdisciplinarily and across sectors, where appropriate together with relevant other parties.
- Communicate the results appropriately.

Lecture notes
Distributed at start of module.

Literature
Distributed at start of module.

Prerequisites / notice
Announced to students of the MAS/CAS at the beginning of the term.

CAS in Future Transport Systems: New Business Models - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
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<td>O</td>
<td>Compulsory</td>
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<td>W+</td>
<td>Eligible for credits and recommended</td>
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<td>Eligible for credits</td>
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### Key for Hours

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<th>Key</th>
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<tr>
<td>V</td>
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<td>G</td>
<td>lecture with exercise</td>
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<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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**ECTS**

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
The "CAS in Future Transport Systems: Systemic Aspects" takes place every 1.5 years according to the program website.

Course duration: Six months part time


### Major Courses

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>166-0100-00L</td>
<td>Transport Systems: Dynamics and Future Developments</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Interrelationships and dynamic change and the impact of these on mobility and transportation are being investigated in this module. The module addresses desirable future development of urban transport systems in Switzerland by covering and critically examining existing transport scenarios (e.g. ARE) in an exercise setting which deploys backcasting.</td>
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<td>Participants - understand the complexity of the transport system status quo as a whole, and are able to describe it qualitatively and create an operational and/or working context (K1). - understand the development of transport systems and future transport scenarios over time, and can infer objectives from the latter (K2). - understand the dynamics between spatial quality and mobility behavior and can evaluate how measures to promote active mobility can contribute to a more sustainable transport system (K3). - understand how digitalisation drives new mobility services (mobility as a service), and are able to qualitatively estimate the changes these bring to transport systems as a whole (K4). - are able to pinpoint the challenges and potential of the transition to autonomous transport forms (K5).</td>
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<td><strong>Methods</strong></td>
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<td></td>
<td>System analysis, scenario analysis, foresight, indicators for sustainable mobility, Case studies, reading and discussion of thesis papers and scientific publications</td>
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<td><strong>Lecture notes</strong></td>
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<td><strong>Prerequisites / notice</strong></td>
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<tr>
<td>166-0101-00L</td>
<td>Development and Assessment of Transport Scenarios</td>
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<td><strong>Abstract</strong></td>
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<td>This module familiarises participants with current methods of developing and evaluating transport scenarios. These include analysis of the interrelationship of space and traffic; traffic modelling methods; and evaluation according to economic and planning criteria.</td>
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<td><strong>Objective</strong></td>
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<td>Participants - are familiar with suitable methods for developing transport scenarios and how to analyse and evaluate them. In particular, they know how to address the challenges of evaluating future forms of transport; - are able to select a suitable method and determine an evaluation concept with relation to a specific problem.</td>
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<td>- Methodological foundations of traffic modelling (44-level model, activity-based model, agent-based simulation) - Design and evaluation of transport scenarios using MATSim (traffic simulation) with a focus on transport with autonomous vehicles - Interrelationship of space and traffic (accessibility measurement, settlement density and mixed usage) and what to consider in designing and evaluating transport scenarios - Approaches to evaluation of traffic scenarios (cost-benefit analyses and their foundations, methodological limits), analysis of effects taking into account user group and space type - Ecobalancing with Life Cycle Assessment (LCA) in addressing passenger and goods transport issues - Development of case studies on shared transport and mobility with an activity- and agent-based transport simulation model</td>
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<td><strong>Methods</strong></td>
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<td>Aggregated and activity-based transport demand models - Agent-based simulation - Cost-benefit analysis - Accessibility analysis</td>
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<td><strong>Case studies</strong></td>
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<td>Shared mobility</td>
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<td>Autonomous mobility</td>
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<td></td>
<td>Densified settlement development and slow forms of mobility</td>
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<td><strong>Lecture notes</strong></td>
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<tr>
<td>166-0102-00L</td>
<td>Foundations of the Design for Transport System</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>Participants are able... - to understand the economic and social-science fundamentals of innovation and change processes in the area of transportation; - to analyse the foundations, opportunities and challenges of disruption in mobility systems; - to set this concepts and frameworks in context to pathways towards more sustainable mobility; - and to set these concepts and frameworks constructively in context to their own work practice.</td>
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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 488 of 2653
In this module, innovation, change and transitions in transportation systems on different levels are discussed from different complementary perspectives. Both economic and social science approaches to the analysis, anticipation and governance of innovation processes are presented, discussed and applied to current issues. Topics are:

- Respective theories and methods;
- Innovation as an economic discovery process, measuring innovation;
- Emerging trends as new opportunities for innovation;
- Innovation today in the transportation/mobility system: theoretical basis and concrete examples;
- Transition of socio-technical systems, co-evolution of technical and societal dynamics;
- The relevance of social acceptance and ethical aspects for innovations in mobility.

166-0103-00L System Aspects of Air and Shipping Traffic ❘ O 3 credits 2G to be announced

Abstract
Air and shipping traffic cover a substantial part of human mobility, air traffic in passenger as well as freight transport, shipping mainly in freight transport. Students gain an overview, limit modes of mobility and learn to classify air and shipping traffic in the overall system of mobility.

Objective
Participants
• know the fundamental differences between air, shipping traffic compared to motorized individual transport and public transport.
• are able to deduce differences between air and shipping traffic.
• know the possibilities and limits as well as pros and cons of different valuation methods used for air and shipping transport.
• develop ideas for suitable indicators to evaluate scenarios in air and shipping traffic.

Content
• Key figures, development and trends in air and shipping traffic.
• Potentials for holistic improvement in air and shipping traffic.
• Life Cycle Assessment (LCA) for questions in air and shipping traffic.
• Overview on technologies and their potentials to improve sustainability in air and shipping transport.
• Berechnung und Interpretation von Kennzahlen.

Lecture notes Distributed at start of module
Literature Distributed at start of module
Prerequisites / notice Announced to students of the of the MAS / CAS at the beginning of the term

CAS in Future Transport Systems: Systemic Aspects - Key for Type

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>166-0190-00L</td>
<td>CAS Thesis on System Aspects ❘</td>
<td>O</td>
<td>3 credits</td>
<td>5D</td>
<td>C. Onder, to be announced</td>
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</tbody>
</table>

Abstract
The participants deal with a current problem from the topics of CAS System Aspects.

Objective
- Deal with a specific problem from the CAS System Aspects subject area.
- Deepen selected content from module independently
- Be able to work interdisciplinary and across sectors, where appropriate together with relevant other parties.
- Communicate the results appropriately.

Content
In der CAS-Arbeit zeigen die Studierenden, dass sie in der Lage sind, eine fundiert aufbereitete Auseinandersetzung mit technischen und nicht-technischen Entwicklungen im Mobilitätssystem und deren mögliche Auswirkungen auf das Schweizer Verkehrssystem oder auf Teilbereiche desselben anzufertigen.

Die Teilnehmenden setzen sich dabei aktiv mit aktuellen und/oder zukünftig erwarteten Entwicklungen im Mobilitätsektor auseinander, übersetzen mögliche Entwicklungen in verkehrliche Parameter (=Zukunft der Mobilität); greifen auf Lerninhalte des Studiums zurück; entwickeln ausgewählte Themen selbständig weiter (bzw. im Rahmen einer Arbeitsgruppe) und setzen sich mit der Relevanz für die Praxis auseinander (Relevanz für Stakeholdergruppen wie z.B. politische Entscheidungsträger, Verkehrsunternehmen, Industrie, Umweltverbände, Energieversorger sowie auch andere gesellschaftliche Gruppen, z.B. für Menschen im Rentenalter).

CAS in Future Transport Systems: Systemic Aspects - Key for Type

| Key for Hours | | | | |
|---------------|----------------|----------------|----------------|
| V | lecture | P | practical/laboratory course |
| G | lecture with exercise | A | independent project |
| U | exercise | D | diploma thesis |
| S | seminar | R | revision course / private study |
| K | colloquium | | |

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Major Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>166-0200-00L</td>
<td>Technology Potential: Powertrain, Systems and Energy Carriers</td>
<td>O</td>
<td>3.5 credits</td>
<td>3G</td>
<td>C. Onder</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>The module provides a foundation in the current situation and short- and middle-term development directions of powertrain and automotive engineering in the context of passenger &amp; goods transport. Corresponding energy sources and resulting consequences for the energy system are addressed. Participants will be enabled to identify potentials of these technologies and apply them to concrete problems.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Familiarity with conventional and alternative powertrain and automotive systems for future sustainable mobility, and the ability to identify and deploy their potential to address concrete problems.</td>
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<tr>
<td><strong>Content</strong></td>
<td>- Drive component efficiency rates and core fields</td>
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<td>- Drive and non-drive energy flow / Vehicle &quot;driving resistance&quot;</td>
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<td>- Energy chains (operating power only) and CO2 emissions to primary energy</td>
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<td>Announced to students of the of the MAS / CAS at the beginning of the term</td>
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<tr>
<td>166-0201-00L</td>
<td>Potential of Spatial Information- and Communication Technologies</td>
<td>O</td>
<td>3 credits</td>
<td>3G</td>
<td>M. Raubal</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The digital revolution, spatial information and communication systems in particular, have a significant influence on the development of new transport systems. Participants acquire an in-depth understanding of the functionality and application potential of spatial information systems and services and of communication technologies for deployment in future transport systems and applications.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Familiarity with information and communication technologies (ICT) and spatial information technologies, and the ability to identify and utilise their potential to address concrete problems.</td>
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<tr>
<td><strong>Content</strong></td>
<td>- Functionality and application of geographic information systems (GIS) to represent and analyse transport systems (acquire, model, analyse and visualise geodata)</td>
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<td>- Deployment potentials of GIS and ICT for efficient transport solutions (tangible, non-tangible)</td>
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<td></td>
<td>- Functionality and application of mobile spatial information technologies in future transport systems</td>
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<td>- Methods of spatiotemporal analysis and geodata analysis</td>
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<td></td>
<td>- Technical aspects of information and communication technologies (ICT)</td>
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<td>- Modelling, simulation and assessment of traffic behaviour</td>
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<td>- Basics of autonomous driving</td>
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<td>- Legal aspects of geodata</td>
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<td></td>
<td>- Applications: Traffic behaviour in Switzerland; location based services for energy-efficient behaviour; GIS for the Zurich traffic system (multimodal)</td>
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<td><strong>Prerequisites / notice</strong></td>
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<tr>
<td>166-0202-00L</td>
<td>Integrated Assessment of Technologies and Transport Systems</td>
<td>O</td>
<td>2 credits</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>The module provides a solid introduction to integrated technology assessment (with regard to economic, ecological and social criteria. It introduces life cycle assessment (LCA), cost assessment, risk assessment and multi-criteria decision analysis. It also presents scenario analyses based upon energy-economic models which explicitly represent transport and energy-supply technologies.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>An overview of suitable methods for analysing and evaluating technical systems (transport systems) and the ability to choose among them to address concrete problems</td>
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<tr>
<td><strong>Content</strong></td>
<td>(1) Introduction to and overview of integrated assessment</td>
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<td>- Current status of transport in Switzerland and internationally</td>
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<td>- Scope and goals of integrated assessment</td>
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<td>- Sustainability: concept and practical implementation via criteria and indicators</td>
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<td>- Overview of concepts and implementation methods</td>
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<td>(2) Selected methods for assessing transport technologies and their application to current and future options</td>
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<td>- Ecobalance / life cycle assessment (LCA)</td>
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<td>- Location-specific assessment of health hazards and environmental pollution</td>
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<td>- Risk analysis</td>
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<td>- Internal cost assessment</td>
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<td>- External cost assessment</td>
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<td>(3) Integrated assessment of transport technologies</td>
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<td>- Overall costs (internal and external)</td>
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<td>- Multi-criteria analysis</td>
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<td>(4) Analysis of transport scenarios</td>
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<td>- Scenarios, influencing factors, policy and sustainability</td>
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<td>- Approaches to scenario modelling</td>
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<td>- Global mobility scenarios: examples</td>
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<td></td>
<td>- Transport scenarios for Switzerland using energy system models</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Distributed at start of module</td>
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<tr>
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<td>Announced to students of the of the MAS / CAS at the beginning of the term</td>
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<tr>
<td>166-0203-00L</td>
<td>Energy Carrier for the Mobility of the Future</td>
<td>O</td>
<td>3.5 credits</td>
<td>3G</td>
<td></td>
</tr>
</tbody>
</table>
Abstract
The module includes the supply of the road mobility of the future with renewable energy. The generation, transport, processing, transfer of energy to the vehicles (refueling, charging) and the energetic evaluation are presented. Electricity, hydrogen, biogenic and synthetic fuels are considered.

Objective
The aim of the module is a detailed energetic and technical understanding of the supply of road vehicles with renewable energy. Graduates know the primary energy production as well as the end energy processing of the different energy carrier concepts. In addition, they know the legal CO₂ requirements for vehicle registration and are able to qualitatively assess the impact on the Swiss energy system.

Content
- The energy system of the future; biogenic and electric renewable primary energy
- End energy processing
- Transfer from the energy system to mobility and influences on the overall energy system

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the of the MAS / CAS at the beginning of the term

CAS Thesis

<table>
<thead>
<tr>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>166-0290-00L</td>
<td>CAS Thesis on Technology Potentials</td>
<td>O</td>
<td>3 credits</td>
<td>5D</td>
<td>C. Onder</td>
</tr>
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</table>

Abstract
The participants, in heterogeneous teams, deal with a current problem from the topics of the CAS Technology Potentials.

Objective
- Deal with a specific problem from the CAS Technology Potentials subject area.
- Be able to work interdisciplinary and across sectors, where appropriate together with relevant other parties.
- Communicate the results appropriately.

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the of the MAS / CAS at the beginning of the term

CAS in Future Transport Systems: Technology Potential - Key for Type

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ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
# CAS in Nutrition for Disease Prevention and Health

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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>752-6101-00L</td>
<td>Nutrition and Chronic Disease</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>F. von Meyenn, M. Andersson</td>
</tr>
</tbody>
</table>

**Abstract**
To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Objective**
To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic disease, as well as the progression of complications of the chronic diseases.

**Content**
The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Lecture notes**
There is no script. Powerpoint presentations will be made available on-line to students.

**Prerequisites / notice**
No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

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<tbody>
<tr>
<td>752-6403-00L</td>
<td>Nutrition and Performance</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>S. Mettler</td>
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</tbody>
</table>

**Abstract**
The course introduces basic concepts of the interaction between nutrition and exercise performance.

**Objective**
To understand the potential effects of nutrition on exercise performance, with a focus on concepts and principles of nutrition before, during and after exercise.

**Content**
The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise. Although this is a scientific course, it is a goal of the course to translate basic sports nutrition science into practical sports nutrition examples.

**Lecture notes**
Lecture slides and required handouts will be available on the ETH website (moodle).

**Literature**
Information on further reading will be announced during the lecture. There will be some mandatory as well as voluntary readings.

**Prerequisites / notice**
General knowledge about nutrition, human biology, physiology and biochemistry is a prerequisite for this course. The course builds on basic nutrition and biochemistry knowledge to address exercise and performance related aspects of nutrition.

The course is designed for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).

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<tr>
<td>752-6301-00L</td>
<td>Nutrition-Related Physiology</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>F. von Meyenn, E. Gasser</td>
</tr>
</tbody>
</table>

**Abstract**
Gives the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand.

**Objective**
Some basic knowledge in physiology is recommended for this course, which revisits important physiological topics, emphasizing their relation to nutrition. The aim is to give the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand. For students with a background in medicine, pharmacy or biology, the course is useful as a review of previously acquired knowledge. Major topics are basic neuroanatomy and neurophysiology; general endocrinology; the physiology of taste and smell; nutrient digestion and absorption; intermediary metabolism and energy homeostasis; and some aspects of cardiovascular physiology and water balance.

**Lecture notes**
Handouts for each lecture will be uploaded to Moodle every week.

**Competencies**

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Assessed</th>
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<tbody>
<tr>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Personal Competencies</td>
<td>Critical Thinking</td>
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# CAS in Nutrition for Disease Prevention and Health - Key for Type

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# Key for Hours

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### Modules

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<tr>
<td>395-0300-00L</td>
<td>Introduction to Nutrition</td>
<td>O</td>
<td>2</td>
<td></td>
<td>1G F. von Meyenn</td>
</tr>
<tr>
<td>Abstract</td>
<td>This first module of the CAS Nutrition in Medicine will provide an overview of the most important concepts of nutrition. The introduction to nutrition specific physiology, will be followed by a more detailed overview of the macro- and micronutrients as well as their importance to health and disease.</td>
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<tr>
<td>Objective</td>
<td>Students can describe the basic concepts of nutrition Students can name the different macronutrients and can explain how they are metabolized Students can classify vitamins and minerals and can describe the most important deficiencies</td>
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<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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395-0301-00L Digital Nutrition Monitoring O 2 credits 1G

Abstract This module introduces the basic concepts of classic dietary assessment and of dietary reference values. In addition, novel, digital methods for food monitoring as well as health in general will be introduced. Biomarkers for nutritional assessment will build the last part of this module.

Objective Students can apply classic dietary assessment methods and interpret generated results Students can describe the general concept of digital health Students know how to apply methods for digital nutrition monitoring and understand their benefits and limitations

Competencies Subject-specific Competencies Concepts and Theories assessed Techniques and Technologies fostered Method-specific Competencies Media and Digital Technologies fostered Social Competencies Cooperation and Teamwork fostered

395-0302-00L Nutrition in Metabolic Disease O 3 credits 2G F. von Meyenn

Abstract The module Nutrition in metabolic disease will cover aspects of endocrinology and physiology in relation to nutrition, as well as specifically focus on nutritional aspects of obesity (including childhood obesity), type 2 diabetes including its therapy as well as muscle and exercise. In addition, different diet forms and their effects will be discussed.

Objective Students understand how nutrition is closely linked to endocrinology. Students can develop nutritional strategies to improve health of obese patients. Students can apply nutritional concepts in the support of treatment and prevention of type 2 diabetes. Students can judge different diet forms in terms of their effect health/specific health aspects.

Competencies Subject-specific Competencies Concepts and Theories assessed Techniques and Technologies fostered Method-specific Competencies Analytical Competencies assessed Social Competencies Communication fostered Cooperation and Teamwork fostered

### CAS in Nutrition in Medicine - Key for Type

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</table>

### ECTS
European Credit Transfer and Accumulation System

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### Module 2: Pharma Project Management and Health Communication

**Type:** W  
**ECTS:** 2.5 credits  
**Hours:** 3G  
**Lecturers:** R. Furegati Hafner, R. Schibli

The enrolment is done by the CAS in Pharmaceuticals study administration.

**Abstract**

In this module, students learn to plan, execute, and manage pharma industry projects effectively, emphasizing clear objectives and timelines. They develop skills in team collaboration, conflict resolution, and stakeholder communication to ensure project success. Students also enhance their ability to convey ideas clearly and persuasively to diverse audiences through role-playing exercises.

**Objective**

- About projects, project management and the project environment
- How to define and plan my project, how to deal with stakeholders and how to manage project risks
- How to manage a project team, develop the project plan and launch the project
- How to monitor and report, project close-out and project leadership
- How to evaluate a project and portfolio management
- How to handle a budget and resource management

**Competencies**

**Subject-specific Competencies**

- Concepts and Theories
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Method-specific Competencies**

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Project Management

**Social Competencies**

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Personal Competencies**

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

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### Module 7: Clinical Development

**Type:** W  
**ECTS:** 2.5 credits  
**Hours:** 3G  
**Lecturers:** R. Schibli

The enrolment is done by the CAS in Pharmaceuticals study administration.

**Abstract**

Module 7 gives an overview about the several steps that have to be followed during the process of clinical development.

**Objective**

- Preclinical bridge to clinical development
- Strategy for clinical development
- Regulatory aspects of clinical development
- Good clinical practice (GCP) and quality assurance
- First in human studies (Phase I), Proof of concept studies (Phase II), Registration studies (Phase III), Post-registration studies (Phase IV)
- Monitoring
- Organizational and financial aspects of clinical development
- Portfolio and life cycle management
- Data management and simulation of a clinical study
- Personalized medicine
Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
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- Sensitivity to Diversity
- Negotiation

Personal Competencies
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Essay

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<td>Essay</td>
<td>O</td>
<td>1</td>
<td>2D</td>
<td>R. Furegati Hafner, R. Schibli</td>
</tr>
</tbody>
</table>

Only for CAS in Pharmaceuticals.

The enrolment is done by the CAS in Pharmaceuticals study administration.

Abstract
The essay is an essential part of the CAS program „Pharmaceuticals – From Research to Market“ (CAS Pharm) and serves as final performance assessment.

Objective
The essay documents the student’s competence development during the program as well as the transfer of acquired knowledge to professional practice/activities.

Literature
www.postgraduate.pharma.ethz.ch documents: essay

CAS in Pharmaceuticals - From Research to Market - Key for Type

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ECTS
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## Core Courses and Seminars

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<th>Hours</th>
<th>Lecturers</th>
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<td>Scientific questions of monument conservation practice</td>
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<td>3 credits</td>
<td>2S</td>
<td>S. J. Slachetzki, S. Langenberg</td>
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</table>

### Abstract
The seminar provides an introduction to the basics of working with heritage theory on a scientific basis. It imparts methodological knowledge, introduces participants to archive-based research, and enables them to critically evaluate the sources consulted. The subsequent communication of the results in the form of an expert's report is also part of the course.

### Objective
The aim of the seminar is to qualify participants to apply methods of architectural and cultural studies in the evaluation of objects of the built environment. Participants are enabled to assess a selected building in the form of a heritage conservation expert's report.

### Content
An essential basis for the responsible handling of the built heritage is the ability to recognize its characteristics and special features from an architectural-historical perspective and to objectively work out its historical testimonial value. This requires knowledge of scientific methods as well as the ability to undertake targeted research and critically evaluate source material in order to productively incorporate it into the analysis. The first part of the seminar is devoted to an introduction to academic work in the field of architecture and cultural studies. This lays the foundation for the second part which deals with the independent academic appraisal of an individual building.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

#### Method-specific Competencies

- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

### Seminar Texts on Preservation

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<td>O</td>
<td>3 credits</td>
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<td>S. Langenberg</td>
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### Abstract
In the seminar, selected texts on architectural theory and monument preservation are read together and discussed in plenary. The focus is on selected writings from John Ruskin, Gottfried Semper and Friedrich Nietzsche to Alois Riegsl and Adolf Loos to Walter Benjamin, Aleida Assmann and Peter Zumthor.

### Objective
Skills in reading complex theoretical and literary writings on architecture and monument preservation are taught. With increasing practice, these enable participants to undertake an independent appropriation of architectural theory and monument preservation content.

### Content
The writings on architectural theory and historic preservation discussed in the seminar provide an overview of the most important theories and concepts of historic preservation. Ruskin’s narrative of architectural historicity, Semper’s conception of “Bekleidung” and Nietzsche's transformation of mythology are covered, as are Riegsl's notions of “Erinnerungswert” and “Gegenwartswert”, Loos’ writings on architecture, Benjamin’s notion of aura and Aleida Assmann’s memory space as well as Peter Zumthor’s atmosphere. Each text is discussed in terms of textual structure, conceptual history, visual language, relationship to poetry and literature, strategies of theory, etc. Identifying the levels and intersections that link a theory with other theories characterizes one of the main tasks of our seminar.

### Literature
- Alois Riegsl, Der moderne Denkmalkultus. Sein Wesen und seine Bedeutung, Wien / Leipzig 1903.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Decision-making
- Problem-solving

#### Method-specific Competencies
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

#### Social Competencies
- Adaptability and Flexibility
- Creative Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

### Future Monuments

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<td>2 credits</td>
<td>2V</td>
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### Abstract
Heritage conservation is dedicated to the preservation and protection of historical buildings. In this lecture, students will learn about the theoretical positions on historic monuments and the basics of preservation in practice.

### Objective
In addition to active participation in the discussions, students will be asked to engage with a topic or object of their own choice in order to be able to develop and comprehensively justify their own positions within the context of preservation. Our goal here is to foster students' communication skills and the culture of discussion.

### Content
The responsible reconstruction and further development of the existing building stock requires knowledge and an understanding of the theoretical positions conservation and the basics of preservation in practice. The core course of spring semester 2024 conveys this knowledge to students with the help of selected writings and discusses them in the context of various guest lectures.
Monographs and edited volumes:


Dehio, Georg, Kunsthistorische Aufsätze. München 1914


Franz, Birgit, Gerhard Vinken and Johanna Blokker (Hg.), Monumenta I: Internationale Grundsätze und Richtlinien der Denkmalpflege, Stuttgart 2012.


Petzet, Michael und Gert Mader (Hg.), Praktische Denkmalpflege, Stuttgart/ Berlin/ Köln 1993.


Schmidt, Leo (Hg.), Einführung in die Denkmalpflege, Darmstadt 2008.


Wohlleben, Marion und Georg Mörsch, Georg Dehio und Alois Riegler-Konservieren, nicht restaurieren. Streitschriften zur Denkmalpflege um 1900, Basel 1988 (Bauwelt Fundamente 80)

Hassler, Uta, Langfriststabilität. Beiträge zur langfristigen Dynamik der gebauten Umwelt, Zürich 2011

Fundamentals and legal texts:

Stadt Zürich Hochbaudepartement, Amt für Städtebau, Denkmalpflege und Archäologie (Hg.), Schulhäuser der Stadt Zürich. Spezialinventar Archäologie und Denkmalpflege, September 2008

Stadt Zürich Hochbaudepartement, Amt für Städtebau (Hg.), Bauten, Gärten und Anlagen 1960 bis 1980. Inventarergänzung, August 2013


Denkmalpflegegesetzgebung in den Heimatkantonen der Kursteilnehmenden.

Die Kunstdenkmäler der Schweiz

INSA – Inventare der Heimatkantonen der Teilnehmenden
The first part is devoted to substantive preservation law: legal foundations and qualification of an object as a "monument", structural-legal
aspects of protection and various protection instruments. It is planned to involve the participants by means of practical examples.

The aim of the course is to familiarise students with the essential subject areas, the most important protagonists and lines of argumentation
in the history of monument conservation. The focus is on European history and German-language sources. In order to get to know the formation of theory, its paths and detours, the most important terms and persons in the history of monument conservation are introduced. Based on various texts, the history of the protection of architectural monuments since antiquity is illuminated. Further focal points in the history of monument preservation were during the Enlightenment, the French Revolution and in the process of the formation of nation states. The discourse on the concept and practice of monument conservation as we understand it today was led by a number of conservators in the German-speaking world around 1900. War-related destruction and the incipient building boom in Europe
led to modern debates on the theory of monuments, which are still relevant today. Dealing with monument values is not an end in itself; it can be essential for the preservation of the monument or for historical mediation. Critical positions on the tasks, goals or practices of heritage preservation can only be developed against the background of a knowledge of its historical approaches.

To follow

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<tr>
<th>Number</th>
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<td>Theory and History of Preservation</td>
<td>O</td>
<td>2 credits</td>
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**Literature**

- Leo Schmidt, Einführung in die Denkmalpflege, Darmstadt 2006.
  (Bauwelt Fundamente, vol. 109).
- Wolfgang Götz, Beiträge zur Vorwissenschaft der Denkmalpflege. Die Entwicklung der Denkmalpflege in Deutschland vor 1800 (Diss. Leipzig 1956), Zurich 1999 (Veröffentlichungen des Instituts für Denkmalpflege an der ETH Zürich, vol. 20).
- Gottfried Kiesow, Einführung in die Denkmalpflege, Darmstadt 1982.
- Denkmalschutz. Texte zum Denkmalschutz und zur Denkmalpflege, Bonn 1996 (Schriftenreihe des Deutschen Nationalkomitees für Denkmalschutz, vol. 52).

**Prerequisites / notice**

To follow
Abstract
In addition to theory, heritage conservation also plays an important practical role in the current building revolution. In order to make the diverse possibilities in architecture visible, this course develops new strategies for communicating the discipline of monument preservation for an exhibition on this topic at S AM in 2025.

Objective
The aim of the seminar is to develop concepts for communicating and exhibiting heritage-related content and debates that go beyond specialist discourse and address a broader public. As part of the course, participants will acquire in-depth knowledge of various exhibition strategies in the field of architecture and will have the opportunity to develop exhibits for an exhibition organised by the S AM Swiss Architecture Museum (Basel) in collaboration with the Chair of Construction Heritage and Monument Preservation at ETH Zurich and ICOMOS Suisse in spring 2025.

Content
At a time when the maintenance of existing buildings is seen as an essential element of the building revolution, the theory and practice of heritage conservation is taking on an integral role. Nevertheless, heritage conservation still has to contend with image problems: people often misunderstand exactly what its aim is and, unaware of its mission, principles and (still highly topical) theories, the discipline is often assumed to have a purely conservative attitude. 50 years after the European Year of Monument Conservation in 1975, when the whole of Europe was dominated by the question of how to preserve the built heritage, there is no need for a fundamental repositioning, but there is certainly a need for an “update” on issues of monument conservation and its attitude in the face of current challenges. The joint exhibition at the S AM Swiss Architecture Museum in spring 2025 is dedicated to this topic. The course offers the opportunity to deal with architectural exhibition strategies and to participate in the development of various concepts for communicating the theory and practice of heritage conservation. New guiding principles for the future practice of heritage conservation will be jointly derived on the basis of best practice examples. In group work, current examples of successful cooperation between heritage conservation and architecture will be analyzed and documented for presentation in the exhibition in the form of drawings, texts and models. Depending on the number of participants, other parts of the exhibition can also be the subject of the work.

Prerequisites / notice
The course addresses primarily students of the MAS ETH in Denkmalpflege und Konstruktionsgeschichte and the CAS ETH in Future Heritage.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: fostered
- Project Management: fostered

Method-specific Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

CAS in Preservation - Key for Type

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Key for Hours

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<td>exercise</td>
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<td>seminar</td>
<td>R</td>
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ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
# CAS in Public Governance and Administration

## CAS Thesis

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<td>7</td>
<td>13D</td>
<td>R. Perich</td>
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**Abstract**
In their CAS thesis, participants synthesize their learning and apply their insights to their own institutions or examine a relevant topic employing the course methodologies.

**Objective**
Practical application of course content and concepts.

**Competencies**

<table>
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## Module

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**Abstract**
The programme equips the next generation of leaders in the public sector and other sectors dealing with governance matters with the necessary competencies to tackle complex governance challenges.

**Objective**
Participants learn to:
- Understand key governance frameworks and international blueprints; comprehend underlying drivers & challenges affecting governance;
- dissect multi-dimensional policy issues; lead effectively across the spectrum of technical, human and conceptual challenges.

**Content**
The program encompasses a sequence of one or half-day modules, which are organized into three interdisciplinary learning blocks:

**I. Contemporary Governance**
In this block, participants examine the broad frameworks within which public sector work takes place. Students will explore what governance in the 21st Century means as well as the theoretical and practical nature of organizational, legal, regulatory and financial dimensions of public institutions and processes. With input from multiple disciplines, students gain the ability to contextualize and critically assess the local, national as well as international context of their individual work.

**II. Public Management**
In this block, students are challenged to expand their management toolbox through lectures providing them with theoretical context and practical insights into various aspects of public management. The goal is for participants to enhance their ability to lead and motivate teams, to negotiate effectively and to communicate with a variety of stakeholders.

**III. Policy Domains**
This block covers relevant and rapidly changing policy domains. Special attention is paid to interlinkages between specific policy areas. Students gain the big picture knowledge necessary to make informed managerial decisions within complex processes and initiatives.

**Competencies**

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**CAS in Public Governance and Administration - Key for Type**

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**Key for Hours**

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Special students and auditors need special permission from the lecturers.

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Data: 15.06.2024 12:39   Autumn Semester 2024   Page 500 of 2653
# CAS in Radiopharmaceutical Chemistry, Radiopharmacy

## Modules

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<tr>
<td></td>
<td>Knowledge of the fundamentals of development, preparation, testing and stability of sterile radiopharmaceutical preparations.</td>
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<td>Acquisition of basic information on European legislation in Radiopharmacy including GMP and Pharmacopoeia.</td>
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<td>• GMP: industrial point of view</td>
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<td>• Molecular and cellular aspects of radiobiology</td>
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<td>• Pharmacopoeia</td>
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<td>• Pharmacopoeia – how to use it</td>
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<td>• Design of dosage forms for pharmaceuticals</td>
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<td>• Pharmaceutical packaging</td>
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<td>• Methods of preparation of sterile products</td>
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<td>• Aseptic preparation</td>
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<td>• The role of excipients in parenteral radiopharmaceutical preparations</td>
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<td>• Sterility testing and endotoxin determination</td>
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<td>• Particulate contamination</td>
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<td>• Principles of medicinal chemistry</td>
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<td>• An overview of modern pharmaceutical analysis</td>
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<td>• Genetic engineering</td>
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<td>• Stability and shelf-life of pharmaceuticals</td>
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<td>• (in)stability of radiopharmaceuticals</td>
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<td>• Quality assurance and preparation of SOP</td>
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<td>• Water for pharmaceutical use</td>
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<td>• Practicals: visit to hospital radiopharmacy</td>
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<td>• Basic concepts of pharmacokinetics</td>
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<td>• Drug regulatory affairs</td>
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<td>• Microbiology in Pharmacy</td>
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<td>• Visit to pharmaceutical company</td>
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<td>Integrity and Work Ethics</td>
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<td>Module III: Radiopharmacology and Clinical Radiopharmacy</td>
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<td>R. Schibli, R. Furegati Hafner</td>
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<td>The enrolment is done by the CAS study administration.</td>
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<tr>
<td>Abstract</td>
<td>Knowledge about the fundamentals of pharmacokinetics and pharmacokinetic modelling, the basic concepts of pharmacology and toxicology, radiopharmaceutical monographs in the European pharmacopoeia, radiological imaging modalities and the basics of applied statistics in biomedical research. Understanding the fundamentals of nuclear medicine: Diagnostic applications in neurology and oncology therapy.</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 501 of 2653
Objective
Students know about:
- Pharmacokinetik and kinetic-modelling
- Statistics and practical session
- Radiotracers in biochemistry and molecular pharmacology
- Selective modification of peptides and proteins to target GPCRs
- Demonstration of experimental set up: Peptide and protein modification, radioactive assays in biochemistry
- Visit ABX Radeberg
- Nuclear medicine: basics and therapy
- Immunology
- Drug interventions/interactions/adverse reactions
- Pharmacology basics, special aspects, clinical studies
- Toxicology
- Teatystems in toxicology and targeted therapeutics and nucleic acids
- Nuclear medicine: clinical diagnostic applications in neurology
- Nuclear medicine: visit to SPECT facility and radiopharmaceutical GMP lag (Tc, Ga, therapy)
- Radiological imaging modalities- technology and applications
- Nuclear medicine: clinical diagnostic applications in oncology
- Radiopharmaceutical monographs in the European pharmacopoeia
- Practical session, visit: cyclotron, GMP PET production and quality control, PET and PET/CT, therapy unit
- Radioligand-binding-assays/autoradiography
- In house tours in groups: radioligand-binding-assays, autoradiography, metabolite analytics with LC-MS, cyclotron and radiochemistry, highlights in Leipzig
- Biological effects of radiation
- Radiotracer transport and blood brain barrier
- Radiotracers for neuromaging

Competencies
Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

CAS in Radiopharmaceutical Chemistry, Radiopharmacy - Key for Type

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Key for Hours

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ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Introduction

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<tr>
<th>Number</th>
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<td>135-0001-00L</td>
<td>Einführung: Grundlagen der Raumentwicklung</td>
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<td>3</td>
<td>2G</td>
<td>S. Kissling, A. Rupf, J. Van Wzemael</td>
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</table>

Abstract
Orientation and preparation for further education in the field of spatial planning and development. Introduction to the Spatial Planning Act and its instruments, assessment of participants' knowledge. Completion through mandatory assessment.

Spatial Development and Planning Practice

<table>
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<tr>
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<td>Module 1: Spatial Planning</td>
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Abstract
Overview of current and future tasks of spatial planning, discussion of formal and informal instruments, and introduction to a methodical way of action-oriented planning. (Tasks, methods and instruments).

<table>
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<tr>
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<td>Module 2: Space as a Complex Situation</td>
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Abstract
Introduction to the nature and pitfalls of complex situations, methods and processes for treatment. Introduction to spatial planning and planning actions in multi-actor networks. (Perceiving, acting and arguing in complex situations).

<table>
<thead>
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Abstract
Inputs for the integrated development of livable urban spaces in connection with central aspects and mechanics of mobility, open spaces, and social spaces. (In the tension field of mobility, open space, and society).

<table>
<thead>
<tr>
<th>Number</th>
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<td>135-0103-00L</td>
<td>Module 4: Functional Regions</td>
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Abstract
Discussion of the development of large-scale and cross-border spaces. Designing and planning in multi-actor networks, spatial concepts as a basis for cooperation and coordination tasks. (Designing and developing large-scale tasks).

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<td>135-0104-00L</td>
<td>Module 5: Shaping Transformation</td>
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Abstract
Exploration of current and future questions of planning law and discussion of the further development of planning instruments and processes. (Law, process, and instruments II).

<table>
<thead>
<tr>
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<td>Design Studio</td>
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</table>

Abstract
Module 1-5: Introduction of the task and excursion, integrated location assessment, development of viable action options and interim critique, overall concept and in-depth study, finalization and final critique.

CAS in Spatial Development and Planning Practice - Key for Type

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<th>Type</th>
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Key for Hours

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ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
CAS in Regenerative Materials - Hygrothermal Specialisation
Offered only in the Autumn Semester.


<table>
<thead>
<tr>
<th>Number</th>
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<td>136-0201-00L</td>
<td>General Knowledge on Hygrothermal Building Physics</td>
<td>O</td>
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<td>3G</td>
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<tr>
<td>Abstract</td>
<td>Regenerative Materials can be used to build high- quality envelopes and high- comfort environments. The course presents the basics of hygrothermal building physics and the state of the art in this field. It gives an overview of the type of earth- and bio-based materials that can be used and their hygrothermal properties.</td>
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</table>
| Objective  | - Learn the diversity of regenerative materials used for high- quality envelopes and high- comfort environments  
- Learn how to distinguish earth- and bio-based materials based on their hygrothermal properties  
- Ensure an efficient and durable impact on participants' professional development |
| Content    | The course presents which Regenerative Materials can be used to build high- quality envelopes and high- comfort environments. It details the basics of hygrothermal building physics: Evolution of standards and models; Strength and weaknesses of Regenerative Materials; State of the art and market evolution. It also gives an overview of the diversity of earth-based materials (plasters, blocs, monolith walls); bio-based materials with fibers (straw bales, wool and rigid panels, bulk fibers) and low-impact composites (light mixes combining mineral binder to bio- sourced materials) from resource to implementation, with a synthesis of their hygrothermal properties and their impact on comfort and energy savings. |
| Competencies | Subject-specific Competencies  
Concepts and Theories  
Techniques and Technologies |
| Method-specific Competencies | Analytical Competencies  
Decision-making |
| Social Competencies | Self-presentation and Social Influence  
Sensitivity to Diversity |
| Personal Competencies | Adaptability and Flexibility  
Creative Thinking |

| 136-0202-00L | Constructive Details & Implementation of Regenerative Envelops | O    | 2    | 3G    | G. Habert |
|             | Does not take place this semester.                      |      |      |       |           |
| Abstract    | The course is focused on constructive details for regenerative materials used to build high-quality envelopes and high-comfort environments. The participant are mainly learning through a hands-on workshop during which they will produce different prototypes in small groups. |
| Objective   | - Apply knowledge from previous course on high-quality envelopes built with regenerative materials  
- Learn how to compare different constructive systems built with regenerative materials to conventional building techniques considering thermal insulation, thermal mass, moisture regulation and air tightness  
- Ensure an efficient and durable impact on participants' professional development |
| Content     | Small groups producing different prototypes during a hands-on workshop. Each group design and realize a prototype to explore a specific constructive technique using Regenerative Materials and considering thermal insulation, thermal mass, moisture regulation and air tightness. Monitoring devices will be installed in each prototype. These prototypes are compared to reference prototypes built with conventional building techniques. |
| Competencies | Subject-specific Competencies  
Concepts and Theories  
Techniques and Technologies |
| Method-specific Competencies | Analytical Competencies  
Decision-making |
| Social Competencies | Cooperation and Teamwork  
Self-presentation and Social Influence  
Sensitivity to Diversity |
| Personal Competencies | Adaptability and Flexibility  
Creative Thinking |

| 136-0203-00L | Advanced Knowledge on Hygrothermal Assessment | O    | 2    | 3G    | G. Habert |
|              | Does not take place this semester.               |      |      |       |           |
| Abstract     | This course offers advanced knowledge on HAM (Heat Air and Moisture) modeling. The most up-to-date simulation models will be presented and used by the participants on real-case projects during simulation workshops. |
| Objective    | - Learn how to use the most up-to-date HAM simulation models  
- Learn how to analyse the transient hygrothermal behaviour of an envelope  
- Ensure an efficient and durable impact on participants' professional development |
| Content      | Advanced knowledge on HAM modeling is presented during simulation workshops:  
- Transient hygrothermal behaviour:  
Presentation of relevant software by experts users or developers  
Presentation of a case study by the HVAC engineers in charge of the calculation  
Calculation exercises based on this case study  
- Digital parametric iteration:  
Presentation of relevant software by experts users or developers  
Presentation of a case study by the HVAC engineers in charge of the calculation  
Calculation exercises based on this case study |
### Competencies

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### Project

#### Number 136-0250-00L

**Title**: Project Work on Hygrothermal Validation  
**Type**: O  
**ECTS**: 6 credits  
**Hours**: 3G  
**Lecturers**: G. Habert

**Abstract**: Based on the content of previous courses, the participants are asked to simulate to analyze the hygrothermal behaviour of a building built with the same constructive technique as their prototype. In addition, they have to reproduce the monitoring conditions of their prototypes and compare measurements to simulation results. The result and discussion are presented in front of a jury.

**Objective** - Apply knowledge from previous courses on a case study  
- Learn how to compare measurements to simulation results  
- Enhance communication skills concerning high-quality envelopes built with regenerative materials

### CAS in Regenerative Materials - Hygrothermal Specialisation - Key for Type

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### Key for Hours

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# CAS in Regenerative Materials - Structural Specialisation

## Modules

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<td>General Knowledge on Structural Analysis</td>
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<td>4G</td>
<td>G. Habert</td>
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<td>136-0302-00L</td>
<td>Constructive Details &amp; Implementation of Regenerative Structural Systems</td>
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<td>G. Habert</td>
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<tr>
<td>136-0303-00L</td>
<td>Advanced Knowledge on Structural Assessment</td>
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<td>G. Habert</td>
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## Project

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### ECTS

- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
### Modules

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**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### CAS in Regenerative Systems: Sustainability to Regeneration

Offered only in the Autumn Semester (two-yearly).

Further information: https://systemicdesignlabs.ethz.ch/cassustainabilitytoregeneration/

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**Abstract**

This learning module navigates the journey from global crises to local interventions by first emphasizing the significance of resilience in DRRS. It then explores global crises through diverse perspectives in the "Framing nested crises" submodule. The subsequent submodules focus on practical skills at the community level and the societal and individual root causes of crises.

**Objective**

The "From global crises to local interventions" module is designed to achieve several key learning objectives within the Designing Resilient Regenerative Systems (DRRS) context. Participants will gain a comprehensive understanding of resilience, appreciating its richness and diversity to maximize practical applications within DRRS. The module encourages a multiperspective analysis of global crises, exploring diverse viewpoints influenced by angles, interests, training, geographies, institutions, and worldviews.

Emphasis is placed on developing practical skills at the community level, equipping participants to enhance local resilience and response capabilities within the framework of DRRS. This includes identifying and applying skills crucial for mitigating the impact of disasters and promoting community well-being.

Furthermore, the module delves into the societal and individual root causes contributing to global crises within the paradigm of DRRS. Participants will learn from experts about strategies to understand and address these root causes, fostering effective intervention at both the societal and individual levels.

Through all modules, the course integrates three domains of learning competencies—cognitive, behavioral, and social—interconnected through the individual Quests of the learners.

**Content**

Centered on the pivotal concept of resilience, the module facilitates a nuanced understanding of its richness and diversity for optimal application in addressing crises. Participants are guided through a multiperspective analysis of global crises, considering various viewpoints influenced by angles, interests, training, geographies, institutions, and worldviews.

A significant focus is placed on practical skills development at the community level within the DRRS paradigm. Participants acquire the necessary tools to enhance local resilience and response capabilities, emphasizing mitigating the impact of disasters and fostering community well-being.

The module delves into the root causes of global crises at both societal and individual levels, aligning with the principles of DRRS. Experts share insights on strategies to understand and address these root causes, fostering effective interventions that resonate with the DRRS approach.

**Lecture notes**

See Module 1.1 in MOOC#1 Worldviews - From Sustainability to Regeneration: https://www.edx.org/learn/ethics/eth-zurich-worldviews-from-sustainability-to-regeneration

**Literature**

See Module 1.1 in MOOC#1 Worldviews - From Sustainability to Regeneration: https://www.edx.org/learn/ethics/eth-zurich-worldviews-from-sustainability-to-regeneration

**Prerequisites / notice**

MOOC#1 Worldviews - From Sustainability to Regeneration is a pathway to CAS#1 Sustainability to Regeneration. To be accepted into the CAS, applicants must have completed the respective MOOC by the time the CAS starts. The content from the MOOC will be supplemented in the CAS by live virtual events with experts from all over the world. In addition, after the first virtual introductory introductory week, a real design excursion to the MonViso Institute in Italy. This trip is obligatory.

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**Abstract**

This learning module focuses on exploring sustainability at a deep and critical level, encouraging participants to delve into the fundamental principles of sustainability, reflect on their mental models, and critically examine the Sustainable Development Goals. The module also aims to expand participants’ thinking towards regeneration.
Objective

In this module, participants will explore sustainability comprehensively, delving into core learning objectives. The journey begins with a profound understanding of sustainability fundamentals, prompting reflection on personal mental models. Participants will critically scrutinize the Sustainable Development Goals (SDGs) and navigate sustainability science theories, explicitly focusing on concepts like Planetary Boundaries. The intersection of artificial intelligence (AI) and sustainability will be examined, fostering critical perspectives.

Practical knowledge takes center stage, focusing on soil regeneration and providing tangible insights into sustainable practices. Participants can engage with the content through flexible mediums, including videos, audio files, or transcripts, tailoring the learning experience to personal preferences.

The application of systems thinking is encouraged, prompting participants to analyze and summarize critical arguments and worldviews presented in the content.

Participants are invited to develop their Quests further, facilitating a holistic exploration of sustainability concepts. Sharing written or graphical reflections with learning partners and the DRRS network promotes collaboration, creating a dynamic community of learners committed to advancing sustainability knowledge.

Content

The learning content of this module is rich and multifaceted, offering a deep exploration of sustainability from various perspectives. Participants engage in a thoughtful journey that begins by understanding the fundamental principles of sustainability and reflecting on personal mental models. Critical examination of the Sustainable Development Goals (SDGs) and exploring sustainability science theories, including concepts like Planetary Boundaries, provide a robust theoretical foundation.

The module goes beyond theory to address the practical aspect of sustainability, focusing on soil regeneration. Participants can choose their preferred learning medium, videos, audio files, or transcripts, enhancing accessibility.

Including artificial intelligence (AI) in the sustainability discourse adds a contemporary dimension, prompting participants to develop critical perspectives on the evolving relationship between technology and sustainability.

Lecture notes

See Module 1.2 in MOOC#1 Worldviews - From Sustainability to Regeneration: https://www.edx.org/learn/ethics/eth-zurich-worldviews-from-sustainability-to-regeneration

Literature

See Module 1.2 in MOOC#1 Worldviews - From Sustainability to Regeneration: https://www.edx.org/learn/ethics/eth-zurich-worldviews-from-sustainability-to-regeneration

Prerequisites / notice

MOOC#1 Worldviews - From Sustainability to Regeneration is a pathway to CAS#1 Sustainability to Regeneration. To be accepted into the CAS, applicants must have completed the respective MOOC by the time the CAS starts. The content from the MOOC will be supplemented in the CAS by live virtual events with experts from all over the world. In addition, after the first virtual introductory introductory week, a real design excursion to the MonViso Institute in Italy. This trip is obligatory.

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Competencies

Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

Social Competencies

- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies

- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: fostered

Module 3: Worldviews

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Abstract

This learning module titled "Worldviews" delves into the exploration of how individuals perceive the world and construct their understanding of reality. It emphasizes the significance of worldviews, defined as fundamental beliefs and modes of participation in the broader context.

In this module, participants will embark on a journey to explore the rich tapestry of worldviews, understanding how different cultures and individuals perceive and reason about the world. The learners delve into the intersection of scientific discourse and practical application (praxis), examining the profound impact of scientific perspectives on shaping our collective understanding. A key focus is introducing "warm data," a concept that adds depth to our comprehension of complex systems, demonstrated through real-world examples such as fast fashion dumps and agroforest systems.

The module highlights the role of design, emphasizing both design processes and meta-design—viewing mental maps as dynamic tools that can foster collaborative transformations toward resilient and regenerative systems. Furthermore, the participants explore the potential of artificial intelligence (AI) as a catalyst for regeneration, investigating its role in sustainable practices and contemplating ethical considerations for its responsible integration. Participants are encouraged to engage actively, broaden their perspectives, and contribute to collectively shaping a more sustainable and regenerative future through these objectives.

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**Content**

The module starts by delving into the fundamental concept of worldviews, emphasizing their role as foundational beliefs and modes of participation in the broader context. The inclusion of perspectives from Daniel Wahl and Jeremy Lent, as well as an exploration of indigenous and Eastern philosophies, provides a well-rounded approach to understanding diverse ways of knowing and reasoning.

Incorporating practical examples, such as fast fashion dumps in Chile and agroforestry systems in African countries, adds a tangible dimension to the theoretical discussions. This approach helps participants connect abstract concepts to real-world scenarios, fostering a deeper understanding of the implications of different worldviews on environmental and societal issues.

The emphasis on "warm data" introduces a holistic perspective, encouraging participants to consider interconnected systems and view challenges comprehensively. Including meta-design as a tool for collaborative transition promotes active engagement in shaping resilient and regenerative systems.

Furthermore, the module's exploration of the role of artificial intelligence (AI) in regeneration adds a forward-looking dimension, addressing the potential for technological innovation to contribute to sustainable practices.

**Lecture notes**

See Module 1.3 in MOOC#1 Worldviews - From Sustainability to Regeneration: https://www.edx.org/learn/ethics/eth-zurich-worldviews-from-sustainability-to-regeneration

**Literature**

See Module 1.3 in MOOC#1 Worldviews - From Sustainability to Regeneration: https://www.edx.org/learn/ethics/eth-zurich-worldviews-from-sustainability-to-regeneration

**Prerequisites / notice**

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**Module 4: Reframing Complexity**

*Does not take place this semester.*

**Abstract**

The module "Reframing complexity" invites participants to explore various access points for dealing with uncertainty, fostering a holistic perspective on complexity and encouraging a more nuanced and informed approach to navigating complex living systems.

**Objective**

The "Reframing complexity" module aims to empower participants to understand the intricacies of living systems deeply. Key learning goals include distinguishing between complexity and simplicity, challenging traditional views by fostering a mindset that embraces complexity, and exploring how to design resilient strategies within complex systems. The module emphasizes the role of big data and visualization tools in intervention strategies. Participants will also grasp the interconnectedness of science, praxis, data types, warm data, and AI in complex systems. The overarching objective is to enable individuals to navigate uncertainty by identifying various access points and weaving diverse perspectives into a holistic understanding of complexity.

**Content**

Beginning with Eric Berlow's perspective on "The Other Side of Complexity," the module challenges conventional views and introduces alternative ways of understanding intricate systems.

Fritjof Capra, a renowned figure in systems thinking, contributes to the module focusing on "Complexity Science and Systems Thinking." Participants can anticipate a deep dive into the foundations of complexity science and the principles of systems thinking.

The Hinnen Brothers bring a practical dimension to the module with "Reframe It!" where participants are guided in adopting a reframed mindset towards complexity, offering tangible tools for navigating complex systems.

Michael Stauffacher from ETH Zurich sheds light on the intersection of "Science and Praxis," providing valuable insights into how scientific knowledge translates into practical applications, particularly within the realm of complex systems.

Nora Bateson contributes to the module focusing on "Warm Data," emphasizing the significance of contextual and relational information in understanding complexity. Participants explore how such insights contribute to a more holistic understanding of complex systems.

The module further investigates the role of artificial intelligence in "When is AI Regenerative?"—examining scenarios where AI positively influences the resilience and regeneration of complex systems.

Finally, the module addresses the intricate challenges involved in "Complexities of Decarbonization," providing participants with a nuanced understanding of the hurdles and considerations in transitioning to sustainable and low-carbon practices.

**Lecture notes**

See Module 1.4 in MOOC#1 Worldviews - From Sustainability to Regeneration: https://www.edx.org/learn/ethics/eth-zurich-worldviews-from-sustainability-to-regeneration

**Literature**

See Module 1.4 in MOOC#1 Worldviews - From Sustainability to Regeneration: https://www.edx.org/learn/ethics/eth-zurich-worldviews-from-sustainability-to-regeneration
The critical learning goals center around biodiversity, deep ecology, and our intrinsic connection to nature. The module emphasizes the need to relearn and cultivate a deeper understanding of nature, its design language, and patterns. The critical learning goals center around biodiversity, deep ecology, and our intrinsic connection to nature. The module emphasizes the need to relearn and cultivate a deeper understanding of nature, its design language, and patterns. The "Design as Nature" module unfolds through several key subchapters, each addressing crucial aspects of the relationship between humanity and the natural world. A pivotal aspect of the learning experience involves embracing the notion that humans are not separate from nature but an integral part of it. This realization forms a foundational understanding that guides the exploration of sustainable practices.

The learning module on "Design as Nature" explores the disconnect between Western cultures and nature. The module emphasizes the need to relearn and cultivate a deeper understanding of nature, its design language, and patterns. By doing so, they gain insights into creating sustainable solutions that align with the regenerative patterns observed in the natural world.

Bio-infused communication emerges as a significant aspect, urging participants to explore ways of interacting with the environment inspired by nature. This approach fosters a harmonious relationship with the ecosystems we inhabit. Finally, the module delves into the realm of nature finance, where economic mechanisms are derived from nature's principles. The goal is to inspire a redesign of financial systems, aligning them with regenerative and sustainable practices. Combining these learning goals, the "Design as Nature" module provides a comprehensive framework for reconnecting with nature, understanding its design language, and actively contributing to a more sustainable and harmonious coexistence.

Beginning with a focus on biodiversity, the module underscores the vital role of diverse life forms in maintaining ecosystem health. It encourages participants to appreciate the intricate interdependence within natural environments.

"Design for Biodiversity" delves into the impact of human designs on biodiversity, urging the development of solutions that actively support and enhance the richness of life rather than compromise it.

The concept of Deep Ecology - connecting with nature is introduced to cultivate a heightened sense of connection and reverence for the environment. Participants are prompted to reflect on their relationship with nature, fostering a holistic perspective.

Moving into the realm of nature-based design, the module explores the principles of biomimicry. Participants are inspired to learn from nature's design to create sustainable and regenerative solutions, with real-world examples highlighting the positive impact of such approaches.

Bio-infused relation building shifts the focus to communication and interaction with the environment. Participants are encouraged to build relationships with nature that are respectful and sustainable and contribute to overall ecological harmony.

Lastly, the module investigates regenerative economics, exploring economic mechanisms derived from nature. The goal is to redesign financial systems in a way that aligns with sustainable practices and contributes positively to the regeneration of ecosystems.

Does not take place this semester.

The final delivery of the CAS should demonstrate the scientific base of our work in evidence-based writing with a foundation in the peer-reviewed literature and graphical, visual, systems-mapping, and spatial ways of designerly expressions. As the main deliverable, participants must submit a framed graphical Quest synthesis process map consisting of two main parts: a graphical synthesis map (pdf format) and a framing text bracket that motivates, introduces, explains, discusses, and concludes the synthesis map.

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### Module 6: Mind and Movement

**Does not take place this semester.**

**Abstract**

This learning module on mind and movement focuses on facilitating cultural changes by guiding participants through their own unlearning journeys. The module emphasizes the importance of enduring challenging processes to design for regeneration, build personal resilience, and lead collective co-creation.

**Objective**

The learning objectives revolve around actively cultivating a profound relationship with one's surroundings through movement, fostering a deep connection to place. The module strongly emphasizes immersive experiences, encouraging participants to fully engage and be present, providing a richer understanding of self, others, and the more-than-human world.

Self-discovery takes center stage as participants are prompted to question and challenge their perceived physical and psychological boundaries. The module equips individuals with the tools to build resilience in their engagements with place, self, and others, navigating challenges with adaptability and strength.

Exploring the transformative power of movement, participants learn to mediate their relationships with self through action, understanding, and expressing emotions physically. The curriculum also guides individuals to develop ecologically attuned and reciprocal conversations, fostering a deeper connection with human and non-human entities in their environment.

Redefining adventure becomes a key theme, encouraging participants to move beyond conventional notions and embody their practices. Participants transform routine experiences into meaningful and adventurous engagements by integrating movement and mindfulness into daily activities.

Philosophically grounded in contemporary neuroscience, the module challenges traditional views that separated the mind and body. It underscores the interconnectedness of these elements, recognizing the profound significance of emotions and bodily experiences in the pursuit of self-realization and holistic growth. Through this multifaceted approach, participants are empowered to reframe their relationship with the world, themselves, and the more-than-human aspects of their environment.

**Content**

This learning module on mind and movement stands out for its holistic approach to personal and collective development. By seamlessly integrating physical movement, mindfulness practices, and ecological awareness, participants are offered a multifaceted exploration of their experiences.

A notable strength lies in the practical application of concepts, focusing on immersive experiences such as cultivating relationships through movement and redefining adventure. This hands-on approach adds a tangible and applicable dimension to the learning journey.

The module emphasizes building resilience in engagements with place, self, and others, recognizing the importance of adaptability and strength in navigating challenges. Additionally, the ecological awareness component, encouraging participants to develop attuned and reciprocal conversations with human and non-human entities, aligns with a contemporary understanding of our interconnectedness with the environment.

**Lecture notes**

See Module 1.6 in MOOC#1 Worldviews - From Sustainability to Regeneration: https://www.edx.org/learn/ethics/eth-zurich-worldviews-from-sustainability-to-regeneration

**Literature**

See Module 1.6 in MOOC#1 Worldviews - From Sustainability to Regeneration: https://www.edx.org/learn/ethics/eth-zurich-worldviews-from-sustainability-to-regeneration

**Prerequisites / notice**

MOOC#1 Worldviews - From Sustainability to Regeneration is a pathway to CAS#1 Sustainability to Regeneration. To be accepted into the CAS, applicants must have completed the respective MOOC by the time the CAS starts. The content from the MOOC will be supplemented in the CAS by live virtual events with experts from all over the world. In addition, after the first virtual introductory introductory week, a real design excursion to the MonViso Design excursion to the MonViso Institute in Italy. This trip is obligatory.

The final delivery of the CAS should demonstrate the scientific base of our work in evidence-based writing with a foundation in the peer-reviewed literature and graphical, visual, systems-mapping, and spatial ways of designerly expressions. As the main deliverable, participants must submit a framed graphical Quest synthesis process map consisting of two main parts: a graphical synthesis map (pdf format) and a framing text bracket that motivates, introduces, explains, discusses, and concludes the synthesis map.
<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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<tr>
<td>Method-specific Competencies</td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Communication</td>
<td>fostered</td>
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<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
<td>fostered</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
<td>fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td></td>
<td>Creative Thinking</td>
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<td></td>
<td>Critical Thinking</td>
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<td></td>
<td>Integrity and Work Ethics</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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<td></td>
<td>Self-direction and Self-management</td>
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<td></td>
</tr>
</tbody>
</table>

**CAS in Regenerative Systems: Sustainability to Regeneration - Key for Type**

| O    | Compulsory             | E- | Recommended, not eligible for credits |
| W+   | Eligible for credits and recommended | Z  | Courses outside the curriculum |
| W    | Eligible for credits   | Dr | Suitable for doctorate |

**Key for Hours**

| V    | lecture                | P  | practical/laboratory course |
| G    | lecture with exercise  | A  | independent project |
| U    | exercise               | D  | diploma thesis |
| S    | seminar                | R  | revision course / private study |
| K    | colloquium             |    |          |

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### CAS in Regulatory Thinking

#### Modules

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>395-0200-00L</td>
<td>Regulatory World</td>
<td>O</td>
<td>1 credit</td>
<td>2G</td>
<td>J. Goldhahn, I. Clay, D. Schaffarczyk</td>
</tr>
</tbody>
</table>

**Abstract**
Participants will be introduced into regulations and landscape including all stake holders. The different types of medicinal products are introduced including subsequent regulations. Participants apply the knowledge in different starting scenarios.

**Objective**
- Understand the complexity of the regulatory landscape
- Know the main characteristics of different medicinal products and subsequent regulatory pathways
- Identify the different stakeholders and players in this landscape
- Analyze different regulatory strategies using real-world cases

**Content**
- The regulatory landscape – a challenge for all players
- Different types of medicinal products - different regulatory pathways
- Health authorities – friend or foe?
- Different countries – different regulations
- Successful regulatory strategy – make or break for a medicinal product
- From idea to product – do it yourself

<table>
<thead>
<tr>
<th>395-0201-00L</th>
<th>Regulatory Thinking</th>
<th>O</th>
<th>2 credits</th>
<th>4G</th>
<th>D. Schaffarczyk, R. Abächerli, further lecturers</th>
</tr>
</thead>
</table>

**Abstract**
Students gain an overview of how to transform a research idea into a finished healthtech product by confidently navigating different regulatory landscapes and developing compelling certification strategies for various healthtech products. Students learn how to use Regulatory Thinking to turn Regulatory Affairs into a business planning tool.

**Objective**
- Applying regulatory thinking and translation of this method into practice.
- Getting an overview of applicable laws, different regulations, directives and guidelines in the healthtech sector: MD, IVD, SaMD, medicine, biotech, ATMP.
- Understanding the different roles and responsibilities of Certification Bodies (CB), Notified Bodies (NB), and other Regulators and/or Reimbursement Agencies, hereafter: Competent Authorities (CAs).
- Knowing how to address CAs, including communication and interaction
- Awareness of the importance of a quality management system (QMS) and knowing different systems, including, but not limited to ISO 13485:2016, GMP, GLP, GCP

**Content**
The journey of regulatory thinking - from medical devices (MDs), to in vitro diagnostics (IVDs), to software as a medical device (SaMD), to medicines and advanced therapeutic medicinal products (ATMPs): Commonalities, differences and the search for the lowest common denominator in terms of:
- Regulations/Directives/Laws/Guidelines
- Interaction with the regulatory authorities
- The principles of safety/efficacy/performance/transparency
- The requirements for the implementation of a QMS

<table>
<thead>
<tr>
<th>395-0202-00L</th>
<th>Intended Use / Indication</th>
<th>O</th>
<th>2 credits</th>
<th>4G</th>
<th>D. Schaffarczyk, R. Abächerli, further lecturers</th>
</tr>
</thead>
</table>

**Abstract**
From software as a medical device to medicinal products: The intended use of a healthtech product serves as strategic pivotal point from conception to reimbursement strategies: Understanding its importance defines advertising claims and ensures that the product meets the needs of patients.

**Objective**
- Know and understand different definitions: medical need / public health assessment; personalized medicine, pharmacogenomics/ customized device.
- Understand the importance of medical and stakeholder needs assessments in medicine / medtech / in-vitro diagnostics / software as medical device / artificial intelligence and among different stakeholders.
- Understand the relationship between indication / intended use / intended purpose and development, including risk assessment.
- Define the intended use / intended purpose for a healthtech product and derive user groups, patient groups, indications and contraindications.
- Understand and derive an overview of the different stakeholders of a healthtech product and their different interests.

**Design and Development Plan, Clinical Development Plan:** Plan development correctly.

**Overview**
- Overview of different development models, starting with requirements engineering, the classical waterfall model and V-model up to agile methods for software as medical device or AI concepts.
- ISO 14971: Understanding and applying principles of risk man-agement.
- IEC 62366: Understanding and applying the principles of usability engineering.

**Artificial Intelligence:** Know the challenges of artificial intelligence in healthtech products, define an AI policy and develop a verification process.
Content

The intended use is the “linchpin” in the development, approval and reimbursement of medicinal products or medical devices: Whether software as a medical device, artificial intelligence in medical devices, but also in pharmaceuticals or biotechnology, the intended use is the first and last touchstone - alpha and omega - of all healthtech concepts.

- Intended use, user and patient groups I/III: How the intended use of a healthtech product influences its development, safety, performance, marketing strategy and reimbursement possibilities.

- Intended use, user and patient groups II/III: How the intended use of a healthtech product determines the patient population and thus defines indications and contraindications.

- Intended use, user and patient groups III/III: How the intended use of a healthtech product determines the requirements for different user groups.

- Software as a medical device or drug: What is the market missing - what does the patient want? Derive product re-requirements by understanding market requirements and patient needs. (development planning).

- Software as a medical device or drug: Who is interested in the product, who benefits from it, who works with it? Derive concepts for usability and risk management by understand-ing the different user groups and their interests (verification and validation).

- Software as a medical device or drug: Who is interested in the product, who benefits from it, who works with it? Derive concepts for usability and risk management by understand-ing the different user groups and their interests (verification and validation).

Abstract

An overview of the preclinical development of drugs as well as medical devices and in vitro diagnostics is given. The relevant regulations are conveyed in a practice-oriented manner.

Objective

- Understanding the principles and limitations of the preclinical efficacy and safety disciplines in product development - pharmacodynamics, pharmacokinetics and toxicology
- Understanding and apply regulations for drug development, development of medical devices and in vitro diagnostics
- Understanding for which purposes GLP (Good Laboratory Practice) is applied
- Understanding and apply the do's and dont's of animal experiments in product development
- Understanding the different possibilities and the importance of communication with the regulatory authority in early product development

Content

The Module 4 "Development Process: Preclinical" includes an overview of preclinical efficacy and safety in drug development as well as in the development of medical devices and in vitro diagnostics. Emphasis will be placed on the applicable regulations and potential interactions with regulatory authorities in early product development. When a preclinical development plan becomes necessary and what is needed to start with will be explained in a practical way. An overview is also given of which preclinical studies and documents are required in order to be able to conduct an early clinical study in humans for the first time.

CAS in Regulatory Thinking - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
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<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
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Key for Hours

| V  | lecture                           | P  | practical/laboratory course           |
| G  | lecture with exercise              | A  | independent project                   |
| U  | exercise                           | D  | diploma thesis                        |
| S  | seminar                           | R  | revision course / private study       |
| K  | colloquium                        |    |                                       |

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## CAS in Robotics

### Module

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>172-0100-00L</td>
<td>CAS Module in Robotics and AI</td>
<td>O</td>
<td>12 credits</td>
<td>25A</td>
<td>Professors</td>
</tr>
</tbody>
</table>

### Abstract

In the CAS Robotics participants are offered a RobotX professor as a mentor together with whom they design their study plan along an individually-specified focus area in the area of Robotics and AI. Based on the individual expertise and interests of the participants, the customised Robotics and AI module consists of a combination of (i) research project, (ii) lectures, (iii) knowledge transfer.

### Objective

The CAS Robotics and AI module offers experienced industry individuals the opportunity to undergo research-related training in Robotics and AI, to update their knowledge and to expand their area of expertise in a targeted manner and aims at:

- training skills at the frontiers of the current state of research in Robotics and AI,
- deepening technical know-how with state-of-the-art knowledge in the specified focus area, and
- advancing practical competencies in the impart of expertise and knowledge transfer across disciplines and educational levels.

### CAS in Robotics - Key for Type

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<tr>
<td>R</td>
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### ECTS

- European Credit Transfer and Accumulation System
  - Special students and auditors need special permission from the lecturers.
## Module

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>139-0101-00L</td>
<td>Module 1: Introduction to Seismic Design and Swiss Seismic Code Provisions</td>
<td>O</td>
<td>2 credits</td>
<td>3G</td>
<td>B. Stojadinovic</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The objective of this Module is to introduce the principles of Seismic Design of Structures and the Swiss Seismic Code Provisions to Civil Engineers working in Switzerland.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>This module enables participants:</td>
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<tr>
<td></td>
<td>- To understand the critical points of the Swiss Code Provisions for the seismic design of new structures and the seismic evaluation of existing structures</td>
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<td>- To get an overview in the dynamics and the principles of seismic design of structures</td>
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<tr>
<td><strong>Content</strong></td>
<td>1.1 Introduction to seismic hazard and seismic risk, seismic performance objectives, common structural deficiencies and observed damage patterns due to earthquake ground motion excitation</td>
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<td>1.2 Seismic elastic and inelastic response of SDOF systems and earthquake response spectra</td>
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<td></td>
<td>1.3 Seismic elastic and inelastic response of MDOF systems, Response Spectrum Analysis and Pushover Analysis</td>
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<td>1.4 Seismic Design of structures using SIA 261: Presentation and Examples</td>
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<td>1.5 Good practices for the seismic design of new structures</td>
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<td>1.6 Seismic safety of non-structural components</td>
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<td><strong>Prerequisites / notice</strong></td>
<td>Anwesenheit (mind. 80% pro Präsenzwoche) und aktive Mitarbeit in den Präsenzwochen</td>
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<td>- mindestens genügende Leistungen bei Leistungskontrollen</td>
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</table>

| 139-0102-00L    | Module 2: Finite Element Modelling and Identification of the Seismic Behavior of Structures | O    | 2 credits | 3G    | B. Stojadinovic         |
| **Objective**   | This module enables participants:                                       |
|                 | - To use the state-of-the-art FEM software and implement the optimal FE modelling techniques for the simulation of the seismic response of existing buildings (concrete, masonry, mixed concrete-masonry) located in Switzerland |
|                 | - To obtain knowledge of the FEM software and the modelling techniques for the simulation of soil-structure interaction |
|                 | - To understand the current methodologies for the identification and monitoring of the vibration and the seismic behavior of structures located in Switzerland. |

| 139-0103-00L    | Module 3: Analysis Methods and Case Study Examples of Seismic Evaluation and Retrofitting | O    | 2 credits | 3G    | B. Stojadinovic         |
| **Abstract**    | The scope of this Module is to present Analysis Methods and Case Study Examples that illustrate established procedures and practical engineering solutions that are applied in the seismic evaluation and retrofitting of existing structures by Civil Engineers working in Switzerland. |
| **Objective**   | This module enables participants:                                       |
|                 | - To acquire practical knowledge of the seismic retrofitting techniques commonly used in Switzerland, their implementation and their cost |
|                 | - To select the appropriate analysis method for the seismic evaluation of structures located in Switzerland and understanding of the governing factors |

| 139-0104-00L    | Module 4: Individual Project Exercise | O    | 4 credits | 2P    | B. Stojadinovic         |
| **Objective**   | This module enables participants:                                       |
|                 | - To conduct independently a seismic evaluation of an existing structure located in Switzerland considering the boundary conditions that influence the seismic behavior of the structure |

### CAS in Seismic Evaluation and Retrofitting - Key for Type

- **O**: Compulsory
- **W+**: Eligible for credits and recommended
- **W**: Eligible for credits

**Key for Hours**

- **V**: lecture
- **G**: lecture with exercise
- **U**: exercise
- **S**: seminar
- **K**: colloquium

- **P**: practical/laboratory course
- **A**: independent project
- **D**: diploma thesis
- **R**: revision course / private study

**ECTS**: European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
CAS in Technology and Public Policy: Impact Analysis
Two-yearly recurring programme, offered only in spring semester. The programme is offered again the spring semester of 2026.

Economic Foundations for Policy Analysis
Two-yearly recurring programme, offered only in spring semester. The programme is offered again in the spring semester of 2026.

Module Technology and Policy Analysis

CAS in Technology and Public Policy: Impact Analysis - Key for Type

<table>
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<tr>
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ECTS European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
CAS in Technology and Public Policy: Policy Process

Two-yearly recurring programme, offered only in spring semester. The programme is offered again in the spring semester of 2025.

- **Module Technology, Society, Markets, and the State**
- **Module Public Sphere and Stakeholders in Policy-Making**
- **Module Communication and Negotiation**

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## CAS in Future of Spatial Development

### Introduction

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>135-0001-00L</td>
<td>Einführung: Grundlagen der Raumentwicklung</td>
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**Abstract**

Orientation and preparation for further education in the field of spatial planning and development. Introduction to the Spatial Planning Act and its instruments, assessment of participants' knowledge. Completion through mandatory assessment.

### Future of Spatial Development

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**Key for Hours**

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<td>practical/laboratory course</td>
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**ECTS** European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
# Chemistry (General Courses)

**General Courses**

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## Chemistry Bachelor

### 1. Semester

#### Compulsory Subjects First Year Examinations

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<td>Introduction to the chemistry of ionic equilibria: Acids and bases, redox reactions, formation of coordination complexes and precipitation reactions</td>
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<td>Understanding and describing ionic equilibria from both a qualitative and a quantitative perspective</td>
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<td>Chemical equilibrium and equilibrium constants, mono- and polynuclear acids and bases in aqueous solution, calculation of equilibrium constants, acidity functions, Lewis acids, acids in non-aqueous solvents, redox reactions and equilibria, Galvanic cells, electrochemicalCELL potentials, Nernst equation, coordination chemistry, stepwise formation of metal complexes, solubility</td>
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<td>Introduction to Organic Chemistry. Classical structure theory, stereochemistry, chemical bonds and bonding, symmetry, nomenclature, organic thermochemistry, conformational analysis, basics of chemical reactions.</td>
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<td>Introduction to the structures of organic compounds as well as the structural and energetic basis of organic chemistry.</td>
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<td>Isomerism, Fischer projections, CIP rules, point groups, molecular symmetry and chirality, topicality, chemical bonding; Lewis bonding model and resonance theory in organic chemistry, description of lineal and cyclic conjugated molecules, aromaticity, Huckel rules, organic thermochemistry, learning of organic chemistry reactions, intermolecular interactions.</td>
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<td>The lecture provides an introduction to some of the physical fundamentals of chemistry, in particular radioactivity, quantum mechanics, the structure of matter and an atom, the periodic table of elements, and chemical bonding.</td>
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<td>- to calculate physical quantities and their units which are important for chemistry,</td>
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<td>- name some properties of chemically relevant particles and propose experimental methods to determine these properties,</td>
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<td>- name applications and hazards of radioactivity,</td>
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<td>- categorize radioactive decay processes and mathematically represent the time course of simple decay reactions and qualitatively predict and represent them,</td>
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<td>- describe wave and particle properties of electromagnetic radiation and matter and propose experimental methods for their detection,</td>
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<td>- to explain the basics of quantum mechanics (meaning of the wave function, Heisenberg's uncertainty principle, operators, commutators) and to perform simple calculations with them,</td>
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<td>- analyze and calculate absorption and emission spectra of single-electron atoms,</td>
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<td>- to set up the Schrödinger equation for a molecular multi-particle system,</td>
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<td>- independently solve the Schrödinger equation for the model systems of particles in a box and harmonic oscillator in one dimension and generalize to higher dimensional non-interacting problems,</td>
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<td>- model molecular vibrations of diatomic molecules using the harmonic and anharmonic oscillator model,</td>
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<td>- explain the concept of an orbital and represent mathematically and pictorially the qualitative form of the orbitals of the hydrogen atom,</td>
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<td>- explain the structure of the periodic table of elements with the help of the orbital concept,</td>
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<td>- recognize and use similarities in the electronic structure of atoms to predict chemically relevant properties, and</td>
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<td>- establish term symbols for atomic ground states.</td>
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<td>Atomic structure and structure of matter: atomic theory, elementary particles, atomic nuclei, radioactivity, nuclear reactions. Atomic orbitals and energy levels: ionisation energies, atomic spectroscopy, term values and symbols. Quantum mechanical atom model: wave-particle duality, the uncertainty principle, Schrödinger’s equation, the hydrogen atom, construction of the periodic table of the elements. Chemical bonding: ionic bonding, covalent bonding, molecular orbitals.</td>
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Introduction to Computer Science

Abstract
Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics of point-like and ridged bodies, periodic motion and mechanical waves.

Objective
The concepts and tools in physics, as well as the methods of an experimental science are taught. The student should learn to identify, communicate and solve physical problems in his/her own field of science.

Content
Mechanics (motion, Newton's laws, work and energy, conservation of momentum, rotation, gravitation, fluids)
Periodic Motion and Waves (periodic motion, mechanical waves, acoustics).

Lecture notes
The lecture follows the book "Physics" by Paul A. Tipler.

Literature
Paul A. Tipler and Gene P. Mosca, Physics (for Scientists and Engineers), W. H. Freeman and Company

Competencies
- Subject-specific Competencies: Concepts and Theories fostered
- Method-specific Competencies: Problem-solving fostered
- Personal Competencies: Critical Thinking fostered

Mathematical Foundations I: Analysis A

Abstract
Introduction to calculus in one dimension. Building simple models and analysing them mathematically. Functions of one variable: the notion of a function, the derivative, the idea of a differential equation, complex numbers, Taylor polynomials and Taylor series. The integral of a function of one variable.

Objective
Introduction to calculus in one dimension. Building simple models and analysing them mathematically.

Content
Functions of one variable: the notion of a function, the derivative, the idea of a differential equation, complex numbers, Taylor polynomials and Taylor series. The integral of a function of one variable.

Literature
G. B. Thomas, M. D. Weir, J. Hass: Analysis 1, Lehr- und Übungsbuch, Pearson-Verlag
R. Sperb/M. Akveld: Analysis I (vdf)
L. Papula: Mathematik für Ingenieure und Naturwissenschaftler (3 Bände), Vieweg

Competencies
- Subject-specific Competencies: Concepts and Theories assessed
- Method-specific Competencies: Analytical Competencies fostered
- Personal Competencies: Creative Thinking fostered

Introduction to Computer Science

Abstract
Introduction to UNIX, introduction to C++ programming, data representation and processing, computational errors, algorithms and scaling, sorting and searching, numerical algorithms, algorithmic strategies, computer simulation, computer architecture, operating systems, programming languages, computer networks, databases, representation of chemical structures, molecular simulation.

Objective
Acquire a starting package concerning the computational aspects of natural sciences; discuss fundamentals of computer architecture, languages, algorithms and programming with an eye to their application in the area of chemistry, biology and material science.

Content
Lecture: Introduction to UNIX, introduction to C++ programming, data representation and processing, computational errors, algorithms and scaling, sorting and searching, numerical algorithms, algorithmic strategies, computer simulation, computer architecture, operating systems, programming languages, computer networks, databases, representation of chemical structures, molecular simulation; Exercises: Make students familiar with the UNIX operating system, C++ programming techniques, simple algorithms and computational applications in chemistry by means of exercise series at the computer.

Lecture notes
Script booklet (copies of powerpoint slides, in English), distributed at first or second lecture.

Literature
See: www.csms.ethz.ch/education/Info

Prerequisites
Since the exercises on the computer do convey and test essentially different skills than those being conveyed during the lectures and tested at the written exam, the results of the exercises are taken into account when evaluating the results of the exam (compulsory performance component, 12% of the exam mark; in case of repetition of the exam, the exercise marks from a previous semester can be kept).

For more information about the lecture: www.csms.ethz.ch/education/Infol

Laboratory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0011-04L</td>
<td>Practical Course General Chemistry</td>
<td>O</td>
<td>8</td>
<td>12P</td>
<td>M. Bezdek, D. Dirin, T. Segawa, A. Yakimov</td>
</tr>
</tbody>
</table>

Information about the practical course will be given on the first day.

Abstract
The general chemistry practical course aims at preparing the students for the work in modern chemistry laboratory. The students are trained to behave safely in the laboratory and use chemicals, chemistry glassware, and related equipment to perform and analyze the equilibrium in basic chemical reactions.

Objective
The students are expected to gain practical experience with as well as establish understanding of the following concepts and phenomena:

- Safe behavior and safety regulations in chemistry laboratory;
- Best practices in common techniques (purification, recrystallization, distillation, etc.);
- Analysis of measured values (measuring error, average value, error analysis);
- Acid-base-equilibria (stresses of acids and bases, pH- and pKa-values, titrations, buffer systems);
- Precipitation equilibria (gravimetry, potentiometry, conductivity measurements);
- Oxidation state and redox reactions (redox-titrations, galvanic elements);
- Metal complexes (syntheses of complexes, ligand exchange reactions, complexometric titration);
- Qualitative analysis (cation and anion separation, determination of cations and anions).
In the general chemistry practical course students are introduced to the work in chemistry laboratory. During the course they become familiar with common chemistry glassware and related equipment as well as learn basic experimental procedures, such as distillation, recrystallization, purification, digestion etc. Upon the measurements of pH, conductivity, and potential in the course of reactions, students establish the understanding of the chemical equilibrium concept.

Students work with various classes of inorganic compounds and types of chemical reactions, e.g. acid-base, redox, precipitation. They also obtain first experience with the synthesis of metal complexes as well as learn basics of qualitative analysis of an unknown substance.

Inorganic Chemistry I

This course consists of the following parts, which introduce the students to the chemistry of transition metals as well as lanthanides and actinides. In this context, students will master the basics of group theory and its application.


Physical Chemistry II: Chemical Reaction Kinetics


401-0373-00L  Mathematics III: Partial Differential Equations  O  4 credits  2V+1U  N. Moshayedi

Abstract

Objective
Classical tools to solve the most common linear partial differential equations.

Content
1) Examples of partial differential equations
- Classification of PDEs
- Superposition principle

2) One-dimensional wave equation
- D'Alembert's formula
- Duhamel's principle

3) Fourier series
- Representation of piecewise continuous functions via Fourier series
- Examples and applications

4) Separation of variables
- Solution of wave and heat equation
- Homogeneous and inhomogeneous boundary conditions
- Dirichlet and Neumann boundary conditions

5) Laplace equation
- Solution of Laplace's equation on the rectangle, disk and annulus
- Poisson formula
- Mean value theorem and maximum principle

6) Fourier transform
- Derivation and definition
- Inverse Fourier transformation and inversion formula
- Interpretation and properties of the Fourier transform
- Solution of the heat equation

7) Laplace transform (if time allows)
- Definition, motivation and properties
- Inverse Laplace transform of rational functions
- Application to ordinary differential equations

Lecture notes
See the course web site (linked under Lernmaterialien)

Literature


Additional books:

4) E. Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons (chapters 1,2,11,12,8)

For additional sources, see the course web site (linked under Lernmaterialien)

Prerequisites / notice
Required background:
1) Multivariate functions: partial derivatives, differentiability, Jacobian matrix, Jacobian determinant

2) Multiple integrals: Riemann integrals in two or three variables, change of variables

3) Basic knowledge of ordinary differential equations

Autumn Semester 2024
Subject-specific Competencies
Inorganic chemistry part: Synthesis and analysis of elemento-organic compounds, metal complexes, and organometallic compounds.

A manual is distributed in the teaching laboratory.

Analytical Competencies
Table of contents:
- M. Hesse, H. Meier, B. Zeeh, Spektroskopische Methoden in der organischen Chemie, 5. überarbeitete Auflage, Thieme, Stuttgart, 1995;

Communication
Application oriented basics of organic and inorganic instrumental analysis and of the empirical employment of structure elucidation methods.

Personal Competencies

Laboratory Courses

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<tr>
<td>529-0129-00L</td>
<td>Inorganic and Organic Chemistry II</td>
<td>O</td>
<td>11</td>
<td>16P</td>
<td>V. Mougel</td>
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<td>Latest online enrolment is one week before the beginning of the semester.</td>
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Abstract
Introduction to the experimental methods of Inorganic Chemistry

Objective
The teaching laboratory offers an insight into different aspects of Inorganic Chemistry, including solid state chemistry, organometallic chemistry, kinetics, etc. The synthesis, characterization and analysis of inorganic compound are a main topic. Special emphasis on experimental techniques of synthetic inorganic chemistry, in particular the safe handling of reactive and pyrophoric chemical and solvent purification and drying techniques.

Content
Inorganic chemistry part: Synthesis and analysis of elemento-organic compounds, metal complexes, and organometallic compounds. Introduction to Schlenk techniques, solid state synthesis, and kinetics. Introduction in the chemistry library: literature data banks and collections of spectra.

Organic synthesis with organometallic compounds and catalysts: Experiments in the framework of a selected specialised project. Possible projects: Rh catalysed asymmetric hydrogenation of enamides, Mn-catalysed epoxidation of olefins, Cu catalysed Diels-Alder reactions, synthesis of organo-boron compounds and Pd catalysed coupling with halides, Ru catalysed transfer hydrogenation.

Lecture notes
A manual is distributed in the teaching laboratory.

Prerequisites / notice
- Passed Basisprüfung
- Passed Practical Course General Chemistry (1. Semester, 529-0011-04)
- Passed Practical Course Inorg. and Org. Chemistry I (2. Sem., 529-0230) or Practical Course BCB III: Organic Chemistry (3. Sem. BSc BCB, 529-0016-00)
- Continuous Attendance of Course Inorg. Chemistry 1 (3. Sem. BSc BCB, 529-0121) and Analytical Chemistry 1 (3. Sem., 529-0051)

This class has a limited number of positions available. If necessary, access priority will be settled according to the results of the first-year examinations. Students that are not accepted following that rule will be given priority for the coming year registration.

By enrolling in the laboratory course, students confirm to study all safety information thoroughly and to follow instructions.

5. Semester

Compulsory Subjects Examination Block III

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<tr>
<td>529-0132-00L</td>
<td>Inorganic Chemistry III: Organometallic Chemistry and O</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>M. Bezdek, C. Copéret</td>
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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 526 of 2653
Homogeneous Catalysis

Abstract
Fundamental aspects of the organometallic chemistry of the transition elements. Mechanistic homogeneous catalysis including oxidative additions, reductive eliminations and insertion reactions. Catalytic hydrogenation, carbonylation, C-C bond-forming and related reactions.

Objective
Towards an understanding of the fundamental coordination-chemical and mechanistic aspects of transition-metal chemistry relevant to homogeneous catalysis.

Content
Fundamental aspects of the organometallic chemistry of the transition elements. Mechanistic homogeneous catalysis including oxidative additions, reductive eliminations and insertion reactions. Catalytic hydrogenation, carbonylation, C-C bond-forming and related reactions.

Organic Chemistry III: Introduction to Asymmetric Synthesis

529-0231-00L

Abstract
Methods of Asymmetric Synthesis

Objective
Understanding of the basic principles of diastereoselective synthesis

Content
Conformational analysis: acyclic and cyclic systems; Diastereoselective sigmatropic rearrangements; Diastereoselective Carbyl addition reactions; Cram- and Felkin-Anh models, carbonyl Lewis acid interactions, chelate controlled reactions; chemistry of enolates, selective formation; asymmetric enolate alkylation; aldol reactions, allyl- and crotyl-metal chemistry; cyclisations, Baldwin rules; Diastereoselective olefin functionalization: hydroboration, dihydroxylation, epoxidation.

Literature

Evans' Problems in Organic Chemistry App

529-0432-00L

Physical Chemistry IV: Magnetic Resonance

Abstract
Theoretical foundations of magnetic resonance (NMR, EPR) and selected applications. Introduction to magnetic resonance in isotropic and anisotropic phase.

Objective
The course gives an introduction to magnetic resonance spectroscopy (NMR and EPR) in liquid, liquid crystalline and solid phase. It starts from a classical description in the framework of the Bloch equations. The implications of chemical exchange are studied and two-dimensional exchange spectroscopy is introduced. An introduction to Fourier spectroscopy in one and two dimensions is given and simple ‘pulse trickery’ is described. A quantum-mechanical description of magnetic resonance experiments is introduced and the spin Hamiltonian is derived. The chemical shift term as well as the scalar, dipolar and quadrupolar terms are discussed. The product-operator formalism is introduced and various experiments are described, e.g. polarization transfer. Applications in chemistry, biology, physics and medicine, e.g. determination of 3D molecular structure of dissolved molecules, determination of the structure of paramagnetic compounds and imaging (MRI) are presented.

Lecture notes
handed out in the lecture (in english)

Literature
see http://www.ssnmr.ethz.ch/education/PC_IV_Lecture

Laboratory Courses

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<td>529-0449-00L</td>
<td>Spectroscopy</td>
<td>O</td>
<td>13</td>
<td>13P</td>
<td>T. Segawa, B. Hattendorf</td>
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</table>

Abstract
Laboratory experiments to acquire a profound knowledge of spectroscopical methods and techniques in chemistry. Evaluation and visualization of measurement data. Writing lab reports.

Objective
Laboratory experiments to acquire a profound knowledge of spectroscopical methods and techniques in chemistry. Evaluation and visualization of measurement data. Writing lab reports.

Content
Laboratory experiments: UV/VIS spectroscopy, luminescence spectroscopy, FT infrared spectroscopy, light diffraction and refraction, thermal lenses, Raman spectroscopy, reflection spectroscopy, optical polarization phenomena, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), FT nuclear magnetic resonance spectroscopy (NMR), electron paramagnetic resonance spectroscopy (EPR), atomic force microscopy (AFM), Fourier transform methods.

Lecture notes
Detailed documentation to each experiment will be handed out.

Prerequisites / notice
Praktikum Physikalische Chemie, 3. Auflage, vdf Hochschulverlag an der ETH, Zürich 2022.
Praktikum Physikalische Chemie (529-0054-00) or Praktikum Physikalische Chemie (529-0054-01).

By enrolling in the laboratory course, students confirm to study all safety information thoroughly and to follow instructions.

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Electives

Students are free to choose from a range of D-CHAB chemistry courses appropriate to their level of study (please note admission requirements). In case of doubt, contact the student administration.

Inorganic Chemistry

<table>
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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tr>
<td>529-0141-00L</td>
<td>Physical Methods for Inorganic Chemistry</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>M. D. Wörle, D. Günther, J. Koch, R. Verel</td>
</tr>
</tbody>
</table>

Abstract
Introduction into the important methods for structural analysis (solid state NMR), crystal structure analysis and surface analysis techniques and their applications.

Objective
Knowledge in solid state NMR, crystal structure analysis and surface analytical techniques relevant for inorganic materials.

Content
This lecture course consists of three parts: 1) Solid-state NMR 2) Surface and direct solid analysis 3) Crystal structure analysis. Most important fundamentals of the individual methods will be presented and details will be explained on most relevant inorganic applications.

Physical Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>529-0441-00L</td>
<td>Signal Processing</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>F. Merkt, U. Hollenstein</td>
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</tbody>
</table>

Abstract
Introduction of the basics of signal processing in spectroscopy. Fourier transformation, linear response theory, stochastic signals, digital data processing, Fourier spectroscopy.

Objective
Basics of signal processing in spectroscopy.

Content

Analytical Chemistry

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>529-0041-00L</td>
<td>Modern Mass Spectrometry, Hyphenated Methods, and Chemometrics</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>R. Zenobi, B. Hattendorf, P. Sinués Martinez-Lozano</td>
</tr>
</tbody>
</table>

Abstract
Modern mass spectrometry, hyphenated analytical methods, speciation, chemometrics.

Objective
Hyphenation of separation with identification methods such as GC-MS, LC-MS, GC-IR, LC-IR, LC-NMR etc.; importance of speciation.

Content
Modern mass spectrometry: time-of-flight, orbitrap and ion cyclotron resonance mass spectrometry, ICP-MS. Soft ionization methods, desorption methods, spray methods. Mass spectrometry imaging. Use of statistical and computer-assisted methods for processing analytical data (chemometrics).

Literature
Information about relevant literature will be available in the lecture & in the lecture notes.

Prerequisites / notice
Exercises are an integral part of the lecture.

Prerequisites:
529-0051-00 "Analytische Chemie I (3. Semester)"
529-0058-00 "Analytische Chemie II (4. Semester)"
(or equivalent)
### Competencies

<table>
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<th>Social Competencies</th>
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<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
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<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
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<td>Media and Digital Technologies</td>
<td>Customer Orientation</td>
<td>Creative Thinking</td>
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<td>Problem-solving</td>
<td>Leadership and Responsibility</td>
<td>Critical Thinking</td>
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<td>Project Management</td>
<td>Self-presentation and Social Influence</td>
<td>Integrity and Work Ethics</td>
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<td>Sensitivity to Diversity</td>
<td>Self-awareness and Self-reflection</td>
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### Biological Chemistry

**529-0240-00L Chemical Biology - Peptides**

- **Number**: 529-0240-00L
- **Title**: Chemical Biology - Peptides
- **Type**: W
- **ECTS**: 6 credits
- **Hours**: 3G
- **Lecturers**: H. Wennemers

**Abstract**: An advanced course on the synthesis, properties and function of peptides in chemistry and biology.

**Objective**: Knowledge of the synthesis, properties and function of peptides in chemistry and biology.

**Content**: Advanced peptide synthesis, conformational properties, combinatorial chemistry, therapeutic peptides, peptide based materials, peptides in nanotechnology, peptides in asymmetric catalysis.

**Lecture notes**: Citations from the original literature relevant to the individual lectures will be assigned weekly.


### Chemical Aspects of Energy

**529-0659-00L Electrochemistry: Fundamentals, Cells & Applications**

- **Number**: 529-0659-00L
- **Title**: Electrochemistry: Fundamentals, Cells & Applications
- **Type**: W
- **ECTS**: 6 credits
- **Hours**: 3G
- **Lecturers**: L. Gubler

**Abstract**: Introduction to electrochemistry from a physical chemistry point of view, focusing on thermodynamics & kinetics of electrochemical reactions, and engineering aspects of electrochemical cells. The topics are of generic nature yet also discussed in the context of specific applications in industrial electrochemistry, energy storage and conversion, electroanalytical techniques, sensors and corrosion.

**Objective**: The course establishes the fundamentals to understand and describe electrochemical reactions and phenomena related to these. The students are familiarized with key concepts and approaches in electrochemistry and selected aspects of materials science and engineering and how they are put to use in selected applications.
Content

- Introduction: important quantities & units, terminology;
- Chapter I - Redox reactions, Faraday's laws;
- Chapter II - Equilibrium electrochemistry: cells, galvanic and electrolytic cells, thermodynamic state functions, theoretical cell voltage, half-cell / electrode potential, hydrogen electrode, the electrochemical series, Nernst equation;
- Chapter III - Electrodes & interfaces: electrochemical potential, phase potentials, work function, Fermi level, the electrified interface, the electrochemical double layer, reference electrodes and laboratory cells;
- Chapter IV - Electrolytes: conductivity, aqueous electrolytes, transference effects, liquid junctions, polymer electrolytes, ion-exchange membranes, Donnan exclusion, solid state ion conductors;
- Chapter V - Dynamic electrochemistry: overpotentials, description of charge-transfer reaction, Butler-Volmer and Tafel equation, exchange current density, mass transport limitations;
- Chapter VI - Industrial electrochemistry: electrochemical engineering, process and reactor types, current density distribution, porous electrodes, chlor-alkali and HCl electrolysis, oxygen depolarized cathode;
- Chapter VII - Energy storage & conversion: important primary and secondary battery chemistries, fuel cells, polymer electrolyte fuel cells, low temperature H2 and O2 electrochemistry, electrocatalysis, triple-phase boundary, solid oxide fuel cell, conversion efficiency;
- Chapter VIII - Electroanalytical methods & sensors: potentiometry, amperometry, cyclic and stripping voltammetry, rotating disc electrode studies, electrochemical sensors;
- Chapter IX - Corrosion: corrosion reactions, Pourbaix diagram, corrosion potential, passivation, corrosion protection

Lecture notes

- Lecture notes, lecture slides, exercise & solutions (PDF files)

Literature


Prerequisites / notice

Students should be familiar with the fundamentals of physical chemistry.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
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<td>Self-direction and Self-management</td>
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Chemical Crystallography

<table>
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<tr>
<th>Number</th>
<th>Title</th>
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<tr>
<td>529-0039-00L</td>
<td>Principles of Crystal Structure Determination</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>M. D. Wörle, N. Trapp</td>
</tr>
</tbody>
</table>

Abstract

An introduction to the principles of X-ray diffraction and crystal structure determination as it relates to Chemistry

Objective

To gain an understanding of the principles of crystal structure determination by X-ray diffraction.

Content

Basic crystallographic concepts: Unit cells, Bravais lattices, Laue symmetry, crystal classes (point groups), space groups, crystal growth, instrumentation, diffraction of X-rays by crystals: physical and geometric basics, powder and single crystal methods, structure solution and modelling, interpretation of crystal structure data; internal coordinates for structure description: atom spacing, co-ordination polyhedra, bond angles, torsion angles; intermolecular interactions, absolute configuration determination. Overview of inorganic, organic and macromolecular databases.

Lecture notes

The script and exercises will be distributed weekly in loose form
What happens to chemicals in the environment? How do we determine whether they degrade over decades and accumulate in the food chain?

Introduction to algorithms (special focus on chemistry):

S. Riniker, J. Hollender

Algorithms and Programming for Chemistry

A. Anastasaki

- The students will be able to recognize different polymer types and associate them with their chemical structure and properties (i.e. rubber elasticity, glass transition temperature, etc.)
- The students will become familiar with various synthetic methods to produce polymers of different architectures and topologies
- The students will be exposed to different characterization methods (e.g. size exclusion chromatography, mass-spectrometry, nuclear magnetic resonance) that are necessary to confirm the successful synthesis and structure of a polymer
- The students will understand the mechanism of selected polymerization methodologies
- The students will be introduced to state-of-the-art polymer synthesis and recent literature examples will be critically discussed

C++ programming:


Materials Science

Offered during Spring Semester.

Environmental Chemistry

What happens to chemicals in the environment? How do we determine whether they degrade over decades and accumulate in the food chain? Answers to these questions are provided in this lecture, which covers basic knowledge about distribution behavior, environmental analysis, abiotic and biotic degradation reactions, and toxic effects of chemicals as part of environmental chemical risk analysis.
Objective
Students will develop a basic understanding for fate and effects of chemicals in the environment and learn how to use simple quantitative tools for the assessment of chemical behaviour and toxic effects.

Content
Part 1: Partitioning and reactivity
* Physico-chemical description of partitioning behaviour of organic compounds
* Partitioning in environmental media including soil/sediment, air, water
* Chemical and biological transformations

Part 2: Effects
* Test systems for the assessment of ecotoxicological effects of chemicals
* Bioavailability and bioaccumulation
* Metabolisms of organic compounds
* Molecular mechanisms of toxic action

Part 3: Analyses
* Analytical methods for quantification of substances in water, soil, and air
* Sampling, sample preparation and quantification of organic compounds in environmental media

Lecture notes
Handouts/lecture slides will be made available electronically

Literature
Fent, Ecotoxicology, Thieme, 4.Auflage, 2013
Campell et al., Ecotoxicology, Cambridge University Press, 2022

Competencies

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<td>Media and Digital Technologies</td>
<td>Problem-solving</td>
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Cometecies

Economics

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<tr>
<td>351-0778-00L</td>
<td>Discovering Management</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td>B. Clarysse, S. Brusoni, V. Hoffmann, T. Netland</td>
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</tbody>
</table>

Abstract
Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

Objective
The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
1. broaden understanding of management principles and frameworks
2. advance insights into the sources of corporate and entrepreneurial success
3. develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

Content
The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. The theory sessions will be assessed via a multiple choice exam.

Lecture notes
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td></td>
<td>Concepts and Theories</td>
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<td>Communication</td>
<td>Creative Thinking</td>
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<td>assessed</td>
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<td>Communication</td>
<td>Problem-solving</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
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</table>

Science in Perspective

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 532 of 2653
### Science in Perspective

*see Science in Perspective: Type A: Enhancement of Reflection Capability*

*Recommended Science in Perspective (Type B) for D-CHAB*

### Language Courses

*see Science in Perspective: Language Courses ETH/UZH*

#### Chemistry Bachelor - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Code</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</table>

#### Key for Hours

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<th>Code</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
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<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</tbody>
</table>

ECTS  European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
## Educational Science

**Course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma".**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>871-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>R. Schumacher</td>
</tr>
</tbody>
</table>

**Abstract**

This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)".

**Objective**

- Get to know cognitively activating instructions in MINT subjects
- Get information about recent literature on learning and instruction

**Prerequisites / notice**

Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>871-0242-07L</td>
<td>Human Intelligence</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>E. Stern</td>
</tr>
</tbody>
</table>

**Abstract**

This focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.

**Objective**

- Understanding of research methods used in the empirical human sciences
- Getting to know intelligence tests
- Understanding findings relevant for education

**see Educational Science Teaching Diploma**

## Subject Didactics in Chemistry

**Important Notice: Enrolment in the courses of this category is only possible if no more than 12 CP of potential additional requirements have to be acquired.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0959-00L</td>
<td>Mentored Work Subject Didactics Chemistry A</td>
<td>O</td>
<td>2</td>
<td>4A</td>
<td>A. Zwyssig</td>
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</table>

**Abstract**

In their mentor guided work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under guidance, students create materials for chemistry classes that are effective for learning.

**Objective**

The goal is for students to
- be able to familiarize themselves with a teaching topic and take into account recommendations from subject didactics
- be able to design cognitively activating teaching material and bring it to readiness for use

**Content**

Die Studierenden wählen ein Thema, besprechen sich mit der Betreuungsperson und erstellen anschliessend eine eigenständige Arbeit. Sie werden dabei von der Betreuungsperson begleitet.

**Lecture notes**

Anleitung zur mentorierten Arbeit siehe http://fdchemie.pbworks.com/mentorierte-Arbeit-in-Fachdidaktik

**Literature**

Die Studierenden beschaffen sich die Literatur in der Regel selber (siehe Lernziele).

**Prerequisites / notice**

Die Arbeit sollte vor Beginn des Unterrichtspraktikums abgeschlossen werden.

**Competencies**

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Self-direction and Self-management

**529-0960-00L**

<table>
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<th>Number</th>
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<tr>
<td>529-0960-00L</td>
<td>Mentored Work Subject Didactics Chemistry B</td>
<td>O</td>
<td>2</td>
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<td>A. Zwyssig</td>
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</table>

**Abstract**

In their mentor guided work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under guidance, students create materials for chemistry classes that are effective for learning.

**Objective**

The goal is for students to
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- be able to design cognitively activating teaching material and bring it to readiness for use

**Content**

Die Studierenden wählen ein Thema, besprechen sich mit der Betreuungsperson und erstellen anschliessend eine eigenständige Arbeit. Sie werden dabei von der Betreuungsperson begleitet.

**Lecture notes**

Anleitung zur mentorierten Arbeit siehe http://fdchemie.pbworks.com/mentorierte-Arbeit-in-Fachdidaktik

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Die Studierenden sammeln zu Beginn ihrer Ausbildung erste Erfahrungen mit der Beobachtung, Konzeption und Durchführung von

The students have basic subject didactic knowledge for teaching chemistry at a secondary school.

They are able to design lessons that are effective for learning, actively involve students in lessons, explain challenging concepts simply, use experiments for theory and reflect on teaching.

Schwerpunkte im ersten Studiensemester bilden die folgenden Themen:

- Auswahl gymnasiusspezifischer Lerninhalte
- Didaktische Vereinfachung
- Modelle und chemischen Formeln zur Beschreibung von Aufbau und Umwandlung der Substanzen
- Wechselspiel zwischen Beobachtung in der realen Welt und Deutung auf Modell-Ebene
- Skizzen entwerfen und zur Erklärung von Reaktionen nutzen
- Chemie im 8. Schuljahr: Das Teilchenmodell erklärt viele Phänomene im Anfangsunterricht
- Atommuster und chemische Bindung
- Radioaktivität und Kernspaltung
- Struktur und Eigenschaft
- Auswahl, Konzeption, Vorbereitung, Durchführung, Einbettung und Auswertung von Demonstrationsexperimenten

Literature

- E. Rossa: Chemie-Didaktik, Cornelsen Verlag, 2015
- H.-J. Bader et al: Konkrete Fachdidaktik Chemie, Oldenbourg Verlag, 2002

Prerequisites / notice

Das Einführungspraktikum findet an einem Gymnasium der Deutschschweiz statt.

Das Chemieunterricht am Gymnasium soll einerseits grundlegende chemische Kenntnisse für den Alltag vermitteln und andererseits auf ein naturwissenschaftlich orientiertes Hochschulstudium vorbereiten. Diese beiden Ziele sind im Unterricht gleichermassen zu berücksichtigen.

Anhand der Diskussion bewährter Beispiele und dem Entwurf eigener Unterrichtsbausteine soll die zukünftige Lehrperson befähigt werden, einen den spezifischen Rahmenbedingungen angepassten Unterricht zu entwickeln, der diesem hohen Qualitätsanspruch genügt.

### Professional Training in Chemistry

**Important Notice: Enrolment in the courses of this category is only possible if no more than 12 CP of potential additional requirements have to be acquired.**

#### 529-0966-00L

**Introductory Internship Chemistry**

*Simultaneous enrolment in Subject Didactics Chemistry I - course 529-0950-00L - is compulsory.*

<table>
<thead>
<tr>
<th>Number</th>
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<td>Introductory Internship Chemistry</td>
<td>O</td>
<td>3</td>
<td>6P</td>
<td>P. Aschwanden</td>
</tr>
</tbody>
</table>

**Abstract**

During the introductory teaching practice, the students sit in on five lessons given by the teacher responsible for their teaching practice, and teach five lessons themselves. The students have given observation and reflection assignments by the teacher responsible for their teaching practice.

**Objective**

The students have basic subject didactic knowledge for teaching chemistry at a secondary school. They are able to design lessons that are effective for learning, actively involve students in lessons, explain challenging concepts simply, use experiments for theory and reflect on teaching.

**Content**


**Literature**

Wird von der Praktikum Lehrperson bestimmt.

**Prerequisites / notice**

Das Einführungspraktikum findet an einem Gymnasium der Deutschschweiz statt.

#### 529-0964-00L

**Teaching Internship Chemistry**

*Simultaneous enrolment in Subject Didactics Chemistry I - course 529-0950-00L - is compulsory.*

<table>
<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
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<td>8</td>
<td>17P</td>
<td>P. Aschwanden</td>
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**Abstract**

The teaching practice takes in 50 lessons: 30 are taught by the students, and the students sit in on 20 lessons. The teaching practice lasts 4-6 weeks. It gives students the opportunity to implement the contents of their specialist-subject, educational science and subject-didactics training in the classroom. Students also conduct work assignments in parallel to their teaching practice.

**Objective**

- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics in their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They acquire the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils’ work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.
This course unit introduces students to the technique of conducting experiments in chemistry lessons. It covers didactic, technical, safety-related and presentation aspects.

Students can:
- demonstrate experiments safely and convincingly
- explain observations in a level-appropriate manner
- use experiments to support theory
- know why experiments need to be tested before demonstration
- know some standard experiments
- develop own experiments

Schwerpunkte bilden die folgenden Themen:
- Theoretische Einführung
- Merkmale für ein sicheres Experimentieren
- Die Studierenden erproben und demonstrieren bereitstehende Experimente
- Experimente mit einer Skizze festhalten
- Auf Basis der Literatur ein Experiment selbständig ausarbeiten, dokumentieren und vorführen
- Experimente in den Unterricht einbetten
- Aufgaben zur Auswertung entwerfen

In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

On the basis of a specified topic, the candidate shows that they are in a position
- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle
- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

Die Studierenden erfahren das Lektionsthema in der Regel eine Woche vor dem Prüfungstermin. Von der zuständigen Lehrperson erhalten sie Informationen über den Wissensstand der zu unterrichtenden Klasse und können sie vor dem Prüfungstermin besuchen.

Sie erstellen eine Vorbereitung gemäss Anleitung und reichen sie bis am Vortag um 12 Uhr den beiden Prüfungsexperten ein.

Die gehaltene Lektion wird kriteriernbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/der Kandidatin über die gehaltene Lektion im Rahmen eines kurzen Kolloquiums.

Nach Abschluss der übrigen Ausbildung.

Will mark the conclusion of the teacher training program in Chemistry.

In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

On the basis of a specified topic, the candidate shows that they are in a position
- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle
- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

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Nach Abschluss der übrigen Ausbildung.

Will mark the conclusion of the teacher training program in Chemistry.
Internship Chemistry Didactics

**Abstract**
During the Internship Chemistry Didactics students teach 8 lessons at a high school. Students try out and evaluate activating forms of instruction presented in the subject didactics.

**Objective**
- Students will be able to use different didactic methods in the classroom and recognize the details necessary for successful implementation.
- To try out different options for specialist further training in their profession.
- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge specialist competence in this way.

**Content**
In this course, participants acquire extended and more in-depth knowledge of selected chemistry topics. The selection is based to a large extent on the partial aspects of chemistry that are typically taught at high school. By gaining a broader understanding, teachers are put in a position where they can comprehend the topics that are to be taught in a larger extent, to some extent, unconventional context and critically process these in respect of their teachability and learnability. At the same time, interrelationships between the classical sub-disciplines of chemistry are highlighted, along with the unique features of chemistry as one of the central natural sciences.

**Learning format**: Lecture.

**Thematic focus of FV I**:
- The language of chemistry: Concepts, formulas, aesthetics, and philosophical aspects
- Stereochemistry: The Coupe du Roi and its chemical meaning, Cyclostereoisomerism, Origin of biomolecular homochirality
- Chemistry and sustainability. The link between chemical products and energy consumption, life cycle assessments and chemical energy storage

**Lecture notes**
Slides and selected literature will be provided.

**Literature**
Selected articles from the primary literature are presented, commented on and recommended reading.

**Prerequisites / notice**
Das Fachdidaktikpraktikum kann erst nach dem Besuch von Fachdidaktik 1 und frühestens mit Fachdidaktik 2 durchgeführt werden (eine gleichzeitige Belegung von Fachdidaktik 2 und Fachdidaktikpraktikum ist möglich).

**Competencies**
- **Subject-specific Competencies**: Concepts and Theories - assessed
- **Method-specific Competencies**: Analytical Competencies - assessed
- **Social Competencies**: Communication - fostered
- **Leadership and Responsibility**: fostered
- **Sensitivity to Diversity**: fostered
- **Personal Competencies**: Creative Thinking - fostered
- **Critical Thinking**: fostered
- **Self-awareness and Self-reflection**: fostered

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Mentored Work Specialised Courses in the Respective Subject with an Educational Focus I

**Abstract**
In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

**Objective**
The aim is for the students
- to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.
- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.
- To try out different options for specialist further training in their profession.

**Content**
Thematikliche Schwerpunkte:


**Lecture notes**
Eine Anleitung zur mentorierten Arbeit in FV wird zur Verfügung gestellt.

**Literature**
Die Literatur ist themenspezifisch. Sie muss je nach Situation selber beschafft werden oder wird zur Verfügung gestellt.

**Prerequisites / notice**
Die Arbeit sollte vor Beginn des Unterrichtspraktikums abgeschlossen werden.
Abstract
In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

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The aim is for the students
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- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.
- To try out different options for specialist further training in their profession.

Content
Thematic Schwerpunkte:

Lernformen:

Lecture notes
Eine Anleitung zur mentorierten Arbeit in FV wird zur Verfügung gestellt.

Literature
Die Literatur ist themenspezifisch. Sie muss je nach Situation selber beschafft werden oder wird zur Verfügung gestellt.

Prerequisites / notice
Die Arbeit sollte vor Beginn des Unterrichtspraktikums abgeschlossen werden.

Compulsory Elective Courses
see Compulsory Elective Courses Teaching Diploma

Chemistry Teaching Diploma - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
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</thead>
<tbody>
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<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</tbody>
</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Organic Chemistry

### 529-0233-01L Organic Synthesis: Methods and Strategies
- **Type:** W+
- **ECTS:** 6
- **Hours:** 3G
- **Lecturers:** E. M. Carreira

**Abstract**
The complex relation between structural analysis, methods leading to desired transformations, and insight into reaction mechanisms is exemplified. Relations between retrosynthetic analysis of target structures, synthetic methods and their combination in a synthetic strategy.

**Objective**

**Content**
- Extension and deepening of the knowledge in organic synthesis and the principles of structure and reactivity.

**Literature**

**Prerequisites / notice**
OC I-IV

**Competencies**
- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: fostered
- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: fostered
- **Social Competencies**
  - Communication: assessed
  - Cooperation and Teamwork: fostered
  - Customer Orientation: fostered
  - Leadership and Responsibility: fostered
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered
  - Negotiation: assessed
- **Personal Competencies**
  - Adaptability and Flexibility: fostered
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

### 529-0241-10L Selectivity in Organic Synthesis
- **Type:** W+
- **ECTS:** 6
- **Hours:** 3G
- **Lecturers:** J. W. Bode

**Abstract**
Fundamentals of selective organic reactions, including current and historical examples of enantioselectivity, regioselectivity, chemoselectivity. Further aspects include recent developments in catalysis, strategies and tools for selective organic synthesis.

**Objective**
Understanding and explaining the origin of selectivity in organic synthesis and the application of selective organic reactions to the construction of complex organic and biological molecules.

**Content**
- Fundamental concepts and recent advances for the selective synthesis of complex organic molecules, including natural products, pharmaceuticals, and biological molecules. Key concepts include the development of enantioselective and regioselective catalysts, the identification of new reaction mechanisms and pathways, and technological advances for facilitating the synthesis of organic molecules.
- Analysis of key primarily literature including identification of trends, key precendents, and emerging topics will be emphasized.

**Lecture notes**
Will be provided in class and online

**Literature**
Suggesting Textbooks

**Competencies**
- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Analytical Competencies: assessed
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: fostered
- **Method-specific Competencies**
  - Communication: assessed
  - Cooperation and Teamwork: fostered
  - Customer Orientation: fostered
  - Leadership and Responsibility: fostered
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered
  - Negotiation: fostered
- **Social Competencies**
  - Adaptability and Flexibility: assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered
- **Personal Competencies**
  - Self-direction and Self-management: fostered

## Physical Chemistry

### 529-0433-01L Advanced Physical Chemistry: Statistical Thermodynamics
- **Type:** W+
- **ECTS:** 6
- **Hours:** 3G
- **Lecturers:** R. Riek, J. Richardson

**Abstract**
Introduction to statistical mechanics and thermodynamics. Prediction of thermodynamic and kinetic properties from molecular data.
Concepts and Theories

Introduction to statistical mechanics and thermodynamics. Prediction of thermodynamic and kinetic properties from molecular data.

Lecture notes
See homepage of the lecture.

Prerequisites / notice
Chemical Thermodynamics, Reaction Kinetics, Molecular Quantum Mechanics and Spectroscopy; Mathematical Foundations (Analysis, Combinatorial Relations, Integral and Differential Calculus)

Competencies
Subject-specific Competencies
Concepts and Theories

Method-specific Competencies
Analytical Competencies

Social Competencies
Problem-solving

Personal Competencies
Communication

Creative Thinking

Critical Thinking

Research Projects

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0200-00L</td>
<td>Research Project I</td>
<td>W</td>
<td>13</td>
<td>16A</td>
<td>Supervisors</td>
</tr>
<tr>
<td>Objective</td>
<td>Students are accustomed to scientific work and they get to know one specific research field.</td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student.</td>
<td></td>
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<tr>
<td>529-0201-00L</td>
<td>Research Project II</td>
<td>W</td>
<td>13</td>
<td>16A</td>
<td>Supervisors</td>
</tr>
<tr>
<td>Objective</td>
<td>Students are accustomed to scientific work and they get to know one specific research field.</td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student.</td>
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Industry Internship or Laboratory Course

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>529-0202-00L</td>
<td>Industry Internship</td>
<td>W</td>
<td>13</td>
<td>16A</td>
<td>Supervisors</td>
</tr>
<tr>
<td>Objective</td>
<td>The aim of the internship is to make students acquainted with industrial work environments. During this time, they will have the opportunity to get involved in current projects of the host institution.</td>
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<tr>
<td>Abstract</td>
<td>Internship in industry with a minimum duration of 7 weeks</td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0739-00L</td>
<td>Biological Chemistry A: Technologies for Directed Evolution of Enzymes</td>
<td>W</td>
<td>13</td>
<td>16P</td>
<td>P. A. Kast</td>
</tr>
<tr>
<td>Objective</td>
<td>Students are accustomed to scientific work and they get to know one specific research field.</td>
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<tr>
<td>Content</td>
<td>This course conducts and supports experiments for a specifically designed genuine research project. We will carry out biological-chemical enzyme evolution experiments using molecular genetic mutation technologies and in vivo selection in recombinant bacterial strains. The relevant technologies will be taught to the students, such as the preparation of competent cells, production and isolation of DNA fragments, transformation of gene libraries, and DNA sequencing. The course participants will generate a variety of different variants of a chorismate mutase. Individual enzyme catalysts will be purified and subsequently characterized using several different spectroscopic methods. The detailed chemical-physical analyses include determination of the enzymes' kinetic parameters, their molecular mass, and the integrity of the protein structure. The students will present the results obtained from their individual evolution experiments at the end of the semester. We expect that during this lab course we will not only generate novel enzymes, but also gain new mechanistic insights into the investigated catalyst.</td>
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<tr>
<td>Lecture notes</td>
<td>The necessary documents and protocols will be distributed to the participants during the course. General literature to “Directed Evolution” and chorismate mutases, e.g.:</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Further literature will be indicated in the distributed script.</td>
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<tr>
<td>- This laboratory course will involve experiments that require a tight schedule and (sometimes) long (!) working days.</td>
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<tr>
<td>- The projects of this course are tightly linked to the ones of the Biology BSc course “529-0739-01 Biological Chemistry B: New Enzymes from Directed Evolution Experiments”, which takes place as a block course during the month of November. There will be joint lectures for the participants of both courses during that time. The teaching language is English.</td>
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<tr>
<td>- The number of participants for the laboratory class is limited. It is mandatory to sign up for the course directly with P. Kast no later than September 1, prior to the start of the fall semester. Until then it will be decided whether the course will take place.</td>
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<td>- A valid registration is considered a commitment for attendance of the entire semester course, as involved material orders and experimental preparations are necessary and, once the class has started, the flow of the experiments must not be interrupted by individual absences. In case of an emergency, please immediately notify P. Kast.</td>
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<td>- For more information, see also <a href="http://www.kast.ethz.ch/teaching.html">http://www.kast.ethz.ch/teaching.html</a> or contact P. Kast directly (HCI F 333, Tel. 044 632 29 08, <a href="mailto:kast@org.chem.ethz.ch">kast@org.chem.ethz.ch</a>).</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 540 of 2653
The complex relation between structural analysis, methods leading to desired transformations, and insight into reaction mechanisms is assessed. The Master's thesis students prove their ability to independent, structured and scientific working. The Master's thesis is usually carried out in a core or optional subject area as chosen by the student. 

**Master's Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>529-0500-10L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>25</td>
<td>54D</td>
<td>Supervisors</td>
</tr>
<tr>
<td></td>
<td>Only students who fulfill the following criteria are allowed to begin with their Master's thesis: a. successful completion of the Bachelor's programme; b. fulfilling of any additional requirements necessary to gain admission to the Master's programme.</td>
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<td><strong>Duration of the Master's Thesis 20 weeks.</strong></td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>In the Master's thesis students prove their ability to independent, structured and scientific working. The Master's thesis is usually carried out in a core or optional subject area as chosen by the student.</td>
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<td><strong>Objective</strong></td>
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<td></td>
<td>In the Master's Thesis students prove their ability to independent, structured and scientific working.</td>
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**Inorganic Chemistry**

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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>529-0141-00L</td>
<td>Physical Methods for Inorganic Chemistry</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>M. D. Wörle, D. Günther, J. Koch, R. Verel</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Introduction into the important methods for structural analysis (solid state NMR), crystal structure analysis and surface analysis techniques and their applications</td>
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<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>Knowledge in solid state NMR, crystal structure analysis and surface analytical techniques relevant for inorganic materials</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<td></td>
<td>This lecture course consists of three parts 1) Solid-state NMR 2) Surface and direct solid analysis 3) Crystal structure analysis. Most important fundamentals of the individual methods will be presented and details will be explained on most relevant inorganic applications</td>
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<td></td>
<td><strong>Lecture notes</strong></td>
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<td>Will be given during the lectures</td>
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**Organic Chemistry**

<table>
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<tr>
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<tr>
<td>529-0243-01L</td>
<td>Transition Metal Catalysis: From Mechanisms to Applications</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>B. Morandi</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint</td>
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<td><strong>Objective</strong></td>
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<td>Understanding and critical evaluation of current research in transition metal catalysis. Design of mechanistic experiments to elucidate reaction mechanisms. Synthetic relevance of transition metal catalysis. Students will also learn about writing an original research proposal during a workshop.</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint. Synthetic applications of these reactions. Introduction and application of tools for the elucidation of mechanisms. Selected examples of topics include: C-H activation, C-O activation, C-C activation, redox active ligands, main group redox catalysis, bimetallic catalysis.</td>
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<td></td>
<td><strong>Lecture notes</strong></td>
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<td></td>
<td>Lecture slides will be provided online. A Handout summarizing important concepts in organometallic and physical organic chemistry will also be provided. Useful references and handouts will also be provided during the workshop.</td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<tr>
<td></td>
<td>Slides will be uploaded 1-2 days before each lecture on <a href="http://morandi.ethz.ch/education.html">http://morandi.ethz.ch/education.html</a></td>
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<tr>
<td></td>
<td><strong>Prerequisites / notice</strong></td>
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<td></td>
<td><strong>Required level:</strong> Courses in organic and physical chemistry (kinetics in particular) of the first and second year as well as ACI and III</td>
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</table>

**Electives**

Students are free to choose from a range of D-CHAB chemistry courses appropriate to their level of study (please note admission requirements). In case of doubt, contact the student administration.
## Literature


## Prerequisites / notice

OC I-IV

## Competencies

### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

### Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: assessed

### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

## 529-0241-10L Selectivity in Organic Synthesis

<table>
<thead>
<tr>
<th>W</th>
<th>6 credits</th>
<th>3G</th>
</tr>
</thead>
<tbody>
<tr>
<td>J. W. Bode</td>
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</tbody>
</table>

### Abstract

Fundamentals of selective organic reactions, including current and historical examples of enantioselectivity, regioselectivity, chemoselectivity. Further aspects include recent developments in catalysis, strategies and tools for selective organic synthesis.

### Objective

Understanding and explaining the origin of selectivity in organic synthesis and the application of selective organic reactions to the construction of complex organic and biological molecules.

### Content

- Fundamental concepts and recent advances for the selective synthesis of complex organic molecules, including natural products, pharmaceuticals, and biological molecules.
- Key concepts include the development of enantioselective and regioselective catalysts, the identification of new reaction mechanisms and pathways, and technological advances for facilitating the synthesis of organic molecules.
- Analysis of key primarily literature including identification of trends, key precedents, and emerging topics will be emphasized.

### Lecture notes

Will be provided in class and online

### Literature

Suggested Textbooks

## 529-0240-00L Chemical Biology - Peptides

<table>
<thead>
<tr>
<th>W</th>
<th>6 credits</th>
<th>3G</th>
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</thead>
<tbody>
<tr>
<td>H. Wennemers</td>
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</tr>
</tbody>
</table>

### Abstract

An advanced course on the synthesis, properties and function of peptides in chemistry and biology.

### Objective

Knowledge of the synthesis, properties and function of peptides in chemistry and biology.

### Content

- Advanced peptide synthesis, conformational properties, combinatorial chemistry, therapeutic peptides, peptide based materials, peptides in nanotechnology, peptides in asymmetric catalysis.
- Lectures notes: Citations from the original literature relevant to the individual lectures will be assigned weekly.

### Literature


## 529-0731-00L Nucleic Acids and Carbohydrates

Note for BSc Biology students: Only one of the two concept courses 529-0731-00 Nucleic Acids and Carbohydrates (autumn semester) or 529-0732-00 Proteins and Lipids (spring semester) can be counted for the Bachelor's degree.

### Abstract

Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

### Objective

Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 542 of 2653
Content
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Lecture notes
No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).

Literature
Mainly based on original literature, a detailed list will be distributed during the lecture

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed
Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Personal Competencies
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

>>>> Physical Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>529-0433-01L</td>
<td>Advanced Physical Chemistry: Statistical</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>R. Riek, J. Richardson</td>
</tr>
<tr>
<td></td>
<td>Thermodynamics</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Introduction to statistical mechanics and thermodynamics. Prediction of thermodynamic and kinetic properties from molecular data.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>Introduction to statistical mechanics and thermodynamics. Prediction of thermodynamic and kinetic properties from molecular data.</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
<td></td>
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<td>See homepage of the lecture.</td>
</tr>
<tr>
<td></td>
<td>Literature</td>
<td></td>
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<td></td>
<td>See homepage of the lecture.</td>
</tr>
<tr>
<td></td>
<td>Prerequisites / notice</td>
<td></td>
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<td></td>
<td>Chemical Thermodynamics, Reaction Kinetics, Molecular Quantum Mechanics and Spectroscopy; Mathematical Foundations (Analysis, Combinatorial Relations, Integral and Differential Calculus)</td>
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<tr>
<td></td>
<td>Competencies</td>
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<td>Subject-specific Competencies assessed</td>
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<td>Method-specific Competencies assessed</td>
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<td>Social Competencies assessed</td>
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<td>Personal Competencies assessed</td>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0027-00L</td>
<td>Advanced Magnetic Resonance - Solid State NMR</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>M. Ernst</td>
</tr>
<tr>
<td></td>
<td>Does not take place this semester.</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>The course is for advanced students and introduces and discusses the theoretical foundations of solid-state nuclear magnetic resonance (NMR).</td>
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<td></td>
<td>Objective</td>
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<td>The aim of the course is to familiarize the students with the basic concepts of modern high-resolution solid-state NMR. Starting from the mathematical description of spin dynamics, important building blocks for multi-dimensional experiments are discussed to allow students a better understanding of modern solid-state NMR experiments. Particular emphasis is given to achieving high spectral resolution.</td>
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<tr>
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<td>Content</td>
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<td>The basic principles of NMR in solids will be introduced. After the discussion of basic tools to describe NMR experiments, basic methods and experiments will be discussed, e.g., magic-angle spinning, cross polarization, decoupling, and recoupling experiments. Such basic building blocks allow a tailoring of the effective Hamiltonian to the needs of the experiment. These basic building blocks can then be combined in different ways to obtain spectra that contain the desired information.</td>
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<td>Lecture notes</td>
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<td>A script which covers the topics will be distributed in the lecture and will be accessible through the web page <a href="http://www.ssnmr.ethz.ch/education/">http://www.ssnmr.ethz.ch/education/</a></td>
</tr>
<tr>
<td></td>
<td>Prerequisites / notice</td>
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<td>Prerequisite: A basic knowledge of NMR, e.g. as covered in the Lecture Physical Chemistry IV, or the book by Malcolm Levitt.</td>
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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0130-00L</td>
<td>Advanced Magnetic Resonance - DNP Instrumentation</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>A. Barnes</td>
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<tr>
<td></td>
<td>and Applications</td>
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<td></td>
<td>Does not take place this semester.</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>The course is for advanced students and covers selected topics from magnetic resonance spectroscopy. The following topics will be covered: DNP theory &amp; instrumentation, Microwave theory &amp; technology, Biological applications of solid-state DNP.</td>
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<tr>
<td></td>
<td>Objective</td>
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<td>The course aims at enabling students to understand the key theoretical points of DNP and to design DNP experiments. Students will be familiarized with the structure of the state-of-the-art DNP instrumentation. Students will be also informed about the technological challenges towards the development of advanced instrumentation for the future DNP experiments. A special focus will be given in the technology of microwave source. Furthermore, students will become familiar with pulse sequences used in biomolecular applications and understand how they are constructed. Students will be able to identify the strengths and weaknesses of biomolecular DNP and how to design DNP experiments for biological applications including sample preparation and choice of NMR experiment and related parameters.</td>
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</tbody>
</table>

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The course is separated in three well separated parts.

The first part will cover DNP concept and mechanisms, while a special focus will be given in DNP instrumentation, such as MAS technology, and the NMR probe. Several details will be also presented on the development high field NMR magnet.

The second part of the course is dedicated to the microwave theory and technology. This part starts with an introduction of the two different types of microwave sources, such as the solid-state devices and vacuum tubes, which are extensively used in DNP and EPR spectroscopy. A special focus will be given to the vacuum tube’s theory and technology. In this context, the Maxwell equations and the propagation of the transverse electric and transverse magnetic modes in circular waveguides will be taught. This material will be the basis for understanding the resonance theory and the fundamentals of the microwave’s generation in vacuum tubes. Based on the theoretical background gained in the previous lectures it will be possible to understand the operation principle of the slow wave devices, such as Klystron, Traveling Wave Tube (TWT), Backward Wave Oscillator (BWO) and Surface Wave Structure (SWS), as well as, the fast wave devices, such as gyro-devices, Free Electron Laser, etc. Finally, some details on the structure of a real DNP gyrotron will be presented.

The third part of the course will cover CPMAS and homonuclear and heteronuclear recoupling schemes and their use in correlation spectroscopy for structure and molecular interaction determination. Sample preparation with particular emphasis of glassing agents and their relationship to DNP enhancements will be discussed. Resolution under DNP including a discussion about inhomogeneous and homogeneous broadening at cryogenic temperatures. Methods for circumventing low resolution at cryogenic temperatures will be discussed including site specific isotope labeling, bio-orthogonal labeling and site specific radical labeling/targeting. Concepts around the role of spin diffusion in DNP, direct and indirect DNP, paramagnetic broadening, longitudinal T1 and methyl quenching in biological NMR will also be discussed. These concepts will then be tied together through discussions of biomolecular applications of solid-state DNP including membrane proteins, in-cell DNP and viruses.

Lecture notes
A script which covers the topics will be accessible through the course Moodle

529-0026-00L Advanced Magnetic Resonance - Biological Magnetic Resonance

Abstract
The course is for advanced students and covers selected topics from magnetic resonance spectroscopy. It is concerned with inference of structure and dynamics of proteins and their complexes from data obtained by EPR and liquid-state NMR experiments. The special focus is on multi-state and ensemble modelling.

Objective
This course enables students to design experimental strategies for characterization of structure and dynamics of proteins whose flexibility is relevant for their function. Students understand the spin dynamics that encodes sidechain and backbone motion as well as distance information into signals measured by magnetic resonance experiments. They learn to solve the inverse problem of inferring dynamics parameters and distances from the experimental results. They acquire skills in modelling protein ensemble structure from constraints derived by analyzing magnetic resonance data. Students are aware of the complications introduced by the use of spin labels in such experiments and learn how to include such labels in modelling.

Content
• Nitroxide spin labels, their interaction with the environment, and influence of their dynamics on EPR line shapes
• Contributions to electron spin decoherence and ways to improve resolution in pulsed EPR
• Measurement of electron-electron dipole-dipole interaction and conversion of the primary data to distance distributions
• Modelling of spin labels by rotamer libraries
• Ensemble modelling with exact NOE constraints
• Ensemble modelling with distance distributions
• Liquid-state NMR experiments for assessing protein structure and dynamics
• Assignment of NMR signals for proteins
• Theory of the nuclear Overhauser effect (NOE)
• Ensemble modelling with exact NOE constraints
• Multistate structure calculation and analysis
• Further constraints on protein structure and dynamics from NMR experiments

Lecture notes
A script, which covers the topics, will be accessible through the course Moodle

Prerequisites / notice
A basic knowledge of magnetic resonance, e.g. as covered in the Lecture Physical Chemistry IV, or the book "Spin Dynamics" by Malcolm Levitt.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-direction and Self-management fostered

ECTS
529-0043-01L Analytical Strategy W 6 credits 3G R. Zenobi, S. Giannoukos, D. Günther

Abstract
Problem-oriented development of analytical strategies and solutions.

Objective
Ability to create solutions for particular analytical problems.

Content
Individual development of strategies for the optimal application of chemical, biochemical, and physico-chemical methods in analytical chemistry solving predefined problems. Experts from industry and administration present particular problems in their field of activity. Principles of sampling.

Lecture notes
Copies of problem sets and solutions will be distributed free of charge

Prerequisites / notice
529-0051-00 "Analytical Chemistry I (3. Semester)"
529-0058-00 "Analytical Chemistry II (4. Semester)"
(or equivalent)
### Chemical Aspects of Energy

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<tbody>
<tr>
<td>151-0209-00L</td>
<td>Renewable Energy Technologies</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>A. Bardow, E. Casati</td>
</tr>
</tbody>
</table>

#### Abstract
The first part of the course covers the engineering aspects of the prominent renewable energy technologies: solar (PV and thermal), wind, hydro, geothermal and bioenergy. We further discuss energy storage, renewable transport and renewable heating & cooling. Finally, we introduce the key concepts of the economics of renewable energy and its integration in the energy system.

#### Objective
Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization.

#### Lecture notes
Lecture Notes containing copies of the presented slides.

#### Prerequisites / notice
Prerequisite: strong background on the fundamentals of engineering thermodynamics, equivalent to the material taught in the courses Thermodynamics I, II, and III of D-MAVT.
Chemical Crystallography

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<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0029-01L</td>
<td>Structure Determination</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>M. D. Wörle, N. Trapp</td>
</tr>
</tbody>
</table>

Abstract
Advanced X-ray crystal structure analysis

Objective
To gain a deeper understanding of crystal structure determination principles and practice by X-ray diffraction and the evaluation of results. Review of principles of diffraction and instrumentation, unit cells, lattices, and symmetry. Inorganic structural chemistry: sphere packings, ionic crystals, covalent networks, intermetallic compounds. Overview of powder diffraction and application of crystal chemistry for structure analysis of polycrystalline phases. Working safely with X-rays, crystal growth, selection and mounting, data collection strategies, data reduction, corrections for absorption, extinction and Lp, advanced structure solution theory and techniques: Patterson function, heavy atom technique, Fourier methods, direct methods. Structure modeling and refinement, disorder, twinning, false symmetry, interpretation of anisotropic shift parameters. Determination of absolute configuration, interpretation of results and scope of chemically useful information, validation and publication of results, critical evaluation of published crystal structures.

Content
Information and exercise sheets will be distributed in loose form.

Literature
(2) J.D. Dunitz, "X-ray Analysis and the Structure of Organic Molecules", 1995, Verlag HCA.

Additional literature

Prerequisites / notice
Students will conduct the computational exercises and examples of structure solution and refinement on personal computers.

Prerequisite: Principles of Crystal Structure Determination (529-0039-00L).

Chemical Technology

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<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>636-0108-00L</td>
<td>Biological Engineering and Biotechnology</td>
<td>W</td>
<td>4</td>
<td>3V</td>
<td>M. Fussemegger</td>
</tr>
</tbody>
</table>

Abstract
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content

Computational Chemistry

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0003-01L</td>
<td>Advanced Quantum Chemistry</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>M. Reiher, T. Weymuth</td>
</tr>
</tbody>
</table>
The course aims to provide an in-depth knowledge of theory and method development in theoretical chemistry. It will be shown that this is necessary in order to be able to solve actual chemical problems on a computer with quantum chemical methods.

## Content

1. Introductory lecture: basics of quantum mechanics and quantum chemistry
2. Einstein’s special theory of relativity and the (classical) electromagnetic interaction of two charged particles
3. Klein-Gordon and Dirac equation; the Dirac hydrogen atom
4. Numerical methods based on the Dirac-Fock-Coulomb Hamiltonian, two-component and scalar relativistic Hamiltonians
5. Response theory and molecular properties, derivation of property operators, Breit-Pauli-Hamiltonian
6. Relativistic effects in chemistry and the emergence of spin
7. Spin in density functional theory
8. New electron-correlation theories: Tensor network and matrix product states, the density matrix renormalization group

## Literature

2. F. Schwabl: Quantenmechanik für Fortgeschrittene (QM II), Springer-Verlag, 1997 (english version available: F. Schwabl, Advanced Quantum Mechanics)

Note also the standard textbooks:

A) A. Szabo, N.S. Ostlund. Verlag, Dover Publications
B) I. N. Levine, Quantum Chemistry, Pearson

## Prerequisites / notice

Strongly recommended (preparatory) courses are: quantum mechanics and quantum chemistry

## Competencies

### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: fostered

### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

### Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: fostered
- Self-awareness and Self-reflection: fostered

## 529-0004-01L

**Classical Simulation of (Bio)Molecular Systems**

- 6 credits
- 4G
- P. H. Hünlenberger, J. Dolenc, S. Riniker

### Abstract

Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

### Objective

Introduction to classical (atomic) computer simulation of (bio)molecular systems, development of skills to carry out and interpret these simulations.

### Content

Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

### Literature

See: www.csms.ethz.ch/education/CSBMS

### Prerequisites / notice

Since the exercises on the computer do convey and test essentially different skills than those being conveyed during the lectures and tested at the oral exam, the results of the exercises are taken into account when evaluating the results of the exam (learning component, possible bonus of up to 0.25 points on the exam mark).

For more information about the lecture: www.csms.ethz.ch/education/CSBMS

## Competencies

### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

### Method-specific Competencies
- Analytical Competencies: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed

### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered

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**Material Science**

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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>327-0703-00L</td>
<td>Electron Microscopy in Material Science</td>
<td>W</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>S. Gerstl, R. Erni, F. Gramm, A. Käch, F. Krumeich, K. Kunze</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
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<td></td>
<td>A comprehensive understanding of the interaction of electrons and ions with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.</td>
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<tr>
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<td><strong>Objective</strong></td>
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<td></td>
<td>A comprehensive understanding of the interaction of electrons and ions with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.</td>
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<tr>
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<td><strong>Content</strong></td>
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<td>This course provides a general introduction into electron- and ion-microscopy of organic and inorganic materials. In the first part, the basics of transmission- and scanning electron microscopy are presented. The second part includes the most important aspects of specimen preparation, imaging and image processing. In the third part, focused ion-beam and atom probe microscopes are presented. Throughout the semester, various applications in materials science, solid state physics, structural biology, structural geology, and structural chemistry will be reported.</td>
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<td><strong>Lecture notes</strong></td>
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<td></td>
<td>will be distributed in English</td>
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<td>Enri: Aberration-corrected imaging in transmission electron microscopy, Imperial College Press (2010, and 2nd ed. 2015)</td>
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</tbody>
</table>

| Competencies | Subject-specific Competencies        | assessed |
|             | Techniques and Technologies         | assessed |
|             | Method-specific Competencies        | fostered |
|             | Analytical Competencies             | fostered |
|             | Decision-making                     | assessed |
|             | Problem-solving                     | assessed |
|             | Social Competencies                 | fostered |
|             | Communication                       | fostered |
|             | Cooperation and Teamwork            | fostered |
|             | Negotiation                         | fostered |
|             | Personal Competencies               | fostered |
|             | Adaptability and Flexibility        | fostered |
|             | Creative Thinking                   | fostered |
|             | Critical Thinking                   | fostered |

<table>
<thead>
<tr>
<th>402-0468-15L</th>
<th>Nanomaterials for Photonic Devices</th>
<th>W</th>
<th>6 credits</th>
<th>2V+1U</th>
<th>R. Grange, E. Bailly, R. Chapman, V. Falcone, A. Morandi</th>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>The lecture describes various nanomaterials (semiconductor, metal, dielectric, carbon-based...) for photonic applications (optoelectronics, plasmonics, photonic integrated circuits, ordered and disordered structures...). It starts with concepts of light-matter interactions, fabrication and characterization, the description of the properties and the state-of-the-art applications and devices.</td>
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<td><strong>Objective</strong></td>
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<td>The students will acquire theoretical and experimental knowledge about the different types of nanomaterials (semiconductors, metals, dielectric, carbon-based,...) and their uses as building blocks for advanced applications in photonics (optoelectronics, plasmonics, photonic crystal,...). Together with the exercises, the students will learn (1) to read, summarize and discuss scientific articles related to the lecture, (2) to estimate order of magnitudes with calculations using the theory seen during the lecture, (3) to prepare a short oral presentation and report about one topic related to the lecture, and (4) to imagine an original photonic device.</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<td></td>
<td>1. Introduction to nanophotonics</td>
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<td>2. Wave physics for nanophotonics</td>
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<td>3. Characterization of nanomaterials</td>
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<td>4. Semiconductors</td>
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<td>5. Nonlinear crystals</td>
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<td>6. Photonic integrated circuits</td>
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<td>7. Optical quantum devices</td>
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<td>8. Plasmonics</td>
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<td>9. Metasurfaces</td>
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<td>10. Graphene &amp; 2D Materials</td>
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<td>11. Nanocomposites</td>
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<td><strong>Lecture notes</strong></td>
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<td>Slides and book chapter will be available for downloading</td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<td>References will be given during the lecture</td>
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<td><strong>Prerequisites / notice</strong></td>
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<td>Basics of solid-state physics (i.e. energy bands) can help</td>
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<td><strong>Competencies</strong></td>
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<td>Subject-specific Competencies</td>
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<td>Techniques and Technologies</td>
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<td>Decision-making</td>
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<td>Cooperation and Teamwork</td>
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<td>Adaptability and Flexibility</td>
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<th>Advanced Polymer Synthesis</th>
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<th>3G</th>
<th>T. L. Choi</th>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 548 of 2653
Modern polymer synthesis (based on recent development of new organic reactions) is discussed to enable students to develop synthesis schemes for certain target structures. Both chain (ionic, coordination, ROMP, radical, catalyst-transfer) and step-growth polymerizations (transition metal catalysis) including how to achieve living polymerization or improve selectivity will be discussed.

Students should be able to:

1. Identify important polymerization procedures and types of polymerization.
2. Predict activities of monomers based on the chemical structures.
3. Devise synthetic pathways to produce a given polymer structure.
4. Evaluate properties of macromolecules based on structure and synthesis method.
5. Develop synthesis schemes for target structures and discuss potential applications of polymers.

Polymerization is a series of continuous organic transformation and connects small molecules. The course will give an overview of the following important polymerization procedures:

- Modern step-growth polymerization
- Living anionic polymerization
- Group transfer polymerization (GTP)
- Controlled cationic polymerization
- Controlled radical polymerization
- Coordination polymerization: Ziegler-Natta and Metallocene catalysts
- Olefin metathesis polymerization: ROMP, ADMET and cyclopolymerization
- Synthesis of conjugated polymers based on transition metal catalysis
- Complex macromolecules including brush and dendronized polymers

Students will learn how to deal with chemical structures and reactivities, and be able to suggest reasonable synthetic pathways to a given polymer structure, like conjugated polymers based on transition metal catalysis or complex macromolecules including brush and dendronized polymers. Aspects like controlling molar masses and structure perfection play a role throughout. The course provides the students with a high-level overview of modern methods of polymer synthesis both in theoretical and practical aspects. It should enable them to develop reasonable synthesis schemes for certain target structures and also to predict the properties of given macromolecules. For all polymers presented, potential or real applications will be discussed.

They will be uploaded on Moodle.

They will be handed out as the lectures progress.

They will be uploaded on Moodle.

They will be uploaded on Moodle.

They will be uploaded on Moodle.

They will be uploaded on Moodle.
Objective

This course intends to enable all students to:

- Acquire and understand the basic jargon, concepts and methods necessary to discuss, in a precise and concise manner, innovation processes and their outcomes at different levels of analysis

- Analyze the differences between individual and organizational decision processes and their innovative outcomes

- Evaluate critically the potential of different (digital) technologies to impact business organizations.

Content

Organizations and people are faced with a fundamental decision: they have to allocate resources between well-known tasks that reliably generate positive results; or explore new ways of doing things, new technologies, products and services. The latter is a high risk choice. Its rewards can be high, but the chances of success are small. How do firms organize to take these decisions? What kind of management skills are necessary to take them? What kind of tools and methods are deployed to sustain managerial decision-making in highly volatile environments? These are the central questions on which this course focuses, relying on a combination of lectures, case-based discussion, and guest speakers.

Lecture notes

Slides will be available on the Moodle page

Literature

Readings will be available on the Moodle page

Prerequisites / notice

The course content and methods are designed for students with some background in management and/or economics

Competencies

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363-0565-00L Principles of Macroeconomics

Abstract

This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

Objective

This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to every-day economic problems.

Content

This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

Lecture notes

The course Moodle page contains announcements, course information and lecture slides.

Literature


This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filippini).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.

Competencies

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Compensatory courses

Inorganic Chemistry
Advanced Magnetic Resonance - Solid State NMR

**Abstract**
The aim of the course is to familiarize the students with the basic concepts of modern high-resolution solid-state NMR. Starting from the mathematical description of spin dynamics, important building blocks for multi-dimensional experiments are discussed to allow students a better understanding of modern solid-state NMR experiments. Particular emphasis is given to achieving high spectral resolution.

**Objective**
The basic principles of NMR in solids will be introduced. After the discussion of basic tools to describe NMR experiments, basic methods and experiments will be discussed, e.g., magic-angle spinning, cross polarization, decoupling, and recoupling experiments. Such basic building blocks allow a tailoring of the effective Hamiltonian to the needs of the experiment. These basic building blocks can then be combined in different ways to obtain spectra that contain the desired information.

**Content**
This lecture course consists of three parts 1) Solid-state NMR 2) Surface and direct solid analysis 3) Crystal structure analysis. Most important fundamentals of the individual methods will be presented and details will be explained on most relevant inorganic applications

**Lecture notes**
Will be given during the lectures

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**Science in Perspective**

- see Science in Perspective: Language Courses ETH/UZH
- see Science in Perspective: Type A: Enhancement of Reflection Capability
- Recommended Science in Perspective (Type B) for D-CHAB

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**Course Units for Additional Admission Requirements**
The courses below are only available for MSc students with additional admission requirements.

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<tr>
<th>Number</th>
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<td>E-</td>
<td>3 credits</td>
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<td>D. Günther, R. Zenobi</td>
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The underlying lecture (529-0051-00L) is offered in autumn semester but only in German.

Abstract
Introduction into the most important spectroscopical methods and their applications to gain structural information.

Objective
Knowledge about the necessary theoretical background of spectroscopical methods and their practical applications.

Content
Application oriented basics of organic and inorganic instrumental analysis and of the empirical employment of structure eludication methods:
- Mass spectrometry: Ionization methods, mass separation, isotope signals, rules of fragmentation, rearrangements.
- NMR spectroscopy: Experimental basics, chemical shift, spin-spin coupling.
- IR spectroscopy: Revisiting topics like harmonic oscillator, normal vibrations, coupled oscillating systems (in accordance to the basics of the related lecture in physical chemistry); sample preparation, acquisition techniques, law of Lambert and Beer, interpretation of IR spectra; Raman spectroscopy.

Lecture notes
Script will be provided for the production price

Literature
- D. A. Skoog and J. D. Leary, Instrumentelle Analytik, Springer, Heidelberg, 1996;
- M. Hesse, H. Meier, B. Zeeh, Spektroskopische Methoden in der organischen Chemie, 5. überarbeitete Auflage, Thieme, Stuttgart, 1995

Prerequisites / notice
Exercises are integrated in the lectures. In addition, attendance in the lecture 529-0289-00 “Instrumental analysis of organic compounds” (4th semester) is recommended.

529-0058-AAL
Analytical Chemistry II
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Enhanced knowledge about the elemental analysis and spectrocopical techniques with close relation to practical applications. This course is based on the knowledge from analytical chemistry I. Separation methods are included.

Objective
Use and applications of the elemental analysis and spectrocopical knowledge to solve relevant analytical problems.

Content
Combined application of spectroscopic methods for structure determination, and practical application of element analysis. More complex NMR methods: recording techniques, application of exchange phenomena, double resonance, spin-lattice relaxation, nuclear Overhauser effect, applications of experimental 2d and multipulse NMR spectroscopy, shift reagents. Application of chromatographic and electrophoretic separation methods: basics, working technique, quality assessment of a separation method, van-Deemter equation, gas chromatography, liquid chromatography (HPLC, ion chromatography, gel permeation, packing materials, gradient elution, retention index), field desorption, field flow fractionation, enhanced knowledge in atomic absorption spectroscopy, atomic emission spectroscopy, X-ray fluorescence spectroscopy, ICP-OES, ICP-MS.

Literature
K. Robards, P. R. Haddad, and P. E. Jackson, Principle and Practice of Modern Chromatographic Methods, Academic Press, London, 1994,

Prerequisites / notice
None.

529-0132-AAL
Inorganic Chemistry III: Organometallic Chemistry and Homogeneous Catalysis
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Fundamental aspects of the organometallic chemistry of the transition elements. Mechanistic homogeneous catalysis including oxidative additions, reductive eliminations and insertion reactions. Catalytic hydrogenation, carbonylation, C-C bond-forming and related reactions.

Objective
Towards an understanding of the fundamental coordination-chemical and mechanistic aspects of transition-metal chemistry relevant to homogeneous catalysis.

Content
Fundamental aspects of the organometallic chemistry of the transition elements. Mechanistic homogeneous catalysis including oxidative additions, reductive eliminations and insertion reactions. Catalytic hydrogenation, carbonylation, C-C bond-forming and related reactions.
Physical Chemistry III: Molecular Quantum Mechanics  
E- 4 credits  
F. Merkt  

Abstract  
Postulates of quantum mechanics, operator algebra, Schrödinger’s equation, state functions and expectation values, matrix representation 
of operators, particle in a box, tunneling, harmonic oscillator, molecular vibrations, angular momentum and spin, generalised Pauli principle, 
perturbation theory, electronic structure of atoms and molecules, Born-Oppenheimer approximation.

Objective  
This is an introductory course in quantum mechanics. The course starts with an overview of the fundamental concepts of quantum 
mechanics and introduces the mathematical formalism. The postulates and theorems of quantum mechanics are discussed in the context 
of experimental and numerical determination of physical quantities. The course develops the tools necessary for the understanding and 
calculation of elementary quantum phenomena in atoms and molecules.

Content  
Postulates and theorems of quantum mechanics: operator algebra, Schrödinger’s equation, state functions and expectation values. Linear 
motions: free particles, particle in a box, quantum mechanical tunneling, the harmonic oscillator and molecular vibrations. Angular 
momentum: electronic spin and orbital motion, molecular rotations. Electronic structure of atoms and molecules: the Pauli principle, angular 
momentum coupling, the Born-Oppenheimer approximation. Variational principle and perturbation theory. Discussion of bigger systems 
(solids, nano-structures).

Literature  

Enrolment ONLY for MSc students with a degree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, 
doctoral students) CANNOT enrol for this course unit.

Physical Chemistry IV: Magnetic Resonance  
E- 4 credits  
G. Jeschke, M. Ernst  

Abstract  
Theoretical foundations of magnetic resonance (NMR,EPR) and selected applications.

Objective  
Introduction to magnetic resonance in isotropic and anisotropic phase.

Content  
The course gives an introduction to magnetic resonance spectroscopy (NMR and EPR) in liquid, liquid crystalline and solid phase. It 
starts from a classical description in the framework of the Bloch equations. The implications of chemical exchange are studied and 
two-dimensional exchange spectroscopy is introduced. An introduction to Fourier spectroscopy in one and two dimensions is given and simple 
pulse trickery’ is described. A quantum-mechanical description of magnetic resonance experiments is introduced and the spin Hamiltonian 
is derived. The chemical shift term as well as the scalar, dipolar and quadrupolar terms are discussed. The product-operator formalism is 
introduced and various experiments are described, e.g. polarization transfer. Applications in chemistry, biology, physics and medicine, e.g. 
determination of 3D molecular structure of dissolved molecules, determination of the structure of paramagnetic compounds and imaging 
(MRI) are presented.

Enrolment ONLY for MSc students with a degree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, 
doctoral students) CANNOT enrol for this course unit.

Inorganic and Organic Chemistry II  
E- 11 credits  
V. Mougel  

Abstract  
Introduction to the experimental methods of Inorganic Chemistry

Objective  
The teaching laboratory offers an insight into different aspects of Inorganic Chemistry, including solid state chemistry, organometallic 
chemistry, kinetics, etc.. The synthesis, characterization and analysis of inorganic compound are a main topic. Emphasis is given to 
scientific writing (experiment reports).

Content  
Inorganic chemistry part: Synthesis and analysis of elemento-organic compounds, metal complexes, and organometallic compounds. 
Introduction to Schlenk techniques, solid state synthesis, and kinetics. Introduction in the chemistry library: literature data banks and 
collections of spectra.

Organic synthesis with organometallic compounds and catalysts: Experiments in the framework of a selected specialised project. Possible 
projects: Rh catalysed asymmetric hydrogenation of enamides, Mn-catalysed epoxidation of olefins, Cu catalysed Diels-Alder reactions, 
synthesis of organo-boron compounds and Pd catalysed coupling with halides, Ru catalysed transfer hydrogenation.

Enrolment ONLY for MSc students with a degree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, 
doctoral students) CANNOT enrol for this course unit.

Note: A manual is distributed in the teaching laboratory.

Prerequisites / notice  
- Practical Course General Chemistry (1. Semester, 529-0011-04)  
- Practical Course Inorg. and Org. Chemistry I (2. Sem., 529-0230)  
- Attendance of Course Inorg. Chemistry 1 (3. Sem., 529-0121)  

If necessary, access priority will be settled according to the results of the first-year examinations.
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**Chemistry Master - Key for Type**

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**Key for Hours**

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**ECTS**

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
**Chemical and Bioengineering Master**

► **Core Subjects**

★★ **Biochemical Engineering**

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<td>A. de Mello</td>
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**Abstract**

Microfluidics describes the behaviour, control and manipulation of fluids geometrically constrained within sub-uL environments. Microfluidic devices enable physical and chemical processes to be controlled with exquisite precision and in an fast and efficient manner. This course introduces the underlying concepts, features and applications of microfluidic systems in the chemical and life sciences.

**Objective**

We will investigate the theoretical concepts behind microfluidic device operation, the methods of microfluidic device manufacture and the application of microfluidic architectures to important problems faced in modern day chemical and biological analysis.

A central component of this course is a research project. This will allow students to develop a practical understanding of the benefits of miniaturization in chemical and biological experimentation. Projects will be performed in groups of between four and six students and will include both experimental and simulation aspects. Each group, under the guidance of a mentor, will plan and execute a novel research project. The results of this activity will be disseminated through an "academic-style" research article and a "conference-style" oral presentation. Course grades will be evaluated through both a written exam and the project grade.

**Content**

Specific topics covered in the course include, but are not limited to:

1. Theoretical Concepts
   - Scaling laws, features of thermal/mass transport, diffusion, basic description of fluid flow in small volumes, microfluidic mixing strategies.

2. Microfluidic Device Manufacture
   - Basic principles of conventional lithography of rigid materials, 'soft' lithography, polymer machining (injection molding, hot embossing, and 3D-printing).

3. Electrokinetics
   - Principles of electrophoresis, electroosmosis, high performance capillary electrophoresis, electrokinetic scaling laws, chip-based electrophoresis and isoelectric focusing.

4. Mass Transfer Phenomena
   - Key features of mass transport in microfluidic systems, diffusive transport, diffusion-convection, Pécel number, Taylor-Aris diffusion, chaotic mixing and Damköhler numbers.

5. Heat Transfer Phenomena
   - Key features of thermal transport in microfluidic systems, conduction, convection, heat transfer by convection in internal flows, heat transfer processes in microfluidic devices.

6. Microfluidic Systems for Materials Synthesis
   - Microfluidic reactors for the controlled synthesis of colloidal nanomaterials, advanced automation for bespoke materials discovery & characterization.

7. Point-of-Care Diagnostics
   - Microscale tools for diagnostics, challenges associated with point-of-care (PoC) diagnostic testing, requirements for PoC devices, common PoC device formats, applications of PoC diagnostics in the developing world.

8. Microscale DNA Amplification
   - Amplification and analysis of nucleic acids using batch, continuous flow and droplet-based microfluidic reactors.

9. Small volume Molecular Detection
   - Spectroscopic approaches for analyte detection in small volumes with a particular focus on single molecule detection.

10. Droplets and Segmented Flows
    - Formation, manipulation and use of liquid/liquid segmented flows in chemical and biological experimentation.

11. Single Cell Analysis
    - Applications of microfluidic tools in cellular analysis, flow cytometry, enzymatic assays and single cell analysis.

**Lecture notes**

- Lecture handouts, background literature, problem sheets and notes will be provided electronically through the course Moodle site.

**Literature**

- There is no set text for the course. All relevant literature will be provided electronically through the course Moodle site.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Assessed</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<td>Analytical Competencies</td>
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<td>Decision-making</td>
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<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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**529-0615-01L Biochemical and Polymer Reaction Engineering**

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0615-01L</td>
<td>Biochemical and Polymer Reaction Engineering</td>
<td>W+</td>
<td>6</td>
<td>3G</td>
<td>P. Arosio, P. Fleckenstein</td>
</tr>
</tbody>
</table>

**Abstract**


**Objective**

The aim of the course is to learn how to design polymerization reactors and bioreactors to produce polymers and proteins with the specific product qualities that are required by different applications in chemical, pharmaceutical and food industry. This activity includes the post-treatment of polymer latexes, the downstream processing of proteins and the analysis of their colloidal behavior.
We will cover the fundamental processes and the operation units involved in the production of polymeric materials and proteins. In particular, the following topics are discussed: Overview on the different polymerization processes, Kinetics of free-radical polymerization and use of population balance models. Production of polymers with controlled characteristics in terms of molecular weight distribution. Kinetics and control of emulsion polymerization. Surfactants and colloidal stability. Aggregation kinetics and aggregate structure in conditions of diffusion and reaction limited aggregation. Modeling and design of colloid aggregation processes. Physico-chemical characterization of proteins and description of enzymatic reactions. Operation units in bioprocessing: upstream, reactor design and downstream. Industrial production of therapeutic proteins. Characterization and engineering of protein aggregation. Protein aggregation in biology and in biotechnology as functional materials.

Lecture notes
Scripts are available on the web page of the Arosio-group: http://www.arosiogroup.ethz.ch/education.html
Additional handout of slides will be provided during the lectures.

Literature
H.W. Blanch, D. S. Clark, Biochemical Engineering, CRC Press, 1995

### Products and Materials

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0619-01L</td>
<td>Chemical Product Design</td>
<td>6</td>
<td>3G</td>
<td>W. J. Stark</td>
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</tbody>
</table>

#### Abstract
The 'Chemical Product Design' course teaches students quantitative concepts to analyze, select and transform theoretical concepts from chemistry and engineering into valuable real-world products. Basic chemistry and chemical engineering knowledge is required (Diffusion, Thermodynamics, Kinetics,...).

#### Objective
This course starts with analyzing existing chemical needs and unmet technical challenges. We then develop the skills to critically analyze a specific chemical idea for a product, to rapidly test feasibility or chance for success and to eventually realize its manufacturing. The chemical engineering basics are then used to assess performance of products or devices with non-traditional functions based on dynamic properties (e.g. responsive building materials, personal medical diagnostics on paper strips). The course teaches the interface between laboratory and market with a specific focus on evaluating the chemical value of a given process or compound, and the necessary steps to pursue the resulting project within an entrepreneurial environment. We therefore extend the questions of process design ('how do we make something?') to the question of 'what should we make?'

#### Content
Part A: The 'Chemical Product Design' course starts with discussing questions along, 'What is a chemical product, and why do people pay for it? How does a given compound in a specific compound provide a service?' We then learn how to translate new, often ill-defined wishes or ideas into quantifiable specifications.

Part B: Thermodynamic and kinetic data allow sharp selection criteria for successful products. We learn how to deal with insufficient data and development of robust case models to evaluate their technical and financial constraints. How can parameters of a running process in one industry be scaled into another industry? Can dimensionless engineering numbers be applied beyond traditional chemical processes?

Part C: Manufacturing of commodity products, devices and molecular products: Chemical reactors, separation and detection or isolation units as part of a toolbox. Planning of manufacturing and decisions based on hard data. Providing quantitative answers on potential value generated.

Students are expected to actively develop chemical products along the course during the exercise sessions. Contributions will be made in small groups, where a larger topic is studied. The progress of each group will be followed by reports and short presentations during the semester, and one final presentation at the end of the semester. Active participation in the group projects is mandatory for the admission to the oral exam.

#### Literature


#### Prerequisites / notice
Prerequisites: Basic chemistry and chemical engineering knowledge (Diffusion, Thermodynamics, Kinetics,...).

### Process Design

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tr>
<td>529-0643-01L</td>
<td>Process Design and Development</td>
<td>6</td>
<td>3G</td>
<td>G. Guillén Gosálbez</td>
</tr>
</tbody>
</table>

#### Abstract
The course is focused on the design of Chemical Processes, with emphasis on the preliminary stages of the design approach, where process creation and quick selection among many alternatives are important. The main concepts behind more detailed process design and process simulation are also examined.

#### Objective
The course is focused on the design of Chemical Processes, with emphasis on the preliminary stage of the design approach, where process creation and quick selection among many alternatives are important. The main concepts behind more detailed process design and process simulation are also examined.

#### Content

#### Lecture notes
no script
The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.

This course aims to develop the competency of chemical engineers in process flowsheeting, process simulation and process optimization.

Specifically, students will develop the following skills:
- Deep understanding of chemical engineering fundamentals: the acquisition of new concepts and the application of previous knowledge in the area of chemical process systems and their mechanisms are crucial to intelligently simulate and evaluate processes.
- Modeling of general chemical processes and systems: students should be able to identify the boundaries of the system to be studied and develop the set of relevant mathematical relations, which describe the process behavior.
- Mathematical reasoning and computational skills: the familiarization with mathematical algorithms and computational tools is essential to be capable of achieving rapid and reliable solutions to simulation and optimization problems. Hence, students will learn the mathematical principles necessary for process simulation and optimization, as well as the structure and application of process simulation software. Thus, they will be able to develop criteria to correctly use commercial software packages and critically evaluate their results.
- Process optimization: the students will learn how to formulate optimization problems in mathematical terms, the main type of optimization problems that exist (i.e., LP, NLP, MILP and MINLP) and the fundamentals of the optimization algorithms implemented in commercial solvers.

Prerequisites
Prerequisite: Basic knowledge on unit operations, mainly reaction engineering and distillation. It is recommended that the student takes the module "Process Simulation and Flowsheeting" before "Process Design and Development", but it is not mandatory.

Literature
Main books

Other references

Prerequisites / notice
A basic understanding of material and energy balances, thermodynamic property methods and typical unit operations (e.g., reactors, flash separations, distillation/absorption columns etc.) is required.

Catalysis and Separation

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
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<tbody>
<tr>
<td>151-0927-00L</td>
<td>Rate-Controlled Separations in Fine Chemistry</td>
<td>W+</td>
<td>6</td>
<td>3V+1U</td>
<td>M. Mazotti, V. Becattini, N. Casas, F. Kiefer</td>
</tr>
</tbody>
</table>

Abstract
The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.
Objective

The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.

Content

The class covers separation techniques that are central in the purification and downstream processing of chemicals and bio-pharmaceuticals. Examples from both areas illustrate the utility of the methods: 1) Adsorption and chromatography; 2) Membrane processes; 3) Crystallization and precipitation.

Lecture notes

Handouts during the class

Literature

Recommendations for text books will be covered in the class

Prerequisites / notice

Requirements (recommended, not mandatory): Thermal separation Processes I (151-0926-00) and Modelling and mathematical methods in process and chemical engineering (151-0940-00)

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies

Communication assessed
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies

Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Abstract

Heterogeneous catalysis, an enabling foundation of the chemical industry, spearheads innovation toward key sustainability targets in clean energy, carbon neutrality, and zero waste. The Catalysis Engineering course provides students with concepts bridging from the molecular-level design of catalytic materials to their technical application.

Objective

To accelerate the discovery and implementation of sustainable technologies, this vibrant discipline is constantly refining its design principles, particularly at the nanoscale, a shift facilitated by the availability of increasingly powerful tools that permit the continued development of fundamental knowledge over different time and length scales. During this course, you will learn current concepts for the defossilization of the chemical industry and strategies for achieving this goal from idea to implementation. By introducing topical case studies both in lectures and through a semester project, you will see aspects of catalyst synthesis and characterization, kinetics, mass and heat transport, deactivation and process design, sustainability metrics, and the potential of digital tools to guide catalyst design. Since this area is rapidly advancing and no textbooks are available, the lectures follow slides and journal articles.

Content

The aspects described above will be demonstrated through industrially-relevant examples such as:
- Natural gas valorization
- CO2 conversion to energy vectors
- Plastics upcycling
- Concept for a glycerol biorefinery
- Halogen chemistry on catalytic surfaces
- Ensemble design for selective hydrogenations
- Single-atom catalysis
- Hierarchical zeolite catalysts

Lecture notes

The course material is based on slides and journal articles.

Prerequisites / notice

It is assumed that students selecting this course are familiar with basic concepts of chemistry and catalysis (chemistry or chemical engineering background). Other students are welcome to contact us to discuss the requirement for prior knowledge.

Case Study

Number  Title  Type  ECTS  Hours  Lecturers

Abstract

The learning objective is to design, simulate and optimize a real (bio-)chemical process from a process systems perspective. Specifically, a commercial process simulation software (Aspen) will be used for the process simulation and optimization. Students have to integrate knowledge and develop engineering thinking and skills acquired in the other courses of the curriculum.

Objective

The students are supposed to design, simulate, and optimize a real (bio-)chemical process from a process systems perspective using a commercial process simulation software.
Create a model describing the production process
- Students will apply a commercial process simulator systematically for process creation and analysis.
- Students will create a process simulation flowsheet for steady-state simulation.

Evaluate the performance of the production process
- Students will analyse and understand the degrees of freedom in modelling process units and flowsheets.
- Students will understand the role of process simulators in process creation.
- Students will make design specifications and follow the iterations implemented to satisfy them.
- Students will judge the role of process simulators in equipment sizing and costing and profitability analysis.
- Students will assess the economic performance of the process, including operating costs (OPEX), and capital investment (CAPEX), based on the outcome of the simulation model.
- Students will assess the environmental impact of the production process following the Life Cycle Assessment (LCA) methodology.

Optimize the design and operating conditions of the production process
- Students will carry out sensitivity analyses and optimizations considering technical and economic criteria.
- Students will generate process integration alternatives to improve the initial design.
- Students will optimize the production process considering economic and environmental criteria.

Before the case study week, students are encouraged to participate in the exercises of the course "Process Simulation and Flowsheeting" in order to get familiar with the Aspen Plus simulation software (this is highly recommended, but not mandatory).

The problem statement and detailed instructions are provided in the project brief made available at the beginning of the case study week.

During the case study week:
- Students work in teams of 4-6 people.
- Students have to pose and solve process equipment and system design related problems.
- Students have to coordinate the activities, the preparation of the written report and the oral presentation.
- Students get support from project assistants and the course supervisor.

The groups deliver the written report on a predefined date.

The students receive the feedback and are asked to implement some changes in their reports.

A final presentation takes place summarizing the main findings of the project.

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<tr>
<th>Research Project or Industry Internship</th>
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<tbody>
<tr>
<td>Number</td>
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<tr>
<td>529-0300-10L</td>
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<th>Industry Internship</th>
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<td>529-0301-00L</td>
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<th>Master's Thesis</th>
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<td>529-0600-10L</td>
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<td>Content</td>
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<td>Prerequisites / notice</td>
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<th>Electives</th>
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<tr>
<td>Biochemical Engineering</td>
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<tr>
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<tr>
<td>636-0108-00L</td>
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<td>636-0007-00L</td>
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Lecture notes: http://www.csb.ethz.ch/education/lectures.html


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<tr>
<th>Code</th>
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<tr>
<td>376-1714-00L</td>
<td>Biocompatible Materials</td>
<td>W 4</td>
<td>3V</td>
<td>K. Manuiri, M. Rottmar, M. Zenobi-Wong</td>
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<td></td>
<td>Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.</td>
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<td>The course covers the following topics:</td>
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<td></td>
<td>1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.</td>
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<td>2. The concept of biocompatibility.</td>
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<td>3. Introduction into methodology used in biomaterials research and application.</td>
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<td>4. Introduction to different material classes in use for medical applications.</td>
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<td>Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed. A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.</td>
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<td>Handouts are deposited online (moodle).</td>
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(available online via ETH library)

- Handouts and references therein.

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<td>529-0615-01L</td>
<td>Biochemical and Polymer Reaction Engineering</td>
<td>W 6</td>
<td>3G</td>
<td>P. Arosio, P. Fleckenstein</td>
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<td>The aim of the course is to learn how to design polymerization reactors and bioreactors to produce polymers and proteins with the specific product qualities that are required by different applications in chemical, pharmaceutical and food industry. This activity includes the post-treatment of polymer latexes, the downstream processing of proteins and the analysis of their colloidal behavior.</td>
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<td>We will cover the fundamental processes and the operation units involved in the production of polymeric materials and proteins. In particular, the following topics are discussed: Overview on the different polymerization processes, Kinetics of free-radical polymerization and use of population balance models. Production of polymers with controlled characteristics in terms of molecular weight distribution. Kinetics and control of emulsion polymerization. Surfactants and colloidal stability. Aggregation kinetics and aggregate structure in conditions of diffusion and reaction limited aggregation. Modeling and design of colloid aggregation processes. Physico-chemical characterization of proteins and description of enzymatic reactions. Operation units in bioprocessing: upstream, reactor design and downstream. Industrial production of therapeutic proteins. Characterization and engineering of protein aggregation. Protein aggregation in biology and in biotechnology as functional materials.</td>
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<td>H.W. Bianch, D. C. Clark, Biochemical Engineering, CRC Press, 1995</td>
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<tr>
<td>529-0837-01L</td>
<td>Biomicrofluidic Engineering</td>
<td>W 6</td>
<td>3G</td>
<td>A. de Mello</td>
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<td>Microfluidics describes the behaviour, control and manipulation of fluids geometrically constrained within sub-μl environments. Microfluidic devices enable physical and chemical processes to be controlled with exquisite precision and in an fast and efficient manner. This course introduces the underlying concepts, features and applications of microfluidic systems in the chemical and life sciences.</td>
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<tbody>
<tr>
<td></td>
<td>Computational Systems Biology</td>
<td>W 6</td>
<td>3G</td>
<td>A. de Mello</td>
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<td></td>
<td>Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification). The objective of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.</td>
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<td>Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label &quot;Systems Biology&quot;, focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks. We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stochiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.</td>
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Lecture notes: http://www.csb.ethz.ch/education/lectures.html


- Handouts are deposited online (moodle).

- Literature:

(available online via ETH library)

- Handouts and references therein.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 560 of 2653
Objective

We will investigate the theoretical concepts behind microfluidic device operation, the methods of microfluidic device manufacture and the application of microfluidic architectures to important problems faced in modern day chemical and biological analysis.

A central component of this course is a research project. This will allow students to develop a practical understanding of the benefits of miniaturization in chemical and biological experimentation. Projects will be performed in groups of between four and six students and will include both experimental and simulation aspects. Each group, under the guidance of a mentor, will plan and execute a novel research project. The results of this activity will be disseminated through an "academic-style" research article and a "conference-style" oral presentation. Course grades will be evaluated through both a written exam and the project grade.

Content

Specific topics covered in the course include, but are not limited to:

1. Theoretical Concepts
   Scaling laws, features of thermal/mass transport, diffusion, basic description of fluid flow in small volumes, microfluidic mixing strategies.

2. Microfluidic Device Manufacture
   Basic principles of conventional lithography of rigid materials, ‘soft’ lithography, polymer machining (injection molding, hot embossing, and 3D-printing).

3. Electrophorotics
   Principles of electrophoresis, electroosmosis, high performance capillary electrophoresis, electrokinetic scaling laws, chip-based electrophoresis and isoelectric focusing.

4. Mass Transfer Phenomena
   Key features of mass transport in microfluidic systems, diffusive transport, diffusion-convection, Péclet number, Taylor-Aris diffusion, chaotic mixing and Damköhler numbers.

5. Heat Transfer Phenomena
   Key features of thermal transport in microfluidic systems, conduction, convection, heat transfer by convection in internal flows, heat transfer processes in microfluidic devices.

6. Microfluidic Systems for Materials Synthesis
   Microfluidic reactors for the controlled synthesis of colloidal nanomaterials, advanced automation for bespoke materials discovery & characterization.

7. Point-of-Care Diagnostics
   Microscale tools for diagnostics, challenges associated with point-of-care (PoC) diagnostic testing, requirements for PoC devices, common PoC device formats, applications of PoC diagnostics in the developing world.

8. Microscale DNA Amplification
   Amplification and analysis of nucleic acids using batch, continuous flow and droplet-based microfluidic reactors.

9. Small volume Molecular Detection
   Spectroscopic approaches for analyte detection in small volumes with a particular focus on single molecule detection.

10. Droplets and Segmented Flows
   Formation, manipulation and use of liquid/liquid segmented flows in chemical and biological experimentation.

11. Single Cell Analysis
   Applications of microfluidic tools in cellular analysis, flow cytometry, enzymatic assays and single cell analysis.

Lecture Notes

Lecture handouts, background literature, problem sheets and notes will be provided electronically through the course Moodle site.

Literature

There is no set text for the course. All relevant literature will be provided electronically through the course Moodle site.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

Method-specific Competencies
- Techniques and Technologies: assessed
- Communication: assessed
- Cooperation and Teamwork: assessed

Social Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed

Personal Competencies

551-0357-00L Cellular Matters: Properties, Functions and Applications of Biomolecular Condensates

The number of participants is limited to 30 and will only take place with a minimum of 6 participants.

At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate this, students must confirm their registration by the beginning of the 3rd week of semester.

Abstract

This Master level course delves into the emerging field of biomolecular condensates - membrane-less organelles in cells. Using interdisciplinary concepts from biology, chemistry, biophysics, and soft matter, we will explore the biological properties of these condensates, their functions in health and disease, and their potential as new biomimetic materials for various applications.
In the last decade, a novel type of cell compartments called biomolecular condensates have been discovered. This discovery is radically changing our understanding of the cell, its organization, and dynamics. The emerging picture is that the cytoplasm and nucleoplasm are highly complex fluids that can (meta)stably segregate into membrane-less compartments, similiary to emulsions.

This interdisciplinairy course encompasses milestone works and cutting-edge research questions in the young field of biomolecular condensates, including their properties, functions, and applications. The course begins with a lecture series that introduces the topic of condensates to an interdisciplinairy audience and provides a theoretical foundation for understanding current research questions in the field. The lectures provide a base for student presentations of recent publications in the field, and for research seminars given by course lecturers, who are all active researchers with diverse expertise. Through this exciting interdisciplinairy understanding of biomolecular condensates, bridging biology, chemistry, biophysics, and soft matter.

Students will not only learn how to critically read and evaluate scientific literature but will also gain valuable experience in giving scientific presentations to an interdisciplinairy audience. Each presentation will require an introduction, critical analysis of the results, and a discussion of their significance, allowing student to substantiate their statements with a critical mindset that considers the pros and cons of chosen approaches and methods, as well as any limitations or possible follow-up experiments. This process will enable student to ask relevant querions and actively participate in class discussions, further enhancing their scientific skills.

This course is divided into two parts. The fist part will introduce the basic concepts essential to the study of biomolecular condensates and phase separation. Topics include: fundamental units and scales in soft matter, phase transitions in biology, biopolymers and molecular self-assembly, introduction to active matter. This will establish a foundation for the second part, which will explore milestone works and current research in the field of biomolecular condensates. Each lecture of this second part will consist of:

1) a short literature seminar, where student groups will present and discuss a milestone paper assigned in advance and
2) a research seminar, where one of the course lecturers will present their own state-of-the-art research in the field, building upon the milestone literature.

At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate this, students must confirm their registration by the beginning of the 3rd week of semester.

The topic of biomolecular condensates goes beyond the boundaries of traditional disciplines and requires a multi-disciplinary approach that leverages and cross-fertilizes biology, physical chemistry, biophysics, and soft matter. This course will explore the properties, functions and potential applications of biomolecular condensates, including their role in neurodegenerative diseases such as Alzheimer's and Parkinson's, as well as their use as smart biomimetic materials.

In preparing the presentations, the students will have the unique opportunity to interact closely with each other and with the lecturers, who are all internationally well-established experts, and receive guidance in selecting a topic for the final presentation and supporting literature.

Objective

This course is divided into two parts. The fist part will introduce the basic concepts essential to the study of biomolecular condensates and phase separation. Topics include: fundamental units and scales in soft matter, phase transitions in biology, biopolymers and molecular self-assembly, introduction to active matter. This will establish a foundation for the second part, which will explore milestone works and current research in the field of biomolecular condensates. Each lecture of this second part will consist of:

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Environment and Energy

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<td>W</td>
<td>4</td>
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<td>A. Bardow, E. Casati</td>
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<tr>
<td>Abstract</td>
<td>The first part of the course covers the engineering aspects of the prominent renewable energy technologies: solar (PV and thermal), wind, hydro, geothermal and bioenergy. We further discuss energy storage, renewable transport and renewable heating &amp; cooling. Finally, we introduce the key concepts of the economics of renewable energy and its integration in the energy system.</td>
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<td>Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization.</td>
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<td>Lecture notes</td>
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<td>529-0659-00L</td>
<td>Electrochemistry: Fundamentals, Cells &amp; Applications</td>
<td>W</td>
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<td>L. Gubler</td>
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<tr>
<td>Abstract</td>
<td>Introduction to electrochemistry from a physical chemistry point of view, focusing on thermodynamics &amp; kinetics of electrochemical reactions, and engineering aspects of electrochemical cells. The topics are of generic nature yet also discussed in the context of specific applications in industrial electrochemistry, energy storage and conversion, electroanalytical techniques, sensors and corrosion.</td>
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Objective
The course establishes the fundamentals to understand and describe electrochemical reactions and phenomena related to these. The students are familiarized with key concepts and approaches in electrochemistry and selected aspects of materials science and engineering and how they are put to use in selected applications.

Content
- Introduction: important quantities & units, terminology;
- Chapter I - Redox reactions, Faraday’s laws;
- Chapter II - Equilibrium electrosynthesis: cells, galvanic and electrolytic cells, thermodynamic state functions, theoretical cell voltage, half-cell / electrode potential, hydrogen electrode, the electrochemical series, Nernst equation;
- Chapter III - Electrodes & interfaces: electrochemical potential, phase potentials, work function, Fermi level, the electrified interface, the electrochemical double layer, reference electrodes and laboratory cells;
- Chapter IV - Electrolytes: conductivity, aqueous electrolytes, transference effects, liquid junctions, polymer electrolytes, ion-exchange membranes, Donnan exclusion, solid state ion conductors;
- Chapter V - Dynamic electrochemistry: overpotentials, description of charge-transfer reaction, Butler-Volmer and Tafel equation, exchange current density, mass transport limitations;
- Chapter VI - Industrial electrosynthesis: electrochemical engineering, process and reactor types, current density distribution, porous electrodes, chlor-alkali and HCl electrolysis, oxygen depolarized cathode;
- Chapter VII - Energy storage & conversion: important primary and secondary battery chemistries, fuel cells, polymer electrolyte fuel cells, low temperature H2 and O2 electrochemistry, electrocatalysis, triple-phase boundary, solid oxide fuel cell, conversion efficiency;
- Chapter VIII - Electroanalytical methods & sensors: potentiometry, amperometry, cyclic and stripping voltammetry, rotating disc electrode studies, electrochemical sensors;
- Chapter IX - Corrosion: corrosion reactions, Pourbaix diagram, corrosion potential, passivation, corrosion protection

Lecture notes
lecture notes, lecture slides, exercise & solutions (PDF files)

Literature

Prerequisites / notice
Students should be familiar with the fundamentals of physical chemistry.
Molecular Aspects of Catalysts and Surfaces

Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatics are assessed.

Analytical Competencies

1) Safety and Health and their importance for sustainability
2) Green metrics: real-life tools
3) The proper choice of technology and their impact
4) Case Study from fragrance industry
5) Case Study from agrochemical industry
6) Case Study from pharmaceutical industry
7) Case Study from the bulk chemical industry

Lecture notes: Course content based on slides

Systems and Process Engineering

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<td>529-0511-01L</td>
<td>Turbulent Flows</td>
<td>W</td>
<td>4 credits</td>
<td>2G+1U</td>
<td>J. A. van Bokhoven, D. Ferri</td>
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Lecture notes: Lecture notes are available


Molecular Aspects of Catalysts and Surfaces

Basic elements of surface science important for materials and catalysis research. Physical and chemical methods important for research in surface science, material science and catalysis. Methods which are covered embrace: Gas adsorption and surface area analysis, IR-Spectroscopy, X-ray diffraction, X-ray photoelectron spectroscopy, X-ray absorption, solid state NMR, Electron Microscopy and others.

Modeling and Simulations

Classical Simulation of (Bio)Molecular Systems

Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Economics and Technology Management

Technology and Innovation Management

This course focuses on the sources of innovation (with a specific focus on digital technologies), the tools and techniques that organizations deploy to innovate routinely, and the strategic implications of technical change at different levels of analysis: individuals, firms and whole ecosystems.

Evaluating the potential of different (digital) technologies to impact business organizations.
Organizations and people are faced with a fundamental decision: they have to allocate resources between well-known tasks that reliably generate positive results; or explore new ways of doing things, new technologies, products and services. The latter is a high-risk choice. Its rewards can be high, but the chances of success are small. How do firms organize to take these decisions? What kind of management skills are necessary to take them? What kind of tools and methods are deployed to sustain managerial decision-making in highly volatile environments? These are the central questions on which this course focuses, relying on a combination of lectures, case-based discussion, and guest speakers.

**Prerequisites / notice**
The course content and methods are designed for students with some background in management and/or economics.

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**363-0565-00L Principles of Macroeconomics**

**Abstract**
This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

**Objective**
This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to everyday economic problems.

**Content**
This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

**Lecture notes**
The course Moodle page contains announcements, course information and lecture slides.

**Literature**

This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filippini).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.

**Competencies**

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**Products and Materials**

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**Abstract**
The 'Chemical Product Design' course teaches students quantitative concepts to analyze, select and transform theoretical concepts from chemistry and engineering into valuable real-world products. Basic chemistry and chemical engineering knowledge is required (Diffusion, Thermodynamics, Kinetics, ...).
Objective

This course starts with analyzing existing chemical needs and unmet technical challenges. We then develop the skills to critically analyze a specific chemical idea for a product, to rapidly test feasibility or chance for success and to eventually realize its manufacturing. The chemical engineering basics are then used to assess performance of products or devices with non-traditional functions based on dynamic properties (e.g. responsive building materials, personal medical diagnostics on paper strips). The course teaches the interface between laboratory and market with a specific focus on evaluating the chemical value of a given process or compound, and the necessary steps to pursue the resulting project within an entrepreneurial environment. We therefore extend the questions of process design ("how do we make something?") to the question of 'what should we make?'

Content

Part A: The 'Chemical Product Design' course starts with discussing questions along, What is a chemical product, and why do people pay for it? How does a given compound in a specific setting provide a service? We then learn how to translate new, often ill-defined wishes or ideas into quantifiable specifications.

Part B: Thermodynamic and kinetic data allow sharp selection criteria for successful products. We learn how to deal with insufficient data and development of robust case models to evaluate their technical and financial constraints. How can parameters of a running process in one industry be scaled into another industry? Can dimensionless engineering numbers be applied beyond traditional chemical processes?

Part C: Manufacturing of commodity products, devices and molecular products: Chemical reactors, separation and detection or isolation units as part of a toolbox. Planning of manufacturing and decisions based on hard data. Providing quantitative answers on potential value generated.

Literature


Prerequisites / Competencies

Prerequisites: Basic chemistry and chemical engineering knowledge (Diffusion, Thermodynamics, Kinetics,...).

Competition

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

fostered

fostered

ECTS

4 credits

3G

T. L. Choi

327-2145-00L Advanced Polymer Synthesis

Abstract

Modern polymer synthesis (based on recent development of new organic reactions) is discussed to enable students to develop synthesis schemes for certain target structures. Both chain (ionic, coordination, ROMP, radical, catalyst-transfer) and step-growth polymerizations (transition metal catalysis) including how to achieve living polymerization or improve selectivity will be discussed.

Objective

Students should be able to: Identify important polymerization procedures and types of polymerization. Predict reactivities of monomers based on the chemical structures Devise synthetic pathways to produce a given polymer structure. Evaluate properties of macromolecules based on structure and synthesis method. Develop synthesis schemes for target structures and discuss potential applications of polymers.

Content

Polymerization is series of continuous organic transformation and connects small molecules. The course will give an overview of the following important polymerization procedures:

- Morden Step-growth polymerization
- Living Anionic polymerization
- Group transfer polymerization (GTP)
- Controlled cationic polymerization
- Controlled radical polymerization
- Coordination polymerization: Ziegler-Natta and Metallicocene catalysts
- Olefin metathesis polymerization: ROMP, ADMET and cyclopolymerization
- Synthesis of conjugated polymers based on transition metal catalysis
- Complex macromolecules including brush and dendronized polymers

Students will learn how to deal with chemical structures and reactivities, and be able to suggest reasonable synthetic pathways to a given polymer structure, like conjugated polymers based on transition metal catalysis or complex macromolecules including brush and dendronized polymers. Aspects like controlling molar masses and structure perfection play a role throughout. The course provides the students with a high-level overview of modern methods of polymer synthesis both in theoretical and practical aspects. It should enable them to develop reasonable synthesis schemes for certain target structures and also to predict the properties of given macromolecules. For all polymers presented, potential or real applications will be discussed.

Lecture notes

They will be uploaded on Moodle

Literature

Lecture notes will be given

Prerequisites / notice

Strong basic knowledge of Organic Chemistry.Any course on Introductory Polymer Chemistry such as *Advanced Building Blocks for Soft Materials* or "Introduction to Macromolecular Chemistry" or equivalent (bachelor level is also sufficient). Please discuss with the lecturer if one is not certain about the prerequisites.

Competencies

Subject-specific Competencies

Concepts and Theories

assessed

Techniques and Technologies

assessed

Method-specific Competencies

Analytical Competencies

assessed

Decision-making

assessed

Problem-solving

fostered

Social Competencies

Communication

fostered

Customer Orientation

fostered

Personal Competencies

Creative Thinking

fostered

Critical Thinking

assessed

Integrity and Work Ethics

fostered

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Process Design

Number  Title                  Type   ECTS   Hours   Lecturers
529-0643-01L Process Design and Development W 6 credits 3G G. Guillen Gosaibez

Abstract

The course is focused on the design of Chemical Processes, with emphasis on the preliminary stages of the design approach, where process creation and quick selection among many alternatives are important. The main concepts behind more detailed process design and process simulation are also examined.

Objective

The course is focused on the design of Chemical Processes, with emphasis on the preliminary stage of the design approach, where process creation and quick selection among many alternatives are important. The main concepts behind more detailed process design and process simulation are also examined.
Content
Process creation: heuristics vs. mathematical programming.
Heuristics for reaction and separation operations, heat transfer and pressure change.
Introduction to optimization in process engineering and the modeling software GAMS.
Process economic evaluation: equipment sizing and costing, time value of money, cash flow calculations.
Process integration: sequencing of distillation columns using mixed-integer linear programming (MILP), and synthesis of heat exchanger networks using mixed-integer nonlinear programming (MINLP).
Batch processes: scheduling, sizing, and inventories.
Principles of molecular design using mixed-integer programming.

Lecture notes
no script

Literature
Main books

Other references

Prerequisites / notice
Prerequisite: Basic knowledge on unit operations, mainly reaction engineering and distillation. It is recommended that the student takes the module "Process Simulation and Flowsheeting" before "Process Design and Development", but it is not mandatory.

529-0613-01L Process Simulation and Flowsheeting W 6 credits 3G G. Guillén Gosálbez

Abstract
This course encompasses the theoretical principles of chemical process simulation and optimization, as well as its practical application in process analysis. The techniques for simulating stationary and dynamic processes are presented, and illustrated with case studies. Commercial software packages (Aspen) are introduced for solving process flowsheeting and optimization problems.

Objective
This course aims to develop the competency of chemical engineers in process flowsheeting, process simulation and process optimization. Specifically, students will develop the following skills:
- Deep understanding of chemical engineering fundamentals: the acquisition of new concepts and the application of previous knowledge in the area of chemical process systems and their mechanisms are crucial to intelligently simulate and evaluate processes.
- Modeling of general chemical processes and systems: students should be able to identify the boundaries of the system to be studied and develop the set of relevant mathematical relations, which describe the process behavior.
- Mathematical reasoning and computational skills: the familiarization with mathematical algorithms and computational tools is essential to be capable of achieving rapid and reliable solutions to simulation and optimization problems. Hence, students will learn the mathematical principles necessary for process simulation and optimization, as well as the structure and application of process simulation software. Thus, they will be able to develop criteria to correctly use commercial software packages and critically evaluate their results.
- Process optimization: the students will learn how to formulate optimization problems in mathematical terms, the main type of optimization problems that exist (i.e., LP, NLP, MILP and MINLP) and the fundamentals of the optimization algorithms implemented in commercial solvers.

Content
Overview of process simulation and flowsheeting:
- Definition and fundamentals
- Fields of application
- Case studies
Process simulation:
- Modeling strategies of process systems
- Mass and energy balances and degrees of freedom of process units and process systems
Process flowsheeting:
- Flowsheet partitioning and tearing
- Solution methods for process flowsheeting
- Simultaneous methods
- Sequential methods
Process optimization and analysis:
- Classification of optimization problems
- Linear programming, LP
- Non-linear programming, NLP
- Mixed-integer linear programming, MILP
- Mixed-integer nonlinear programming, MINLP
Commercial software for simulation (Aspen Plus):
- Thermodynamic property methods
- Reaction and reactors
- Separation / columns
- Convergence, optimisation & debugging

Literature
An exemplary literature list is provided below:
- Smith, R. Chemical process design and integration, Wiley (2005).
**Catalysis and Separation**

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>151-0927-00L</td>
<td>Rate-Controlled Separations in Fine Chemistry</td>
<td>W</td>
<td>6</td>
<td>3V+1U</td>
<td>M. Mazzotti, V. Becattini, N. Casas, F. Kiefer</td>
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</table>

**Abstract**
The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.

**Objective**
The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.

**Content**
The class covers separation techniques that are central in the purification and downstream processing of chemicals and biopharmaceuticals. Examples from both areas illustrate the utility of the methods: 1) Adsorption and chromatography; 2) Membrane processes; 3) Crystallization and precipitation.

**Lecture notes**
Handouts during the class

**Literature**
Recommendations for text books will be covered in the class

**Prerequisites / notice**
Requirements (recommended, not mandatory): Thermal separation Processes I (151-0926-00) and Modelling and mathematical methods in process and chemical engineering (151-0940-00)

**Competencies**

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<th>Subject-specific Competencies</th>
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<td>Media and Digital Technologies</td>
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**Catalysis Engineering**

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<tr>
<td>529-0617-01L</td>
<td>Catalysis Engineering</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>J. Pérez-Ramírez, S. J. Mitchell</td>
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**Abstract**
Heterogeneous catalysis, an enabling foundation of the chemical industry, spearheads innovation toward key sustainability targets in clean energy, carbon neutrality, and zero waste. The Catalysis Engineering course provides students with concepts bridging from the molecular-level design of catalytic materials to their technical application.

**Objective**
To accelerate the discovery and implementation of sustainable technologies, this vibrant discipline is constantly refining its design principles, particularly at the nanoscale, a shift facilitated by the availability of increasingly powerful tools that permit the continued development of fundamental knowledge over different time and length scales. During this course, you will learn current concepts for the defossilization of the chemical industry and strategies for achieving this goal from idea to implementation. By introducing topical case studies both in lectures and through a semester project, you will see aspects of catalyst synthesis and characterization, kinetics, mass and heat transport, deactivation and process design, sustainability metrics, and the potential of digital tools to guide catalyst design. Since this area is rapidly advancing and no textbooks are available, the lectures follow slides and journal articles.

**Content**
The aspects described above will be demonstrated through industrially-relevant examples such as:
- Natural gas valorization
- CO2 conversion to energy vectors
- Plastics upcycling
- Concept for a glycerol biorefinery
- Halogen chemistry on catalytic surfaces
- Ensemble design for selective hydrogenations
- Single-atom catalysis
- Hierarchical zeolite catalysts

A supervised semester project conducted in small groups provides a taster of catalysis research on a timely topic. Students will learn basic skills including critical literature analysis, problem definition and solving, methods of catalyst synthesis, characterization, and testing, and data evaluation and communication through a short talk.

**Lecture notes**
The course material is based on slides and journal articles.

**Prerequisites / notice**
It is assumed that students selecting this course are familiar with basic concepts of chemistry and catalysis (chemistry or chemical engineering background). Other students are welcome to contact us to discuss the requirement for prior knowledge.

**Science in Perspective**

*see Science in Perspective: Language Courses ETH/UZH*

*see Science in Perspective: Type A: Enhancement of Reflection Capability*

*Recommended Science in Perspective (Type B) for D-ChAB*

**Course Units for Additional Admission Requirements**
The courses below are only available for MSc students with additional admission requirements.

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<thead>
<tr>
<th>Number</th>
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<td>529-0051-AAL</td>
<td>Analytical Chemistry I</td>
<td>E-</td>
<td>3</td>
<td>6R</td>
<td>D. Günther, R. Zenobi</td>
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Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

The underlying lecture (529-0051-00L) is offered in autumn semester but only in German.

Abstract
Introduction into the most important spectroscopical methods and their applications to gain structural information.

Objective
Knowledge about the necessary theoretical background of spectroscopical methods and their practical applications.

Content
Application oriented basics of organic and inorganic instrumental analysis and of the empirical employment of structure elucidation methods:
- Mass spectrometry: Ionization methods, mass separation, isotope signals, rules of fragmentation, rearrangements.
- NMR spectroscopy: Experimental basics, chemical shift, spin-spin coupling.
- IR spectroscopy: Revisiting topics like harmonic oscillator, normal vibrations, coupled oscillating systems (in accordance to the basics of the related lecture in physical chemistry); sample preparation, acquisition techniques, law of Lambert and Beer, interpretation of IR spectra;
- Raman spectroscopy.

Lecture notes
Script will be provided for the production price.

Literature
- M. Hesse, H. Meier, B. Zeeh, Spektroskopische Methoden in der organischen Chemie, 5. überarbeitete Auflage, Thieme, Stuttgart, 1995

Prerequisites / notice
Exercises are integrated in the lectures. In addition, attendance in the lecture 529-0289-00 "Instrumental analysis of organic compounds" (4th semester) is recommended.

Chemical and Bioengineering Master - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<td>Eligible for credits</td>
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Key for Hours

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<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
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<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Chemical Engineering Bachelor

### 1. Semester

#### Compulsory Subjects First Year Examinations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<td>529-0011-02L</td>
<td>General Chemistry (inorganic Chemistry) I</td>
<td>O</td>
<td>3</td>
<td>2V+1U</td>
<td>A. Togni</td>
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</table>

**Abstract**

Introduction to the chemistry of ionic equilibria: Acids and bases, redox reactions, formation of coordination complexes and precipitation reactions.

**Objective**

Understanding and describing ionic equilibria from both a qualitative and a quantitative perspective.

**Content**

Chemical equilibrium and equilibrium constants, mono- and polyprotic acids and bases in aqueous solution, calculation of equilibrium concentrations, acidity functions, Lewis acids, acids in non-aqueous solvents, redox reactions and equilibria, Galvanic cells, electrode potentials, Nernst equation, coordination chemistry, stepwise formation of metal complexes, solubility.

**Lecture notes**

Copies of the course slides as well as other documents will be provided as pdf files via the moodle platform.

**Literature**


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<thead>
<tr>
<th>Number</th>
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<td>O</td>
<td>3</td>
<td>2V+1U</td>
<td>P. Chen</td>
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</table>

**Abstract**

Introduction to Organic Chemistry. Classical structure theory, stereochemistry, chemical bonds and bonding, symmetry, nomenclature, organic thermochemistry, conformational analysis, basics of chemical reactions.

**Objective**

Introduction to the history of organic chemistry, introduction to nomenclature, learning of classical structures and stereochemistry: isomerism, Fischer projections, CIP rules, point groups, molecular symmetry and chirality, topicality, chemical bonding: Lewis bonding model and resonance theory in organic chemistry, description of linear and cyclic conjugated molecules, aromaticity, Huckel rules, organic thermochemistry, learning of organic chemistry reactions, intermolecular interactions.

**Lecture notes**

Unterlagen werden als PDF über die ILIAS-Plattform zur Verfügung gestellt.

**Literature**


<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
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<tr>
<td>529-0011-01L</td>
<td>General Chemistry (Physical Chemistry) I</td>
<td>O</td>
<td>3</td>
<td>2V+1U</td>
<td>H. J. Wörner</td>
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</table>

**Abstract**

The lecture provides an introduction to some of the physical fundamentals of chemistry, in particular radioactivity, quantum mechanics, the structure of matter and an atom, the periodic table of elements, and chemical bonding.

**Objective**

After the lecture, students will be able to,

- to calculate physical quantities and their units which are important for chemistry,
- name some properties of chemically relevant particles and propose experimental methods to determine these properties,
- name applications and hazards of radioactivity,
- categorize radioactive decay processes and mathematically represent the time course of simple decay reactions and qualitatively predict and represent them,
- describe wave and particle properties of electromagnetic radiation and matter and propose experimental methods for their detection,
- to explain the basics of quantum mechanics (meaning of the wave function, Heisenberg's uncertainty principle, operators, commutators) and to perform simple calculations with them,
- analyze and calculate absorption and emission spectra of single-electron atoms,
- to set up the Schrödinger equation for a molecular multi-particle system.

**Content**

Atomic orbitals and energy levels: ionisation energies, atomic spectroscopy, term values and symbols. Quantum mechanical atom model: wave-particle duality, the uncertainty principle, Schrödinger's equation, the hydrogen atom, construction of the periodic table of the elements. Chemical bonding: ionic bonding, covalent bonding, molecular orbitals.

**Lecture notes**

See homepage of the lecture.

**Literature**

See homepage of the lecture.

**Prerequisites / notice**

Voraussetzungen: Maturastoff. Insbesondere Integral- und differentielle Rechnung.

**Competencies**

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Project Management

Communication

Cooperation and Teamwork

Customer Orientation

Leadership and Responsibility

Self-presentation and Social Influence

Sensitivity to Diversity

Negotiation

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

Techniques and Technologies

Sensitivity to Diversity

Customer Orientation

Integrity and Work Ethics

Self-reflection

Self-management

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fostered

The students are expected to gain practical experience with as well as establish understanding of the following concepts and phenomena:

- Problem-solving
- Mechanics (motion, Newton's laws, work and energy, conservation of momentum, rotation, gravitation, fluids)
- Periodic Motion and Waves (periodic motion, mechanical waves, acoustics).

Lecture notes
The lecture follows the book “Physics” by Paul A. Tipler.

Literature
Paul A. Tipler and Gene P. Mosca, Physics (for Scientists and Engineers), W. H. Freeman and Company

Mathematical Foundations I: Analysis A

- Functions of one variable: the notion of a function, of the derivative, the idea of a differential equation, complex numbers, Taylor polynomials and Taylor series. The integral of a function of one variable.

Literature
G. B. Thomas, M. D. Weir, J. Hass: Analysis I, Lehr- und Übungsbuch, Pearson-Verlag
R. Sperb/M. Akveld: Analysis I (vdf)
L. Papula: Mathematik für Ingenieure und Naturwissenschaftler (3 Bände), Vieweg

Personal Competencies
Creative Thinking
Critical Thinking
Integrity and Work Ethics

Method-specific Competencies
Problem-solving

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Lecture notes
Script booklet (copies of powerpoint slides, in English), distributed at first or second lecture.

Objective
Introduction to calculus in one dimension. Building simple models and analysing them mathematically.

Content
Functions of one variable: the notion of a function, of the derivative, the idea of a differential equation, complex numbers, Taylor polynomials and Taylor series. The integral of a function of one variable.

Lab courses

Practical Course General Chemistry

- The general chemistry practical course aims at preparing the students for the work in modern chemistry laboratory. The students are trained to behave safely in the laboratory and use chemicals, chemistry glassware, and related equipment to perform and analyze the equilibrium in basic chemical reactions.

- The students are expected to gain practical experience with as well as establish understanding of the following concepts and phenomena:
  - Safe behavior and safety regulations in chemistry laboratory;
  - Best practices in common techniques (purification, recrystallization, distillation, etc.);
  - Analysis of measured values (measuring error, average value, error analysis);
  - Acid-base-equilibria (strengths of acids and bases, pH- and pKa-values, titrations, buffer systems);
  - Precipitation equilibria (gravimetry, potentiometry, conductivity measurements);
  - Oxidation state and redox reactions (redox-titrations, galvanic elements);
  - Metal complexes (syntheses of complexes, ligand exchange reactions, complexometric titration)
  - Qualitative analysis (cation and anion separation, determination of cations and anions).
Content
In the general chemistry practical course students are introduced to the work in chemistry laboratory. During the course they become familiar with common chemistry glassware and related equipment as well as learn basic experimental procedures, such as distillation, recrystallization, purification, digestion etc. Upon the measurements of pH, conductivity, and potential in the course of reactions, students establish the understanding of the chemical equilibrium concept.

Students work with various classes of inorganic compounds and types of chemical reactions, e.g. acid-base, redox, precipitation. They also obtain first experience with the synthesis of metal complexes as well as learn basics of qualitative analysis of an unknown substance.

Literature
Moodle Lernplattform

Prerequisites / notice
Compulsory: online enrolment latest one week after start of the semester

By enrolling in the laboratory course, students confirm to study all safety information thoroughly and to follow instructions.

Competencies

<table>
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<tr>
<th>Subject-specific Competencies</th>
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3. Semester

Compulsory Subjects

Examination Block I

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</thead>
<tbody>
<tr>
<td>529-0121-00L</td>
<td>Inorganic Chemistry I</td>
<td>O</td>
<td>3</td>
<td>2V+1U</td>
<td>P. Steinegger, V. Mougel</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Discussion of syntheses, structures, and general reactivity of coordination compounds of the transition metals (as well as the lanthanides and actinides). Introduction of methods of characterization and physicochemical properties of coordination compounds.</td>
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<td><strong>Objective</strong></td>
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<td>The students will learn and understand the methodological basics of binding theory in complexes of transition metals. They will be able to explain the structure, chemical bonding, spectroscopic properties as well as general strategies for the synthesis of complexes of transition metals. In this context, students will master the basics of group theory and its application.</td>
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<td><strong>Content</strong></td>
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<td>This course consists of the following parts, which introduce the students to the chemistry of transition metals as well as lanthanides and actinides: 1) General definitions and terms in coordination chemistry; 2) Coordination numbers and structures; 3) Ligand types; 4) The chemical bond in coordination compounds part A: Crystal field theory and ligand field theory; 5) The chemical bond in coordination compounds part B: Qualitative MO theory; 6) Reactivity and reaction mechanisms of coordination compounds; 7) Group theory and character tables; 8) vibrational spectroscopy; 9) electronic excitation.</td>
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<td><strong>Lecture notes</strong></td>
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<td>A (commented) collection of slides and a script will be made available via Moodle.</td>
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<td><strong>Literature</strong></td>
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<td><strong>Competencies</strong></td>
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<td>Subject-specific Competencies</td>
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<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<td>Analytical Competencies</td>
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<td>Decision-making</td>
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<td>Cooperation and Teamwork</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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</tbody>
</table>

529-0422-00L  Physical Chemistry II: Chemical Reaction Kinetics  O  4  3V+1U  R. Signorell

Abstract

Objective
Introduction to Chemical Reaction Kinetics

Content

Lecture notes
Will be provided
Mathematics III: Partial Differential Equations

Abstract


Objective

Classical tools to solve the most common linear partial differential equations.

Content

1) Examples of partial differential equations
   - Classification of PDEs
   - Superposition principle

2) One-dimensional wave equation
   - D'Alembert's formula
   - Duhamel's principle

3) Fourier series
   - Representation of piecewise continuous functions via Fourier series
   - Examples and applications

4) Separation of variables
   - Solution of wave and heat equation
   - Homogeneous and inhomogeneous boundary conditions
   - Dirichlet and Neumann boundary conditions

5) Laplace equation
   - Solution of Laplace's equation on the rectangle, disk and annulus
   - Poisson formula
   - Mean value theorem and maximum principle

6) Fourier transform
   - Derivation and definition
   - Inverse Fourier transformation and inversion formula
   - Interpretation and properties of the Fourier transform
   - Solution of the heat equation

7) Laplace transform (if time allows)
   - Definition, motivation and properties
   - Inverse Laplace transform of rational functions
   - Application to ordinary differential equations

Lecture notes

See the course web site (linked under Lernmaterialien)

Literature


Additional books:


4) E. Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons (chapters 1,2,11,12,6)

For additional sources, see the course web site (linked under Lernmaterialien)

Prerequisites / notice

Required background:

1) Multivariate functions: partial derivatives, differentiability, Jacobian matrix, Jacobian determinant

2) Multiple integrals: Riemann integrals in two or three variables, change of variables

3) Basic knowledge of ordinary differential equations
The lecture slides, problem sets, and additional documents are provided online. Link: https://wennemers.ethz.ch/education.html


**529-0051-00L** Analytical Chemistry I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0051-00L</td>
<td>Inorganic and Organic Chemistry II</td>
<td>O</td>
<td>3</td>
<td>3G</td>
<td>D. Günther, M.-O. Ebert, G. Schwarz, R. Zenobi</td>
</tr>
</tbody>
</table>

Abstract

Introduction into the most important spectroscopical methods and their applications to gain structural information.

Objective

Knowledge about the necessary theoretical background of spectroscopical methods and their practical applications

Content

Application oriented basics of organic and inorganic instrumental analysis and of the empirical employment of structure elucidation methods:

- Mass spectrometry: Ionization methods, mass separation, isotope signals, rules of fragmentation, rearrangements.
- NMR spectroscopy: Experimental basics, chemical shift, spin-spin coupling.
- IR spectroscopy: Revisiting topics like harmonic oscillator, normal vibrations, coupled oscillating systems (in accordance to the basics of the related lecture in physical chemistry); sample preparation, acquisition techniques, law of Lambert and Beer, interpretation of IR spectra; Raman spectroscopy.
- UV/VIS spectroscopy: Basics, interpretation of electron spectra. Circular dichroism (CD) and optical rotation dispersion (ORD).

Lecture notes

Script will be for the production price

Literature

- M. Hesse, H. Meier, B. Zeeh, Spektroskopische Methoden in der organischen Chemie, 5. überarbeitete Auflage, Thieme, Stuttgart, 1995

Prerequisites

- Passed Practical Course Inorg. and Org. Chemistry I (2. Sem., 529-0230) or Practical Course BCB III: Organic Chemistry (3. Sem. BSc BCB, 529-0016-00)

Lecture notes

- Passed Basisprüfung
- Passed Practical Course General Chemistry (1. Semester, 529-0011-04)
- Passed Practical Course Inorg. and Org. Chemistry I (2. Sem., 529-0230) or Practical Course BCB III: Organic Chemistry (3. Sem. BSc BCB, 529-0016-00)
- Continuous Attendance of Course Inorg. Chemistry 1 (3. Sem. BSc BCB, 529-0121) and Analytical Chemistry 1 (3. Sem., 529-0051)

This class has a limited number of positions available. If necessary, access priority will be settled according to the results of the first-year examinations. Students who are not accepted following that rule will be given priority for the coming year registration.

By enrolling in the laboratory course, students confirm to study all safety information thoroughly and to follow instructions.

**5. Semester**

**Compulsory Subjects**

**Examination Block III**
<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<tr>
<td>529-0557-00L</td>
<td>Chemical Engineering Thermodynamics</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>A. de Mello, S. Stavrakis</td>
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</table>

**Abstract**
This course introduces the basic principles and concepts of chemical engineering thermodynamics. Whilst providing insights into the meaning and properties of fundamental thermodynamic quantities, the course also has a primary focus on the application of thermodynamic concepts to real chemical engineering problems.

**Objective**
A primary objective of the course is to present a rigorous treatment of classical thermodynamics, whilst retaining a strong engineering perspective. Accordingly, real-world engineering examples will be used to highlight how thermodynamics is applied in engineering practice. The core ideas presented and developed within the course will provide a foundation for subsequent studies in such fields as fluid mechanics, heat transfer and statistical thermodynamics.

**Content**
The first part of the course introduces the basic concepts and language of chemical engineering thermodynamics. This is followed by an analysis of energy and energy transfer, with a specific focus on the concept of work and the first law of thermodynamics. Next, the notion of a pure substance is introduced, with a discussion of the physics of phase-changes being presented. The description of pure substances is further developed through an analysis of the PVT behavior of fluids, equation of states, ideal and non-ideal gas behaviour and compressibility factors.

The second part of the course begins with a discussion of the use of the energy balance relation in closed systems that involve pure substances and then develops relations for the internal energy and enthalpy of ideal gases. Next, the second law of thermodynamics is introduced, with a discussion of why processes occur in certain directions and why energy has quality as well as quantity. Applications to cyclic devices such as thermal energy reservoirs, heat engines and refrigerators are provided. Entropy changes that take place during processes for pure substances, incompressible substances and ideal gases are described.

The third part of the course establishes thermodynamic formulations for the calculation of enthalpy, internal energy and entropy as function of pressure and temperature, Gibbs energy, fugacity and chemical potential. Two-phase systems are introduced as well as the use of equations of state to construct the complete phase diagrams of pure fluid.

The final part of the course focuses on the properties of mixtures and the phase behavior of multicomponent systems. The fundamental equations of phase equilibria in terms of the chemical potential and fugacity are also discussed. The concept of an ideal solution is introduced and developed. This is followed by an assessment of non-ideal behavior and the use of activity coefficients for describing phase diagrams. Particular focus is given to phase equilibria. Finally, concepts relating to chemical equilibria are introduced with the general concepts developed being applied to reacting species. Examples here include the calculation of the Gibbs free energy and the equilibrium constant of a reaction.

**Lecture notes**
Lecture handouts, background literature, problem sheets and notes will be made accessible to enrolled students through the lecture Moodle site.

**Literature**
Although there is not set text for the course, the following three texts will be used in part and are excellent introductions to Chemical Engineering thermodynamics:


**Prerequisites / notice**
A basic knowledge of chemical thermodynamics is required.

**Competencies**
<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Problem-solving</th>
<th>Creative Thinking</th>
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<td>Subject-specific Competencies</td>
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<td>Method-specific Competencies</td>
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<td>Personal Competencies</td>
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**Prerequisites / notice**
Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.
This course covers common numerical algorithms and statistical methods used by chemical engineers to solve typical problems arising in physico-chemical processes. Lecture notes will be handed out. 

Topics covered:

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

529-0636-00L Heat Transport and Fluid Dynamics

Abstract: This course teaches the basis and the methods for the description and for the quantitative treatment of heat transfer and fluid flow with emphasis on physico-chemical processes.

Objective: At the end of this course students should be familiar with the basics of heat transfer and fluid dynamics, and have acquired the ability to describe these phenomena in practical processes and to perform corresponding calculations.

Content: Mechanisms of heat and momentum transfer; analogy between mass, heat and momentum transfer; dimensional analysis; kinematics and continuum mechanics; steady and non-steady; laminar and turbulent flow; incompressible flows; Bernoulli equation; Navier-Stokes equations; boundary layer theory; steady and non-steady heat conduction; convective heat transfer; heat transfer correlations; radiative heat transfer.

Lecture notes: Lecture notes will be handed out.

529-0632-00L Homogeneous Reaction Engineering


Objective: Provide to the students a complete methodology for the analysis and design of homogeneous reactors.


Lecture notes: Scripts are available online on the website page of the Arosio group.

752-4001-00L Microbiology

Abstract: Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Objective: Teaching of basic knowledge in microbiology.


752-4001-00L Microbiology

Abstract: Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Objective: Teaching of basic knowledge in microbiology.


752-4001-00L Microbiology

Abstract: Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Objective: Teaching of basic knowledge in microbiology.


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Abstract: Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Objective: Teaching of basic knowledge in microbiology.


752-4001-00L Microbiology

Abstract: Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Objective: Teaching of basic knowledge in microbiology.


Competencies: Subject-specific Competencies

Content: Concepts and Theories

Objective: Fostered

Assessed

Literature:

4) W. A. Stahel, Statistische Datenanalyse, Vieweg, 4th edition 2002

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 576 of 2653
Discovering Management

Does not take place this semester.

Entry level course in management for BSc, MSc and PHD students at all levels not belonging to D-MTEC. This course can be complemented with Discovering Management (Excercises) 351-0778-01.

Abstract

Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

Objective

The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:

1. broaden understanding of management principles and frameworks
2. advance insights into the sources of corporate and entrepreneurial success
3. develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

Content

The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. The theory sessions will be assessed via a multiple choice exam.

Lecture notes

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

Compeencies

Subject-specific Competencies
Concepts and Theories
Analytical Competencies
Problem-solving

Method-specific Competencies

Social Competencies
Communication
Cooperation and Teamwork
Self-presentation and Social Influence

Personal Competencies
Creative Thinking
Critical Thinking
Self-direction and Self-management

Technology Entrepreneurship for Chemical Engineers

Only for students in BSc Chemical Engineering.

Abstract

Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding. This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are success factors in the creation of new firms, including founding, financing and growing a venture.

Objective

This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures. A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases. The project work links technology entrepreneurship with challenges in the chemical industry.

Content

Weekly sessions - recorded.

10+ sessions carried out by guest lecturers: experts in the broad field of technology entrepreneurship (e.g., serial entrepreneurs, venture capitalists, (E)MBA professors, company builders, patent experts, scale-up executives, …)

Typical lecture format (2h):
15': Introduction
60': Guest testimonial
15': Discussion related to topic (in groups)
10': Plenary discussion
20': Q&A with (guest) lecturer

Special workshops will complement the course.

Laboratory Courses and Case Studies

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<th>Number</th>
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</table>

Abstract

The focus of part I of the case study course lies on the literature-based comparison of chemical process alternatives. Based on this compilation and selected quantitative as well as qualitative measures, a process assessment and comparison is conducted. A basic flow sheet is then generated, and mass and energy balances are performed to carry out a preliminary economic and environmental assessment.

Objective

- to obtain knowledge about different databases and sources of information
- application of the knowledge obtained in lectures to a real problem
- problem-oriented problem solving (application of different methods to the same subject)
- team work
- report writing and presentation techniques
The focus of part I of the case study course lies on the literature-based comparison of chemical process alternatives. For this purpose, relevant substance data (i.e. physico-chemical, toxicological, safety, and environmental data), as well as information about synthesis routes and technical implementations (i.e. on reaction kinetics; possible separation operations; economic, safety, and environmental aspects), are collected from the literature. Based on this compilation and selected quantitative as well as qualitative measures, a process assessment and comparison is conducted and the most promising process alternative is chosen for further evaluation. For this alternative, a basic flowsheet and mass and energy balances are generated.

529-0639-01L  Chemical Engineering Laboratory  O  6 credits  8P  N. Kobert, R. Grass

Abstract
The internship is exclusively for chemical engineering BSc 05 semester students. For justified exceptions, please contact the teaching staff before the start of the semester.

Objective
Introduction to various tools of chemical engineering techniques with reference to the running lectures.

Content
In groups of two, students will conduct experiments in the following areas: thermodynamics and phase equilibria including electrochemistry, transport phenomena, kinetics and selectivity of complex reactions, characterisation of ideal and real reactors.

Prerequisites / notice
Registration for the course unit is only possible for the primary target group (Chemical Engineering Bachelor 05 semester students).

Competencies

Subject-specific Competencies
- Concepts and Theories fostered
- Techniques and Technologies fostered

Method-specific Competencies
- Analytical Competencies fostered
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving fostered

Social Competencies
- Communication fostered

Personal Competencies
- Cooperation and Teamwork fostered
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered

► Science in Perspective

►► Science in Perspective

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-CHAB

►► Language Courses

see Science in Perspective: Language Courses ETH/UZH

Chemical Engineering Bachelor - Key for Type

| E-   | Recommended, not eligible for credits | O   | Compulsory |
| Z   | Courses outside the curriculum       | W+  | Eligible for credits and recommended |
| Dr  | Suitable for doctorate               | W   | Eligible for credits |

Key for Hours

| V   | lecture                           | P   | practical/laboratory course |
| G   | lecture with exercise             | A   | independent project         |
| U   | exercise                          | D   | diploma thesis              |
| S   | seminar                           | R   | revision course / private study |
| K   | colloquium                        |     |                             |

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Core Seminars

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>857-0001-00L</td>
<td>Methods I: Research Design, Qualitative Methods, and Data Collection</td>
<td>O</td>
<td>6</td>
<td>2U+2S</td>
<td>A. Abdelrahman, F. Schimmelfennig, S. Hegewald, L. Kakhištshili, J. Kissling</td>
</tr>
</tbody>
</table>

**Abstract**
The seminar covers basic issues of research design, small-n research, and data collection. It deals with issues of causality, conceptualization, case study design and QCA. Data collection includes interviews, surveys, text analysis, and experimental research.

**Objective**
This MACIS core seminar covers basic issues of research design, small-n research, and data collection. It familiarizes students with general research design problems such as defining research questions, analyzing causality, and designing single and comparative case studies. It then introduces them to basic issues in small-n research. Students acquire an understanding of the specific challenges and design problems in qualitative analysis. Finally, students are introduced to exemplary methods of data collection. By the end of the course, students should be able to use the principal methods of data collection used by political scientists, have a critical understanding of the advantages and disadvantages of the methods, and should be able to reflect on and discuss the methods in light of research questions of their interest.

**Competencies**
- Subject-specific Competencies: Concepts and Theories, Techniques and Technologies
- Method-specific Competencies: Analytical Competencies, Project Management
- Social Competencies: Communication
- Personal Competencies: Creative Thinking, Critical Thinking

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<th>Number</th>
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<tr>
<td>857-0007-00L</td>
<td>Democracy</td>
<td>W</td>
<td>8</td>
<td>2S</td>
<td>F. Schimmelfennig, D. Kübler</td>
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</tbody>
</table>

**Abstract**
The seminar focuses on seminal books and articles as well as brand new analyses on topical issues of democratic theory and practice. After reviewing theoretical models and different types of democracy, the seminar deals with core problems of democratic governance and with challenges to democracy stemming from globalization and international institutions.

**Objective**
At the end of the seminar, students are familiar with the relevant theoretical and empirical literature on democracy and democratization in national and international contexts. They are able to reflect on contemporary challenges to democracy, in particular those stemming from the internationalization of politics.

**Content**
see http://www.cis.ethz.ch/education/macis/courses

**Literature**
see http://www.cis.ethz.ch/education/macis/courses

**Competencies**
- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies
- Social Competencies: Communication
- Personal Competencies: Creative Thinking, Critical Thinking

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<tr>
<th>Number</th>
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<th>Type</th>
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</tr>
</thead>
<tbody>
<tr>
<td>857-0009-00L</td>
<td>Political Violence</td>
<td>W</td>
<td>8</td>
<td>2S</td>
<td>A. Wenger, C. Bara</td>
</tr>
</tbody>
</table>

**Abstract**
This course offers an introduction to political violence in domestic and international politics. The course covers explanations of interstate wars, theories of civil and ethnic wars and regional conflict. Other topics include new threats, including transnational terrorist networks and other non-state actors, and the relationship between conflict and nation-building and democratization processes.

**Objective**
This course offers an introduction to political violence in domestic and international politics. The course covers explanations of interstate wars, theories of civil and ethnic wars and regional conflict. Other topics include new threats, including transnational terrorist networks and other non-state actors, and the relationship between conflict and nation-building and democratization processes.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>857-0091-00L</td>
<td>Methods II: Quantitative Methods</td>
<td>O</td>
<td>6</td>
<td>2U+2S</td>
<td>N. Berk, P. Grech</td>
</tr>
</tbody>
</table>

**Abstract**
This course provides an introduction to quantitative methods for social science and policy analysis. The class covers statistical inference, introductory probability, descriptive statistics, regression, and statistical and database programming.

**Objective**
After this course, students should be able to assemble a dataset, prepare descriptive statistics, develop and test hypotheses, and present their results in a high-quality presentation or paper.

## Research Seminars

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>857-0103-00L</td>
<td>Topics in Public Policy: Governing the Energy Transition</td>
<td>W</td>
<td>8</td>
<td>2S</td>
<td>L. P. Fesenfeld, T. Schmidt</td>
</tr>
</tbody>
</table>

**Abstract**
This course addresses the role of policy change and its underlying politics in the transformation of the energy and other climate and sustainability-related sectors. It focuses on political perspectives (while also touching on historical and socio-economic perspectives) and applies various theoretical concepts to understand specific aspects of transition governance.

**Objective**
- To gain an overview of the history of the transition of large socio-technical systems
- To recognize challenges for transformative policy change and to understand the theoretical frameworks and concepts for studying transitions
- To develop own research question and address it in research paper that demonstrates knowledge of the role of policy and politics in transitions

**Content**
Climate change, access to energy and other societal challenges are directly linked to the way we use and create energy. Both the recent United Nations Paris climate change agreement and the UN Sustainable Development Goals make a fast and extensive transition of socio-technical systems necessary. This course introduces the social and environmental challenges involved in the energy sector as a key sector in need of transition. It compares the current situation with historical socio-technical transitions and derives the consequences for policy-making. It then focuses on the role of public policy and policy change in governing complex socio-technical transitions, considering the role of political actors, institutions and policy feedback.

**Lecture notes**
Slides and reading material will be made available via moodle.ethz.ch (only for registered students).

**Literature**
A reading list will be provided via moodle.ethz.ch at the beginning of the semester.
The objectives in this course are to (1) gain an overview of important questions pertaining to international environmental politics from a fostered perspective; (2) develop collaborative research including project management, spanning the entire project cycle from ideation, study design and pre-analysis planning, field phase and data collection, statistical analysis and paper writing.

Literature
The reading materials consist of a series of academic papers (see detailed syllabus)

Prerequisites / notice

**857-0052-00L** Comparative and International Political Economy ■ W 8 credits 2S V. Koubi, E. K. Smith
MacIS students are given priority.
Registration required to koubi@ir.gess.ethz.ch

Abstract
This research seminar complements the MACIS core seminar in Political Economy. It covers topics such as international trade, environmental policy, international finance and foreign direct investment, and welfare state policy. Students will, based on reading assignments and discussions in class, develop a research question, present a research design, and write a paper.

Objective
Students will acquire an advanced understanding of some of the key issues and arguments in comparative and international political economy. They will also prepare the ground for a high-quality MA thesis in political economy.

Content
Because the number of students will be very small, the Political Economy core course runs in parallel, and research interests will be heterogeneous, the general approach will be informal and decentralized. Before the seminar starts we will identify what research topics - within the broader field of Comparative and International Political Economy - the participating students are most interested in. In the first two weeks of the semester, we will meet twice for two hours each as a group to discuss how to write a good research seminar paper, and to identify more closely what each student will be working on. Each student will then receive a reading list, so that she/he can get familiar with the state-of-the-art in her/his area of interests and develop a research design in close consultation with Profs. Bernauer and Koubi as well as postdocs and doctoral students in her/his research group.

Prerequisites / notice
This seminar is restricted to students enrolled in the MACIS program.

**857-0108-00L** Introduction to Security Studies ■ W 8 credits 2S T. Bernauer

Abstract
This seminar introduces students to international security studies research by covering a substantive topic in the field each week (such as war, nuclear weapons, etc.). Students will study the discipline’s fundamental questions and will engage with how scholars generate knowledge as well as the various research designs, inferential strategies, and analytical methods they have used.

Objective
Students will study the discipline’s fundamental questions, such as why wars occur, if there are ways to make the outbreak of war less likely, and what the advent of nuclear weapons and emergent technologies means for international affairs. The course will also expose students to recent debates and research in the field. It will cover how scholars have generated knowledge as well as the various research designs, inferential strategies, and analytical methods they have used. After completing the course, students should have increased familiarity with essential readings in international security studies and the skills to conduct meaningful independent research.

**EElectives**

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>860-0023-00L</td>
<td>International Environmental Politics</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>T. Bernauer</td>
</tr>
</tbody>
</table>

Abstract
This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined.

Objective
The objectives in this course are to (1) gain an overview of important questions pertaining to international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions in this policy area and how to address them in a conceptually and methodologically meaningful and insightful way; (3) gain an overview of important global and regional environmental problems and how they are or could be solved.

Content
This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined, for example international efforts to reduce air pollution, manage international water resources, mitigate and adapt to global warming, protect the stratospheric ozone layer, address biodiversity challenges, deal with plastic waste, and prevent pollution of the oceans.
| Lecture notes | Reading materials and slides will be available via Moodle. |
| Literature | Reading materials and slides will be available via Moodle. |
| Prerequisites / notice | Access / Prerequisites |

The course is open to all ETH students and visiting students from other universities. Participation does not require previous coursework in the social sciences or environmental policy. This course will take place on campus (ETH Main Building, HG F.3). There will be no live-streaming, and the course is NOT in hybrid (on-campus plus online) format. However, the lecture will be recorded and the recordings will be made available via the Moodle platform for this course a few days after the respective lecture for students who are unable to attend in person. All electronic correspondence will take place via the ETH mystudies system and Moodle, so please make sure you are properly registered there with a functioning email address/account.

Credits and Exam

After passing a written test at the end of the course (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test). Visiting students (e.g., from the University of Zurich, exchange students) are subject to the same conditions. Registration of visiting students who obtain a grade of < 4.0 for the test will have a second chance (see table below). Students who did not participate in the test on 18 December 2023 will not have access to the repeat test unless they submit compelling and documented (e.g. medical, other exam in parallel at ETH) reasons for why they were unable to participate in the first test. It covers all contents of the lectures and the reading assignments. Visiting students (e.g., from the University of Zurich or other universities) subject to the same conditions. Registration for the course in the mystudies system at ETH is compulsory. No separate registration for the exam is required, registration for the course as such covers everything. The exam will take place on campus, either in the F3 lecture hall or in a computer room. That is, you must be present in person at ETH Zurich on the exam date/time.

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
<th>Type</th>
<th>Prerequisites / notice</th>
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</thead>
<tbody>
<tr>
<td>857-0027-00L</td>
<td>International Organizations (Field Trip)</td>
<td>2</td>
<td>W</td>
<td>V. Koubi</td>
</tr>
<tr>
<td>Abstract</td>
<td>A two-day field trip to international organizations in Geneva - e.g., the World Trade Organization, the World Health Organization and the International Committee of the Red Cross.</td>
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<tr>
<td>Objective</td>
<td>Become familiar with the work and challenges of international organizations based in Geneva.</td>
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<td>Prerequisites / notice</td>
<td>Teams of 2-3 students prepare a 2-3 page background reading for the group on a specific international organization and lead the discussion with representatives of that organization during the visit.</td>
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<tr>
<th>Course Code</th>
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<th>Credits</th>
<th>Type</th>
<th>Prerequisites / notice</th>
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</thead>
<tbody>
<tr>
<td>851-0609-06L</td>
<td>Governing the Energy Transition</td>
<td>2</td>
<td>W</td>
<td>T. Schmidt, L. P. Fesenfeld</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course addresses the role of policy and its underlying politics in the transformation of the energy sector. It covers historical, socio-economic, and political perspectives and applies various theoretical concepts to understand specific aspects of the governance of the energy transition.</td>
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<tr>
<td>Objective</td>
<td>To gain an overview of the history of the transition of large technical systems</td>
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<tr>
<td>Content</td>
<td>Climate change, access to energy and other societal challenges are directly linked to the way we use and create energy. Both the 2015 United Nations Paris climate change agreement and the UN Sustainable Development Goals make a fast and extensive transition of the energy system necessary.</td>
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<tr>
<td>Lecture notes</td>
<td>Slides and reading material will be made available via moodle.ethz.ch (only for registered students).</td>
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<tr>
<td>Literature</td>
<td>A reading list will be provided via moodle.ethz.ch at the beginning of the semester.</td>
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<tr>
<th>Course Code</th>
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<th>Type</th>
<th>Prerequisites / notice</th>
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<tbody>
<tr>
<td>865-0024-00L</td>
<td>The SDGs in an Urbanising World</td>
<td>1</td>
<td>W</td>
<td>2G</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course draws out good practices in promoting sustainability development at the city level. Participants gain insights on designing urban- focused development interventions.</td>
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<tr>
<td>Objective</td>
<td>Historically, cities have been hubs of innovation, economic activity and rising prosperity. However, the unprecedented speed and scale at which cities are growing today is a huge challenge. As epicenters of migration, environmental degradation, health hazards and unemployment, urban areas are especially vulnerable to disasters, social conflict and inequality. Despite this, some of the most promising initiatives to achieve the SDGs have been implemented by cities. What strategies and processes do successful city initiatives to achieve the SDGs have been implemented by cities. What strategies and processes do successful city</td>
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<tr>
<td>Content</td>
<td>Key Topics: - Drivers, dynamics and challenges of urbanisation - The urban- rural continuum – why does it matter? - Localisation of global development and sustainability agendas: challenges and opportunities - Three to four case studies selected from the following: informal settlements, urban food systems, WASH, children’s well-being, circularity, migration.</td>
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</table>
**Migration and Development**

**W**

1 credit

2G

Does not take place this semester.

Only for MAS/CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.

ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

ETH MA/MSc students apply with a letter of motivation to the NADEL administration office.

Registration only through the NADEL administration office.

**Abstract**

Globally, over 280 million people live outside their countries of origin. While the concept of migration has negative connotations for some, migration can bring significant benefits – to both countries of origin and destination, if the right policies and initiatives are in place. The course explores the role that international cooperation can play in promoting the positive aspects of migration.

**Objective**

Course participants have improved understanding of the following issues:

- Definition of migration concepts and terms
- International legal frameworks related to migration
- The geography of migration flows
- Major drivers of migration
- The evolving concept of "migration and development"
- International cooperation organisations and their strategies and activities in terms of migration and development.

**Content**

Globally, over 280 million people are currently living outside their countries of origin, voluntarily and involuntarily, and a further 60 million people live in internal displacement settings within their countries of origin. Migration is multifaceted, and driven by various, often interlinked factors including conflict and violence, economic, social and political factors, as well as environmental and climate related events. While the concept of migration has negative connotations for some, migration can bring significant benefits – to both countries of origin and destination, if the right policies and initiatives are in place. The course explores the role that international cooperation can play in promoting the positive aspects of migration and in reducing the potential negative consequences.

This course covers:
- Important terms and concepts related to migration;
- International legal frameworks related to migration;
- The geography of migration flows;
- Major drivers of migration;
- The evolving concept of migration and development;
- Actions, strategies and initiatives of international cooperation actors when it comes to migration and development.

**Competencies**

- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies
- Social Competencies: Cooperation and Teamwork
- Personal Competencies: Critical Thinking

**Engaging with Policy Processes: Strategies and Tools**

**W**

1 credit

2G

Does not take place this semester.

Only for MAS/CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.

ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

Registration only through the NADEL administration office.

**Abstract**

The course enables participants to understand the significance of the engagement of civil society organisations in policy processes in order to overcome exclusion and foster voice. The course acquaints participants with concepts and practice of civil society participation in shaping policies at micro and macro level and provides practical tools for influencing political processes.

**Objective**

Recognizing that development is inherently political, this course covers political processes and how they intertwine with the goals and strategies of various agents in international cooperation. It discusses the significance and implications of civil society’s efforts to foster voice and inclusion. The course provides a nuanced understanding of different strategic options and approaches to contribute to policy processes and offers tools that have proven to be effective in practical development cooperation work. It provides an opportunity for participants to apply concepts related to the strengthening of civil society to their projects and case studies.

**Content**

- Understanding policy processes: Institutions and actors at the macro, meso and micro level
- Political settlements, power distribution and inequalities of access to rights and resources
- Exclusive and fragile institutions, and the influence of dominant coalitions
- Policy in terms of rules and norms emerging from a negotiation process between interdependent actors
- Actor-oriented approaches, methods and tools to analyse, engage with and contribute to policy processes

**Prerequisites**

Students of the course must fulfill requirements specified on the homepage of NADEL. Electronic registration may be done only after registration with the NADEL secretariat.
This course on gender and economics is intended to provide basic- and intermediate-level training to development practitioners and policy and program staff in international development agencies.

Objective

The overall objective of the course is to strengthen the capacity of technical advisors and program staff on the importance of gender-responsive economic policy. The course conveys basic knowledge about genders aspects in economics. Key elements are:

- Feminist approaches to macroeconomics, microeconomics and international economics
- Critical analysis of global and regional economic trends, including those related to economic crises
- Gender-responsive economic policy for program implementation, policymaking, and advocacy

Content

Economic inequalities between men and women persist in many countries. For example, in many countries, men earn more money and are more likely to own land and control productive assets than women. This course on gender and economics is intended to provide basic- and intermediate-level training to development practitioners and policy and program staff in international development agencies. The overall objective of the course is to strengthen the capacity of technical advisors and program staff on the importance of gender-responsive economic policy. The course is taught in cooperation with SDC and UN women.

865-0069-00L Health and Development

MAS ETH in Global Cooperation and Sustainable Development

| Credit | W | 2 | 2G | K. Hartgen |

Abstract

The following topics will be discussed: Basic principles of epidemiology and global burden of disease distribution, Health systems and health system strengthening including economic aspects and health insurance, communicable diseases such as HIV/AIDS, Malaria, tuberculosis and neglected tropical diseases, mother and child health, non-communicable diseases and transition in health in LAMICs.

Competencies

Subject-specific Competencies: Concepts and Theories

- fostered
This course will introduce students to a variety of foundational economic models of politics and policy making. This includes—but is not limited to—models of electoral competition, political agency, legislative bargaining, and the interaction between political and market outcomes (e.g., via market and business regulations).

The course material will mainly be theoretical and mathematical (primarily using game theory). Real-world examples and empirical research will be discussed to help motivate and evaluate the theoretical material. Most of the content will focus on the United States, for which rich theoretical and empirical literatures exist. However, the key tools, ideas, and insights can be applied more generally and beyond the United States.

The course assumes basic mathematical competencies (e.g., familiarity with algebra, multi-variable calculus, and probability). We will not assume prior knowledge of game theory—the course will introduce game theoretic concept as they are required. However, having previously taken an introductory course in game theory will be an advantage (e.g., D-MTEC courses such as: 363-0558-00L "Introduction to Game Theory: Strategic and Cooperative Thinking" or the recent edition of 363-0515-00L “Decisions, Markets, and Games”).

The course material primarily draws from the following textbook:

Other useful resources:

There are no formal admission requirements. It is expected that students have a basic level of mathematical competence. It will be beneficial if students have taken an ungraded level course in microeconomics or game theory.

### Master's Thesis

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>857-0019-00L</td>
<td>Master's Thesis Colloquium Permission to begin master thesis is required to take part in Colloquium.</td>
<td>O</td>
<td>4 credits</td>
<td>3K</td>
<td>J. Spirig</td>
</tr>
</tbody>
</table>

**Abstract**
In this colloquium, students enrolled in the MACIS program first present and discuss research design and methods issues concerning their prospective MA theses. Towards the end of the semester they present preliminary findings from their MA thesis work.

**Objective**
It is the goal of the colloquium to help students with the initial steps of writing their master theses. During the colloquium, they will develop a relevant research question and hypotheses and select appropriate methods and data.

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>857-0021-00L</td>
<td>Master's Thesis Only students who fulfill the following criteria are allowed to begin with their master thesis: a. successful completion of the bachelor programme; b. fulfilling of any additional requirements necessary to gain admission to the master programme.</td>
<td>O</td>
<td>26 credits</td>
<td>56D</td>
<td>Professors</td>
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</table>

**Abstract**
The Master Thesis is an independent piece of research on an issue in comparative and international politics. It combines theory, methods, and empirical work.

**Objective**
The Thesis should demonstrate the students’ ability to conduct independent research on the basis of the theoretical and methodological knowledge acquired during the MA program.
### Key for Hours

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

**ECTS** European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Core Courses

The list of core courses is a closed list, no other courses can be added in this category. Also, the assignment of the courses to the respective subcategories cannot be changed. Students need to pass at least one course in each core course subcategory. A total of 40 ECTS needs to be acquired in the core course category (including the mandatory CBB seminar).

### Bioinformatics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>636-0009-00L</td>
<td>Evolutionary Dynamics</td>
<td>W</td>
<td>6</td>
<td>2V+1U+2A</td>
<td>N. Beerenwinkel</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
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<td>Evolutionary dynamics is concerned with the mathematical principles according to which life has evolved. This course offers an introduction to mathematical modeling of evolution, including deterministic and stochastic models, with an emphasis on tumor evolution.</td>
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<tr>
<td></td>
<td>Objective</td>
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<td>The goal of this course is to understand and to appreciate mathematical models and computational methods that provide insight into the evolutionary process in general and tumor evolution in particular. Students should analyze and evaluate models and their application critically and be able to design new models.</td>
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<tr>
<td></td>
<td>Content</td>
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<td>Evolution is the one theory that encompasses all of biology. It provides a single, unifying concept to understand the living systems that we observe today. We will introduce several types of mathematical models of evolution to describe gene frequency changes over time in the context of different biological systems, focusing on asexual populations. Viruses and cancer cells provide the most prominent examples of such systems and they are at the same time of great biomedical interest. The course will cover some classical mathematical population genetics and population dynamics, and also introduce several new approaches. This is reflected in a diverse set of mathematical concepts which make their appearance throughout the course, all of which are introduced from scratch. Topics covered include the quasispecies equation, evolution of HIV, evolutionary game theory, evolutionary stability, evolutionary graph theory, tumor evolution, stochastic tunneling, genetic progression of cancer, diffusion theory, fitness landscapes, branching processes, and evolutionary escape.</td>
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<td></td>
<td>Lecture notes</td>
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<td>No.</td>
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<td></td>
<td>Prerequisites / notice</td>
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<td></td>
<td>Prerequisites: Basic mathematics (linear algebra, calculus, probability)</td>
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<td></td>
<td>Competencies</td>
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<td>Subject-specific Competencies</td>
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<td>Concepts and Theories assessed</td>
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<td>Method-specific Competencies</td>
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<td>Analytical Competencies assessed</td>
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<td>Problem-solving assessed</td>
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<td>Social Competencies</td>
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<td>Communication fostered</td>
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<td>Cooperation and Teamwork fostered</td>
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<td>Personal Competencies</td>
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<td>Critical Thinking assessed</td>
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<td>Self-direction and Self-management fostered</td>
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<tr>
<td>636-0017-00L</td>
<td>Computational Biology</td>
<td>W</td>
<td>6</td>
<td>3G+2A</td>
<td>T. Vaughan, C. Magnus, T. Stadler</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.</td>
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<td></td>
<td>Objective</td>
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<td>Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:</td>
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<td>* stochastic models in molecular evolution</td>
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<td>* phylogenetic &amp; phylodynamic inference</td>
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<td>* maximum likelihood and Bayesian statistics</td>
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<td>Attendees will apply these concepts to a number of applications yielding biological insight into:</td>
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<td>* epidemiology</td>
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<td>* pathogen evolution</td>
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<td></td>
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<td></td>
<td>* macroevolution of species</td>
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<td></td>
<td>Content</td>
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<td>The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation &amp; extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, Influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.</td>
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<td></td>
<td>Lecture notes</td>
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<td>Lecture slides will be available on moodle.</td>
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<tr>
<td></td>
<td>Literature</td>
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<td>The course is based not on any of the textbooks below, but they are excellent choices as accompanying material:</td>
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<td>* Yang, Z. 2006. Computational Molecular Evolution.</td>
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<td></td>
<td>* Drummond, A. &amp; Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.</td>
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<tr>
<td></td>
<td>Prerequisites / notice</td>
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<td>Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place in Basel before the start of the semester.</td>
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<td>Competencies</td>
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<td>Subject-specific Competencies</td>
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<td>Concepts and Theories assessed</td>
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<td>Techniques and Technologies assessed</td>
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<td>Method-specific Competencies</td>
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<td>Analytical Competencies assessed</td>
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<td>Decision-making assessed</td>
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<td>Problem-solving assessed</td>
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<td>Personal Competencies</td>
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<td>Creative Thinking assessed</td>
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<td>Critical Thinking assessed</td>
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<tr>
<td>262-6100-00L</td>
<td>Evolutionary Genetics (University of Basel)</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>external organisers</td>
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<tr>
<td></td>
<td>Abstract</td>
<td></td>
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<td>The course must be registered for directly at Uni Basel. Uni Basel course number: 25600-01</td>
</tr>
</tbody>
</table>
Abstract

Evolutionary genetics covers three important areas of modern evolutionary genetics: bioinformatics, molecular evolution and population genetics. Treating these three areas together in a single course provides an integrated education in evolutionary genetics. A solid understanding of these areas is also central to other fields such as conservation biology or behavioural and evolutionary ecology.

262-6110-00L Bioinformatics Algorithms (University of Basel)  
W  4 credits  3G  external organisers

Mind the enrolment deadlines at Uni Basel:
https://www.unibas.ch/en/Studies/Mobility/Mobility-Switzerland/Students-Registering-From-Other-Swiss-Universities.html

Abstract

The course must be registered for directly at Uni Basel. 
Uni Basel course number: 45401-01

Objective

Students can understand the main algorithmic design principles for problems like sequence alignment, motif finding and phylogenetic inference. Further, students get an overview of modern machine learning methods and their applications to bio-medical problems.

401-6282-00L Statistical Analysis of High-Throughput Genomic and Transcriptomic Data (University of Zurich)  
W  5 credits  3G  H. Rehrauer

Mind the enrolment deadlines at UZH:  

Abstract

A range of topics will be covered, including basic molecular biology, genomics technologies and in particular, a wide range of statistical and computational methods that have been used in the analysis of DNA microarray and high throughput sequencing experiments.

Content

Lectures will include: microarray preprocessing; normalization; exploratory data analysis techniques such as clustering, PCA and multidimensional scaling; Controlling error rates of statistical tests (FPR versus FDR versus FWER); limma (linear models for microarray analysis); mapping algorithms (for RNA/ChIP-seq); RNA-seq quantification; statistical analyses for differential count data; isoform switching; epigenomics data including DNA methylation; gene set analyses; classification

Lecture notes

Lecture notes, published manuscripts

Prerequisites / notice

Prerequisites: Basic knowledge of the programming language R, sufficient knowledge in statistics

Former course title: Statistical Methods for the Analysis of Microarray and Short-Read Sequencing Data

>>> Biophysics

Number  Title  Type  ECTS  Hours  Lecturers

262-6106-00L Current Topics in Biophysics (University of Basel)  
W  6 credits  3G  external organisers

The course must be registered for directly at Uni Basel. 
Uni Basel course number: 25661-01

Abstract

This course reviews how ideas and concepts from physics have helped understanding biological systems by discussing landmark papers in the field.

636-0104-00L Biophysical Methods  
W  4 credits  3G  D. J. Müller

Abstract

Students will be imparted knowledge in basic and advanced biophysical methods applied to problems in molecular biotechnology. The course is fundamental to applying the methods in their daily and advanced research routines. The students will learn the physical basis of the methods as well as their limitations and possibilities to address existing and future topics in molecular biotechnology.

Objective

Gain of interdisciplinary competence in experimental and theoretical research, which qualifies for academic scientific work (master's or doctoral thesis) as well as for research in a biotechnology or a pharmaceutical company. The module is of general use in courses focused on modern biomolecular technologies, systems biology and systems engineering.
The students will learn basic and advanced knowledge in applying biophysical methods to address problems and overcome challenges in biotechnology, cell biology and life sciences in general. The biological and physical possibilities and limitations of the methods will be discussed and critically evaluated. By the end of the course the students will have assimilated knowledge on a portfolio of biophysical tools widening their research capabilities and aptitude.

The biophysical methods to be taught will include:

- **Light microscopy**: Resolution limit of light microscopy, fluorescence, GFP, fluorescence microscopy, DIC, phase contrast, difference between wide-field and confocal microscopy
- **Super resolution optical microscopy**: STED, PALM, STORM, other variations
- **Electron microscopy**: Scanning electron microscopy, transmission electron microscopy, electron tomography, cryo-electron microscopy, single particle analysis and averaging, tomography, sectioning, negative stain
- **X-ray, electron and neutron diffraction**
- **MRI imaging**
- **Scanning tunneling microscopy and atomic force microscopy**
- **Patch clamp technologies**: Principles of patch clamp analysis and application. Various patch clamp approaches used in research and industry
- **Surface plasmon resonance-based biosensors**
- **Molecular pore-based sensors and sequencing devices**
- **Mechanical molecular and cellular assembly devices**
- **Optical and magnetic tweezers**
- **CD spectroscopy**
- **Optogenetics**
- **Molecular dynamics simulations**

**Objective**

Introduction to classical (atomistic) computer simulation of (bio)molecular systems, development of skills to carry out and interpret these simulations.

**Content**

Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies
- **Method-specific Competencies**
  - Analytical Competencies
  - Media and Digital Technologies
  - Problem-solving
- **Personal Competencies**
  - Adaptability and Flexibility
  - Creative Thinking

**Lecture notes**

The powerpoint slides of the lectures will be made available weekly on the website in pdf format (on the day preceding each lecture).

**Literature**

- See: www.csms.ethz.ch/education/CSBMS
- Methods in Molecular Biophysics (5th edition), Serdyuk et al., Cambridge University Press

**Prerequisites / notice**

The module is composed of 3 SWS (3 hours/week): 2-hour lecture, 1-hour seminar. For the seminar, students will prepare oral presentations on specific in-depth subjects with/under the guidance of the teacher.
This course focuses on modeling spatio-temporal problems in biology, in particular on the cell and tissue level. The main focus is on mechanisms and concepts, but mathematical and numerical techniques are introduced as required. Biological examples discussed in the course provide an introduction to key concepts in developmental biology.

Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides an introduction to dynamical system, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

1. Introduction to Modelling in Biology
2. Bioimage Analysis
3. Morphogen Gradients
4. Precision & Robustness of Patterning
5. Mathematical Description of Growing Biological Systems
6. Travelling Waves & Wave Pinning
7. Turing Patterns
8. Chemotaxis
9. Epithelial Organisation
10. Tissue Simulation Frameworks
11. Tissue Mechanics & Fluid Dynamics
12. Growth Control
13. Image-Based Modelling
14. Summary

All lecture material will be made available online via Moodle.

The lecture course is not based on any textbook. The following textbooks are related to some of its content. The textbooks may be of interest for further reading, but are not necessary to follow the course:

Murray, Mathematical Biology, Springer
Forgacs and Newman, Biological Physics of the Developing Embryo, CUP
Keener and Sneyd, Mathematical Physiology, Springer
Fall et al, Computational Cell Biology, Springer
Szallasi et al, System Modeling in Cellular Biology, MIT Press
Wolkenhauer, Systems Biology
Kreyszig, Engineering Mathematics, Wiley

The course is self-contained. The course assumes no background in biology but a good foundation regarding mathematical and computational techniques.
Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
- What is data?
- Bayesian Learning
- Computational learning theory

Supervised learning:
- Ensembles: Bagging and Boosting
- Max Margin methods
- Neural networks

Unsupervised learning:
- Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

636-0101-00L Systems Genomics W 4 credits 3G B. Treutlein, C. Beisel, Z. He

Abstract
This course is an introduction to the wide field of Genomics. It addresses how fundamental questions in biological systems are studied using methods in genomics and how the resulting data is analysed to make quantitative interpretations of biological phenomena.

Objective
The goal of this course is to get detailed insights in how state-of-the-art DNA sequencing technologies can be applied for a qualitative and quantitative description of molecular and cellular processes and function. Students will learn how to analyse RNA-seq / transcriptomics data and make biological interpretations in a quantitative manner.

Content
This course will be a mix of lecture sessions, hands-on computational data analysis using public datasets and seminars discussing own results in the context of the published studies. In the lectures we will introduce current Next-Generation Sequencing technologies and their application to address basically all facets of modern biology and biomedical research. We will cover the major sample processing methods used for investigating functional genomic aspects like transcriptome and chromatin profiling, review recent advances in (cancer) genome sequencing and give an overview of public big data sequencing projects (ENCODE, GTEx, TCGA, ...).

For the computational data analysis we will focus on differential gene expression profiling (RNA-seq) experiments that have been selected from fascinating published biological studies. Data analysis based on R will follow a detailed tutorial describing all required steps of sequence read processing and will be conducted in small groups to enable every student hands-on experience.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

636-0704-00L Computational Biology and Bioinformatics Seminar O 2 credits 2S N. Beerenwinkel, D. Iber, T. Stadler

Number of participants limited to 30.
The seminar is addressed primarily at students enrolled in

Seminar
The CBB seminar is mandatory.

Number Title Type ECTS Hours Lecturers
636-0704-00L Computational Biology and Bioinformatics Seminar O 2 credits 2S N. Beerenwinkel, D. Iber, T. Stadler

The seminar is addressed primarily at students enrolled in

The course language is English.

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the MSc CBB programme. Students of other ETH study programmes interested in this course need to ask the lecturer for permission to enrol in the course.

The Seminar will be offered in autumn semester in Basel (involving professors and lecturers from the University of Basel) and in spring semester in Zurich (involving professors and lecturers from the University of Zurich). Professors and lecturers from ETH Zurich are involved in both semesters.

Uni Basel lecturers: Richard Neher, Attila Becskei, Mihaela Zavolan, Erik van Nimwegen

Abstract
Computational biology and bioinformatics aim at an understanding of living systems through computation. The seminar combines student presentations and current research project presentations to review the rapidly developing field from a computer science perspective. Areas: DNA sequence analysis, proteomics, optimization and bio-inspired computing, and systems modeling, simulation and analysis.

Objective
Studying and presenting fundamental papers of Computational Biology and Bioinformatics. Learning how to make a scientific presentation and how classical methods are used or further developed in current research.

Content
Computational biology and bioinformatics aim at advancing the understanding of living systems through computation. The complexity of these systems, however, provides challenges for software and algorithms, and often requires entirely novel approaches in computer science. The aim of the seminar is to give an overview of this rapidly developing field from a computer science perspective. In particular, it will focus on the areas of (i) DNA sequence analysis, sequence comparison and reconstruction of phylogenetic trees, (ii) protein identification from experimental data, (iii) optimization and bio-inspired computing, and (iv) systems analysis of complex biological networks.

The seminar combines the discussion of selected research papers with a major impact in their domain by the students with the presentation of current active research projects / open challenges in computational biology and bioinformatics by the lecturers. Each week, the seminar will focus on a different topic related to ongoing research projects at ETHZ, University of Basel and University of Zurich, thus giving the students the opportunity of obtaining knowledge about the basic research approaches and problems as well as of gaining insight into (and getting excited about) the latest developments in the field.

Literature
Original papers to be presented by the students will be provided in the first week of the seminar.

Advanced Courses
A total of 30 ECTS needs to be acquired in the Advanced Courses category. Thereof at least 16 ECTS in the Theory and at least 10 ECTS in the Biology category.

Theory
At least 16 ECTS need to be acquired in this category.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>401-0663-00L</td>
<td>Numerical Methods for Computer Science</td>
<td>W</td>
<td>7 credits</td>
<td>2V+2U+2R</td>
<td>V. C. Gradinaru</td>
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Abstract
The course gives an introduction into fundamental techniques and algorithms of numerical mathematics which play a central role in numerical simulations in science and technology. The course focuses on fundamental ideas and algorithmic aspects of numerical methods.

The exercises involve actual implementation of numerical methods in C++.

Objective
* Knowledge of the fundamental algorithms in numerical mathematics
* Knowledge of the essential terms in numerical mathematics and the techniques used for the analysis of numerical algorithms
* Ability to choose the appropriate numerical method for concrete problems
* Ability to interpret numerical results
* Ability to implement numerical algorithms efficiently
Content
First two weeks: A gentle introduction to C++

1. Computing with Matrices and Vectors
   1.1 Fundamentals
   1.2 Software and Libraries
   1.4 Computational Effort
   1.5 Machine Arithmetic and Consequences

2. Direct Methods for (Square) Linear Systems of Equations
   2.1 Introduction: Linear Systems of Equations
   2.3 Gaussian Elimination
   2.6 Exploiting Structure when Solving Linear Systems
   2.7 Sparse Linear Systems

3. Direct Methods for Linear Least Squares Problems
   3.1 Least Squares Solution Concepts
   3.2 Normal Equation Methods
   3.3 Orthogonal Transformation Methods
     3.3.1 Transformation Idea
     3.3.2 Orthogonal/Unitary Matrices
     3.3.3 QR-Decomposition
     3.3.4 QR-Based Solver for Linear Least Squares Problems
   3.4 Singular Value Decomposition

4. Filtering Algorithms
   4.1 Filters and Convolutions
   4.2 Discrete Fourier Transform (DFT)
   4.3 Fast Fourier Transform (FFT)

5. Machine Learning of One-Dimensional Data
   (Data Interpolation and Data Fitting in 1D)
   5.1 Abstract Interpolation (AI)
   5.2 Global Polynomial Interpolation

8. Iterative Methods for Non-Linear Systems of Equations
   8.1 Introduction
   8.2 Iterative Methods
   8.3 Fixed-Point Iterations
   8.4 Finding Zeros of Scalar Functions
   8.5 Newton’s Method in Rn
   8.6. Quasi-Newton Method

Lecture notes
Lecture materials (PDF documents and codes) will be made available to the participants through the course web page and online repositories. Access information will be communicated in the beginning of the course.

Literature
M. Hanke-Bourgeois “Grundlagen der Numerischen Mathematik und des wissenschaftlichen Rechnens”, BG Teubner, 2002

Prerequisites / notice
The course will be accompanied by programming exercises in C++ relying on the template library EIGEN. Familiarity with C++, object oriented and generic programming is an advantage. Participants of the course are expected to learn C++ by themselves, in case they do not know it already.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Problem-solving assessed
Project Management fostered

263-5210-00L Probabilistic Artificial Intelligence
W 8 credits 3V+2U+2A A. Krause

Abstract
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice
Solid basic knowledge in statistics, algorithms and programming.
The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.
The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.

401-0647-00L Introduction to Mathematical Optimization

**Objective**
The course aims to convey a deep understanding of the key concepts of sequential object-oriented programming and their applications to a variety of problems in engineering.

**Content**
Topics covered in this course include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.

**Literature**
Information about relevant literature will be given in the lecture.

**Prerequisites / notice**
This course is meant for students who did not already attend the course "Mathematical Optimization", which is a more advanced lecture covering similar topics. Compared to "Mathematical Optimization", this course has a stronger focus on modeling and applications.

227-0225-00L Linear System Theory

**Objective**
Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

**Content**
- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

**Literature**
Available on the course Moodle platform.

**Prerequisites / notice**
Sufficient mathematical maturity, in particular in linear algebra, analysis.

151-0575-01L Signals and Systems

**Objective**
Master the basics of signals and systems. Apply this knowledge to problems in the homework assignments and programming exercises.

**Content**

**Prerequisites / notice**
Lecture notes available on course website.

252-0237-00L Introduction to Mathematical Optimization

**Objective**
Course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object and class initialization, program correctness, reflection.

**Content**
After this course, students will:
- Have a deep understanding of advanced concepts of object-oriented programming and their support through various language features.
- Be able to understand language concepts on a semantic level and be able to compare and evaluate language designs.
- Be able to learn new languages more rapidly.
- Be aware of many subtle problems of object-oriented programming and know how to avoid them.

The main goal of this course is to convey a deep understanding of the key concepts of sequential object-oriented programming and their support in different programming languages. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.

The topics discussed in the course include among others:
- The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing).
- The key problems of single and multiple inheritance and how different languages address them.
- Generic type systems, in particular, Java generics, C# generics, and C++ templates.
- The situations in which object-oriented programming does not provide encapsulation, and how to avoid them.
- The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing.

How to maintain the consistency of data structures
The aim of this course is to introduce certain topics in Probability Theory and Stochastic Processes that have been specifically selected for students in the life sciences. The course aims to train the students into the proficient use of programming in analyzing data derived from projects in life sciences. The Basics of the theory of stochastic processes and an overview of selected applications will be announced in the lecture.

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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>ECTS</th>
<th>Prerequisites / notice</th>
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<tbody>
<tr>
<td>262-6140-00L</td>
<td>Random Processes: Theory and Applications from Physics to Finance (University of Basel)</td>
<td>4</td>
<td>3G</td>
<td>external organisers</td>
</tr>
<tr>
<td>262-6150-00L</td>
<td>Programming for Life Sciences (University of Basel)</td>
<td>4</td>
<td>2P</td>
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<tr>
<td>636-0015-00L</td>
<td>An Introduction to Probability Theory and Stochastic Processes with Applications to Biology</td>
<td>4</td>
<td>3G</td>
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</table>

Abstract

Biology is becoming increasingly quantitative and mathematical modeling is now an integral part of biological research. In many biological processes, ranging from gene-expression to evolution, randomness plays an important role that can only be understood using stochastic models. This course will provide the students with a theoretical foundation for developing such stochastic models and analyzing reaction networks.

Objective

By the end of the course, students should be comfortable with accessing and analyzing a wide variety of biological data. Concepts such as reproducibility, modularity, interoperability, and scalability will be emphasized.

Content

1. The mathematical representation of random phenomena: The probability space, properties of the probability measure, Independence of events, Conditional probability and Bayes formula, applications to parameter inference.


3. Convergence of Random Variables: Modes of convergence, Laws of large numbers, the central limit theorem, the law of the iterated logarithm, Applications to the analysis of cell population data.


Literature

While no specific textbook will be followed, much of the material and homework problems will be taken from the following books:


Prerequisites / notice

The course will involve a healthy balance between mathematical rigor (theorem proving) and biological applications. Students are expected to have a good grasp of Linear Algebra and Multivariable Calculus. Basic knowledge of set theory will also be needed. Students should be prepared for abstract reasoning.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>ECTS</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-3010-00L</td>
<td>Big Data</td>
<td>10</td>
<td>3V+2U+4A</td>
<td>G. Fourny</td>
</tr>
</tbody>
</table>

Abstract

The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations.
Objective

Do you want to be able to query your own data productively and efficiently in your future semester projects, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This course teaches you how to do so as well as the dos and don'ts.

“Big Data” refers to the case when the amount of data is very large (100 GB and more), or when the data is not completely structured (or messy). The Big Data revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the “fourth paradigm”.

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it are needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each one of your projects efficiently and consistently.

Content

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage(S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBLR, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (? , *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Large scale analytics and machine learning are outside of the scope of this course.

Course textbook: https://ghislainfourny.github.io/big-data-textbook/

Literature

Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

Prerequisites / notice

The lecture is hybrid, meaning you can attend with us in the lecture hall, or on Zoom, or watch the recordings on YouTube later. Exercise sessions are in presence.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departments interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2023

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving fostered

Social Competencies
Communication fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking assessed
Algorithms and Data Structures for Population Scale Genomics

Abstract
Research in Biology and Medicine have been transformed into disciplines of applied data science over the past years. Not only size and inherent complexity of the data but also requirements on data privacy and complexity of search and access pose a wealth of new research questions.

Objective
This interactive course will explore the latest research on algorithms and data structures for population scale genomics applications and give insights into both the technical basis as well as the domain questions motivating it.

Content
Over the duration of the semester, the course will cover three main topics. Each of the topics will consist of 70% lecture content and 30% practical content. Thereby, the practical implementation of the concepts presented in the lecture forms an integral part of the course.

1) Algorithms and data structures for the efficient compression of and search in texts and graphs. Motivated through applications in compressive genomics, the course will cover succinct indexing schemes for strings, trees and general graphs, compression schemes for binary matrices as well as the efficient representation of haplotypes and genomic variants.

2) Stochastic data structures and algorithms for approximate representation of strings and graphs as well as sets in general. This includes winnowing schemes and minimizers, sketching techniques, (minimal perfect) hashing, approximate membership query data structures, and approximate counting.

3) Data structures supporting encryption and data privacy. As an extension to data structures discussed in the earlier topics, this will include secure indexing using homomorphic encryption as well as design for secure storage and distribution of data.

Competencies

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<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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<tr>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Media and Digital Technologies</td>
<td>Critical Thinking</td>
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<td>Analytical Competencies</td>
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<td>Integrity and Work Ethics</td>
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<td>Critical Thinking</td>
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Information Systems for Engineers

Abstract
This course provides the basics of relational databases from the perspective of the user. We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

Objective
Do you want to be able to query your own data productively and efficiently in your future semester projects, bachelor's thesis, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This courses teaches you how to do so as well as the dos and don'ts.

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.
Using a relational database
================================
1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level
================================
6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database
================================
12. Data cubes

Outlook
================================
13. Outlook

Literature
- Lecture material (slides).
   (It is not required to buy the book, as the library has it)

Prerequisites / notice
The lecture is hybrid, meaning you can attend with us in the lecture hall, or on Zoom, or watch the recordings on YouTube later. Exercise sessions are in presence.

For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logic
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving fostered

Social Competencies
Communication fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking assessed

Applied Bioinformatics: Microbiomes W 5 credits 2V+2U N. Bokulich, M. Ziemski

Abstract
Learn to apply practical bioinformatics/computational skills for analysis of microbiomes in foods and human health! Students will apply basic programming skills for scientific computing and bioinformatics, and learn and discuss the importance of microbiomes to foods and human health, through recognition and comparison of ecological theory, methodology, and experimental design across systems.

Objective
Learn to apply bioinformatics and computational methods for analysis of microbiome next-generation sequencing data. A secondary goal is to critically examine the relevance of microbiomes to food quality, safety, and human health, through application of theory and appropriate experimental design. Students completing this course will thus be able to both apply appropriate methodology to study microbiomes (or other high-dimensional data) in different systems, as well as evaluate and interpret bioinformatics results.

Content
1. Introduction to microbiomes and microbial bioinformatics toolkit. Python, Pandas, Jupyter, GitHub, visualization libraries for Python.
3. Microbial diversity, function, and ecology. Molecular ecology, diversity metrics, ordination methods.

This course requires extensive engagement in learning outside of the classroom (using online resources and practical exercises), with a focus on active learning in the classroom.

Prerequisites / notice
No specific pre-requisites, but students should have some familiarity with microbiology, molecular biology, programming (Python), bioinformatics, and statistics.

Students will bring and work on their own laptop computers.

All software used in the course is free and open-source.

Modelling and Simulation in Drug Development W 2 credits 3V H.-M. Kaltenbach

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management fostered

Social Competencies
Communication assessed
Cooperation and Teamwork fostered

Personal Competencies
Critical Thinking fostered
Self-direction and Self-management fostered

752-5500-00L Modelling and Simulation in Drug Development W 2 credits 3V H.-M. Kaltenbach

Autumn Semester 2024
Abstract

This course introduces how Modelling and Simulation (=mathematical modelling) is applied today for the development of novel drugs in the pharmaceutical industry. Background lectures are combined with hands-on exercises on real-world examples.

Objective

The goal of this course is to provide students with a general understanding of drug development and pharmacology and how Modelling and Simulation is used to develop new drugs. Together with the application, the course will provide the background in the statistical methodologies used to model multivariate and time-dependent data with several levels of statistical variability.

Content

Understanding the pharmacology, pharmacokinetics and pharmacodynamics (PK/PD) of novel drugs is key for a successful drug development process. Modelling and Simulation of these data is at the core to gain this understanding. Focusing on the application using real world examples, this course will introduce the statistical methodologies that have been developed to describe complex biological and pharmaceutical data with several levels of statistical variability.

The course will cover the basics of drug development and pharmacology with a focus on the principles of drug absorption, distribution, metabolism and excretion (ADME) and drug pharmacokinetics and pharmacodynamics (PK/PD). The different drug formats (small molecules, biologics, cell-based therapies, gene therapies and oligonucleotide formats) and their pharmacological properties will be introduced. The translation from animal to human to inform first-in human dose selections will be discussed.

The methodology part will cover compartmental PK/PD modelling, the practical aspects of numerical solutions of ordinary differential equation (ODEs) and the theory on non-linear mixed effects (NLME) modelling, which has become the de-facto standard methodology in the pharmaceutical industry. Practical problems of Modelling and Simulations will be discussed including parameter identifiability, model development and model evaluation and the application (or not) of the Occam’s Razor.

The course will focus on hands-on exercises using contemporary real-world examples from the pharmaceutical industry and provide necessary theoretical and methodological background in accompanying lectures.

The course is organized jointly by D-BSSE and LYO-X, a Quantitative Systems Pharmacology consulting company situated in Basel.

Prerequisites / notice

Basics of dynamics systems (e.g., BSSE courses by Iber or Kammash, or CSB course by Stelling).

263-5351-00L Machine Learning for Genomics W 6 credits 2V+2U+1A V. Boeva

Abstract

The course reviews solutions provided by machine learning to the most challenging questions in human genomics.

Objective

Over the last few years, the parallel development of machine learning methods and molecular profiling technologies for human cells, such as sequencing, created an extremely powerful tool to get insights into the cellular mechanisms in healthy and diseased contexts. In this course, we will discuss the state-of-the-art machine learning methodology solving or attempting to solve common problems in human genomics. At the end of the course, you will be familiar with (1) classical and advanced machine learning architectures used in genomics, (2) bioinformatics analysis of human genomic and transcriptomic data, and (3) data types used in this field.

Content

- Short introduction to major concepts of molecular biology: DNA, genes, genome, central dogma, transcription factors, epigenetic code, DNA methylation, signaling pathways
- Prediction of transcription factor binding sites, open chromatin, histone marks, promoters, nucleosome positioning (convolutional neural networks, position weight matrices)
- Prediction of variant effects and gene expression (hidden Markov models, topic models)
- Deconvolution of mixed signal (NMF, ICA)
- DNA, RNA and protein folding (RNN, LSTM, transformers)
- Data imputation for single-cell RNA-seq data, clustering and annotation (diffusion and methods on graphs)
- Batch correction (autoencoders, optimal transport)
- Survival analysis (Cox proportional hazard model, regularization penalties, multi-omics, multi-tasking)

Prerequisites / notice

Introduction to Machine Learning, Statistics/Probability, Programming in Python, Unix Command Line

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

fostered

fostered

Communication

assessed

Social Competencies

fostered

From Publication to the Doctor’s Office

The deadline for deregistering expires at the end of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract

This seminar course is designed to provide students with an opportunity to review and critically evaluate recent publications in medical field focusing on examples when CS method or bioinformatics/statistical technique has lead to an instrumentation, technique or drug approved for clinical practice use.

Objective

Throughout the course, students will read and analyze recent publications that demonstrate successful applications and sometimes failures in medicine. Promising research applications will also be discussed. The publications will cover a wide range of topics, including drug discovery, image analysis, prognostic models, and learning healthcare.
The course will be structured as half lecture content and half seminar content. Lectures will review state of the medical practice prior to the
discovery, obstacles in moving the field forward, and the need for improvement. Lecture will be followed by the seminar part where
students will take turns presenting the assigned publications and leading the discussions. Students’ presentations will focus on the main
findings, and specific steps taken to translate the finding into clinical practice.

Publications will include examples of:
- specific CS/bioinformatics/statistics applications that has been brought to „bedside“ – has been approved by European Medicines Agency
  / Food and Drug Administration (USA) for clinical use or are widely used in medical research;
- examples of failures of how a discovery did not translate into an endproduct and why;
- current active research areas.

Covered topics will include some of the following:
- Drug discovery: Computer-aided drug discovery has become an integral part of the drug development process, enabling researchers to
design and screen large libraries of molecules in silico (i.e., using computer simulations) before synthesizing and testing them in the lab.
This has led to the discovery of new drug candidates for a wide range of diseases, including cancer, Alzheimer’s disease, and HIV/AIDS.
- Genomics: Advances in computational genomics have enabled researchers to analyze and interpret large-scale genomic data, including
DNA sequencing data, to identify disease-causing mutations, genetic risk factors, and drug targets. Examples of the development of
personalized medicine, where treatments are tailored to an individual’s genetic makeup. Examples when drug target identified by genetics
has led to approved treatment.
- Imaging: Computer vision and image processing techniques have revolutionized medical imaging, enabling researchers to extract
quantitative information from medical images that were previously inaccessible. This has led to the development of new diagnostic and
prognostic tools for a wide range of diseases, including cancer, cardiovascular disease, and neurological disorders.
- Real-world data applications: emulation of clinical trials using electronic health records data.
- Large language models: Generating clinical trial protocols using large language models. Natural Language Processing for information
extraction and interpretation.
- Learning healthcare systems: Advances in data analytics and information technology have enabled the development of learning
healthcare systems, which use real-time data from electronic health records, medical devices, and other sources to improve patient
outcomes and reduce healthcare costs. This has the potential to transform the way healthcare is delivered, making it more personalized,
efficient, and effective.

In addition to the presentations, students will also be required to write critical reviews of the assigned publications throughout the course.
The reviews will be evaluated based on the students’ ability to identify the strengths and weaknesses of the publications and to provide
insightful and constructive feedback.

Prerequisites / notice
The course is intended for advanced undergraduate and graduate students with a background in computer science, bioinformatics, or a
related field and interest in applying their skills to medical research.

This course assumes a working knowledge of R/Python and intermediate statistical analysis, including linear, logistic, survival regressions
or ability and interest to learn them outside of the class.

Competencies

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<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<tr>
<td>Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>fostered</td>
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<tr>
<td>Social Competencies</td>
<td>Analytical Competencies</td>
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<td>Communication</td>
<td>assessed</td>
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<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>fostered</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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At least 10 ECTS need to be acquired in this category.

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<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>551-0309-00L</td>
<td>Concepts in Modern Genetics</td>
<td>W</td>
<td>6</td>
<td>4V</td>
<td>Y. Barral, A. Hajnal, O. Voinnet, University lecturers</td>
</tr>
</tbody>
</table>

*Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.
Please mind the ETH enrolment deadlines for UZH students: https://www.ETHZ.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html*

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse
 genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair
and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of
eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of
developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.
Microbiology (Part I)  W 3 credits  2V  W.-D. Hardt, L. Eberl, B. Nguyen, J. Piel, M. Pilhofer, A. Vagstad

Abstract
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Objective
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Content
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Literature
Updated handouts will be provided during the class.

Immunology I  W 3 credits  2V  M. Kopf, A. Oxenius

Abstract
Introduction into structural and functional aspects of the immune system.

Objective
Basic knowledge of the mechanisms and the regulation of an immune response.

Content
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Literature
- Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020

Developmental Neuroscience (University of Basel)  W 2 credits  2V  external organisers

Does not take place this semester.
The course must be registered for directly at Uni Basel.

Uni Basel course number: 14467-01

Mind the enrolment deadlines at Uni Basel:
https://www.unibas.ch/en/Studies/Mobility/Mobility-Switzerland/Students-Registering-From-Other-Swiss-Universities.html

Abstract
Development of cerebral cortex, hippocampus, motor system, olfactory system, visual system, auditory system, somatosensory system, navigation and memory systems, developmental disorders (autism, stem cells in the developing, adult and diseased brain.

Molecular Medicine I (University of Basel)  W 2 credits  2V  external organisers

The course must be registered for directly at Uni Basel.

Uni Basel course number: 22831-01

Mind the enrolment deadlines at Uni Basel:
https://www.unibas.ch/en/Studies/Mobility/Mobility-Switzerland/Students-Registering-From-Other-Swiss-Universities.html

Abstract
This lecture series will introduce biologists to the mechanisms that cause human diseases. Emphasis will be on the genetic and environmental factors that lead to diseases, and how this knowledge can be used to develop diagnostic and therapeutic procedures.

Molecular Mechanisms of Development (University of Basel)  W 2 credits  2V  external organisers

Wks 2 credits  2V  external organisers
Molecular Control of Vertebrate Development and Organogenesis (University of Basel)  W  2 credits  2V  external organisers

Evolutionary Medicine: Morphological Changes and Pathologies (University of Zurich)  W  6 credits  5G  University lecturers

New Approaches to Tackle Antibiotic Resistance (University of Basel)  W  1 credit  1V  external organisers

Functional Organization of the Cell Nucleus (University of Basel)  W  2 credits  2V  external organisers

Cellular Signalling (University of Basel)  W  2 credits  2V  external organisers

Frontiers in RNA Biology (University of Basel)  W  2 credits  2V  external organisers

Stem Cells: Biology and Therapeutic Manipulation  W  4 credits  3G  T. Schroeder
Abstract

Stem cells are central in tissue regeneration and repair, and hold great potential for therapy. We will discuss the role of stem cells in health and disease, and possibilities to manipulate their behavior for therapeutic application. Basic molecular and cell biology, engineering and novel technologies relevant for stem cell research and therapy will be discussed.

Objective

Understanding of current knowledge, and lack thereof, in stem cell biology, regenerative medicine and required technologies. Theoretical preparation for practical laboratory experimentation with stem cells.

Content

We will use different diseases to discuss how to potentially model, diagnose or heal them by stem cell based therapies. This will be used as a guiding framework to discuss relevant concepts and technologies in cell and molecular biology, engineering, imaging, bioinformatics, tissue engineering, that are required to manipulate stem cells for therapeutic application.

Topics will include:

- Embryonic and adult stem cells and their niches
- Induced stem cells by directed reprogramming
- Relevant basic cell biology and developmental biology
- Relevant molecular biology
- Cell culture systems
- Cell fates and their molecular control by transcription factors and signalling pathways
- Cell reprogramming
- Disease modelling
- Tissue engineering
- Bioimaging, Bioinformatics
- Single cell technologies

Competencies

Subject-specific Competencies

- Concepts and Theories

Method-specific Competencies

- Techniques and Technologies

Social Competencies

- Communication

Personal Competencies

- Critical Thinking

636-0108-00L  Biological Engineering and Biotechnology  4 credits  6V  M. Fussenegger

Abstract

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content


Lecture notes

Handout during the course.

262-5120-00L  Principles of Evolution: Theory (University of Zurich)  6 credits  3V  University lecturers

Abstract

"Nothing in Biology Makes Sense Except in the Light of Evolution". Evolutionary theory and methods are essential in all branches of modern biology.

Objective

Subject specific skills:

- By the end of the course, students will be able to:
  - describe basic evolutionary theory and its applications
  - discuss ongoing debates in evolutionary biology
  - critically assess the presentation of evolutionary research in the popular media

Key skills:

- By the end of the course, students will be able to:
  - approach biological questions from an evolutionary perspective

Content

This course will provide a broad overview of current evolutionary thought, including the mechanisms of evolutionary change, adaptation and the history of life and will involve practical field and lab work as well as lecture material.

551-0307-00L  Molecular and Structural Biology I: Protein Structure and Function  3 credits  2V  R. Glockshuber, K. Locher, E. Weber-Ban

Abstract

Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

Objective

Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

Lecture notes

Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.
Literature
Basics:
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

262-6107-00L Applied Mathematics and Informatics in Drug Discovery (University of Basel) W 2 credits 2G external organisers

Mind the enrolment deadlines at Uni Basel: https://www.unibas.ch/en/Studies/Mobility/Mobility-Switzerland/Students-Registering-From-Other-Swiss-Universities.html

Abstract
This introductory course will offer a practitioner’s review of mathematical concepts, informatics tools, and industrial approaches in relevant fields, especially bioinformatics, molecular modelling, cheminformatics, mathematical modelling, experiment design and statistical inference, and machine learning.

Objective
We explore the drug-discovery process and study applications of mathematics and informatics with case studies. We examine how mathematics concepts and informatics tools are used to model complex systems at multiple levels - molecular level, cellular and omics level, organ- and system-level, and population level - and how the multiscale modelling approach contributes to drug discovery.

529-0733-02L Chemical Biology and Synthetic Biochemistry W 6 credits 3G K. Lang, M. Fottner

Abstract
Overview of modern chemical biology and synthetic biochemistry techniques, focussed on protein modification and labeling and on methods to endow proteins with novel functionalities.

Objective
After taking this course, students should be capable of the following: A) Recall different possibilities for modifying proteins in vitro and in vivo and their applications in a biological context, B) Understand the chemical and biochemical consequences of modifications and assess the different reaction possibilities in the context of in vivo - in vitro, C) Critically analyze and assess current chemical biology articles D) Question the approaches learned and apply them to new biological problems.

Content
principles of protein labeling and protein modification (fluorescent proteins, enzyme-mediated labeling, bioorthogonal chemistries)
directed evolution and protein engineering
chemical biology of ubiquitin and targeted protein degradation

Lecture notes
A script will not be handed out. Handouts to the lecture will be provided through moodle.

Literature
Citations from the original literature relevant to the individual lectures will be assigned during the lectures.

Prerequisites / notice
Knowledge provided in the bachelor lectures 'Nucleic Acids and Carbohydrates' and 'Proteins and Lipids' is assumed for this lecture.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

Lab Rotations
18 ECTS in total. (MSc CBB students starting after Autumn 2021 must register courses with course number 262-0*3*). At least one lab rotation in different group/ supervisor than master’s thesis.

Further information and options: https://cbb.ethz.ch/studies/lab-rotations-internship.html

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<tr>
<th>Number</th>
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<td>W</td>
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<td>13A</td>
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<td>Abstract</td>
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<tr>
<td>Objective</td>
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</table>
Supervisors
Students gain an overview of different research areas by applying concepts taught in the core courses and advanced courses.

Industry internship of at least 12 weeks, completed with a written report.
The students look for a placement themselves.

Lecturers

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<td>19A</td>
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<td>Industry internship of at least 8 weeks, completed with a written report. Students gain experience in an industrial environment and an overview of different research areas by applying concepts taught in the core courses and advanced courses.</td>
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<td>17A</td>
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<td>Industry internship of at least 6 weeks, completed with a written report. Students gain experience in an industrial environment and an overview of different research areas by applying concepts taught in the core courses and advanced courses.</td>
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▶ Science in Perspective
see Science in Perspective: Language Courses ETH/UZH
see Science in Perspective: Type A: Enhancement of Reflection Capability
Recommended Science in Perspective (Type B) for D-BSSE

▶ Master’s Thesis

Number | Title | Type | ECTS | Hours | Lecturers |
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<td>262-0800-00L</td>
<td>Master’s Thesis</td>
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<td>30</td>
<td>64D</td>
<td>Professors</td>
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<td>Only students who fulfill the following criteria are allowed to begin with their master thesis: a. successful completion of the bachelor programme; b. fulfilling of any additional requirements necessary to gain admission to the master programme. The Master Thesis is the result of an independent scientific research and/or constructive development project in the chosen area of specialization. The Master thesis concludes the Master programme. By writing up the Master thesis, students show their ability to independently produce a coherent and scientific piece of work. The program concludes with a Master thesis that includes a written report and an oral presentation. The topic of the thesis can be chosen according to the student’s interests in the field of computational biology &amp; bioinformatics. The duration for the master's thesis in the study regulation 2017 (per Autumn Semester 2021) is 24 working weeks (thereof, 2 weeks are reserved for compensation of public holidays, sick leave and other unplanned short term absences.)</td>
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▶ Course Units for Additional Admission Requirements
The courses below are only available for MSc students with additional requirements.

Number | Title | Type | ECTS | Hours | Lecturers |
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<tr>
<td>252-0002-AAL</td>
<td>Data Structures and Algorithms</td>
<td>E-</td>
<td>8</td>
<td>15R</td>
<td>F. Friedrich Wicker, M. Fischer</td>
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<tr>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.</td>
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This course is about fundamental algorithm design paradigms (such as induction, divide-and-conquer, backtracking, dynamic programming), classic algorithmic problems (such as sorting and searching), and data structures (such as lists, hashing, search trees). Moreover, an introduction to parallel programming is provided. The programming model of C++ will be discussed in some depth.

An understanding of the design and analysis of fundamental algorithms and data structures. Knowledge regarding chances, problems and limits of parallel and concurrent programming. Deeper insight into a modern programming model by means of the programming language C++.

Data structures and algorithms: mathematical tools for the analysis of algorithms (asymptotic function growth, recurrence equations, recurrence trees), informal proofs of algorithm correctness (invariants and code transformation), design paradigms for the development of algorithms (induction, divide-and-conquer, sweep-line method, backtracking and dynamic programming), classical algorithmic problems (searching, selection and sorting), data structures for different purposes (linked lists, hash tables, balanced search trees, quad trees, heaps, union-find), further tools for runtime analysis (e.g. amortized analysis). The relationship and tight coupling between algorithms and data structures is illustrated with geometric problems (convex hull, line intersections, closest point pairs) graph algorithms (traversals, topological sort, transitive closure, shortest paths, minimum spanning trees, max flow).

Programming model of C++: correct and efficient memory handling, generic programming with templates, functional approaches with functors and lambda expressions.

Parallel programming: concepts of parallel programming (Amdahl's and Gustavson's laws, task/data parallelism, scheduling), problems of concurrency (data races, bad interleavings, memory reordering), process synchronisation and communication in a shared memory system (mutual exclusion, semaphores, monitors, condition variables), progress conditions (freedom from deadlock, starvation).

The concepts provided in the course are motivated and illustrated with practically relevant algorithms and applications.

All required mathematical tools above high school level are covered, including a basic introduction to graph theory.

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.

Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens "behind the scenes" when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.

The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.

Lecture slides and all other material will be made available for download on the course web page.

Standard textbooks:
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies assessed
Problem-solving assessed

Social Competencies
Communication fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking fostered

406-0603-AAL  Stochastics (Probability and Statistics) E- 4 credits 9R M. Kalisch

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

Objective
The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

Content
From "Statistics for research" (online)
Ch 1: The Role of Statistics
Ch 2: Populations, Samples, and Probability Distributions
Ch 3: Binomial Distributions
Ch 6: Sampling Distribution of Averages
Ch 7: Normal Distributions
Ch 8: Student's t Distribution
Ch 9: Distributions of Two Variables

From "Introductory Statistics with R (online)"
Ch 1: Basics
Ch 2: The R Environment
Ch 3: Probability and distributions
Ch 4: Descriptive statistics and tables
Ch 5: One- and two-sample tests
Ch 6: Regression and correlation

Literature
- "Statistics for research" by S. Dowdy et al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
From within the ETH, this book is freely available online under:

From within the ETH, this book is freely available online under:
http://www.springerlink.com/content/m1757b/

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies assessed
Problem-solving assessed

Personal Competencies
Self-direction and Self-management assessed

262-0945-AAL  Cell and Molecular Biology for Engineers I and II E- 6 credits 13R B. Treutlein

Does not take place this semester.
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
The course gives an introduction into cellular and molecular biology, specifically for students with a background in engineering. The focus will be on the basic organization of eukaryotic cells, molecular mechanisms and cellular functions. Textbook knowledge will be combined with results from recent research and technological innovations in biology.

Objective
After completing this course, engineering students will be able to apply their previous training in the quantitative and physical sciences to modern biology. Students will also learn the principles how biological models are established, and how these models can be tested.

Content
Lectures will include the following topics: DNA, chromosomes, RNA, protein, genetics, gene expression, membrane structure and function, vesicular traffic, cellular communication, energy conversion, cytoskeleton, cell cycle, cellular growth, apoptosis, autophagy, cancer, development and stem cells.

Literature

Computational Biology and Bioinformatics Master - Key for Type

O Compulsory E- Recommended, not eligible for credits
W+ Eligible for credits and recommended Z Courses outside the curriculum
W Eligible for credits Dr Suitable for doctorate
**Key for Hours**

<table>
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<tr>
<th>Key</th>
<th>Description</th>
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<tr>
<td>V</td>
<td>lecture</td>
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<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Cyber Security Master

Field of Specialization

Core Courses

<table>
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<tr>
<th>Number</th>
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<td>252-0463-00L</td>
<td>Security Engineering</td>
<td>W</td>
<td>7 credits</td>
<td>2V+2U+2A</td>
<td>D. Basin, S. Krstic</td>
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Abstract

Subject of the class are engineering techniques for developing secure systems. We examine concepts, methods and tools, applied within the different activities of the SW development process to improve security of the system. Topics: security requirements & risk analysis, system modeling & model-based development methods, implementation-level security, and evaluation criteria for secure systems.

Objective

Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software.

Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems
Security engineering is an evolving discipline that unites two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software. Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security,
* evaluation criteria for the development of secure systems

Modules taught:

1. Introduction
   - Introduction of Infsec group and speakers
   - Security meets SW engineering: an introduction
   - The activities of SW engineering, and where security fits in
   - Overview of this class
2. Requirements Engineering: Security Requirements and some Analysis
   - Overview: functional and non-functional requirements
   - Use cases, misuse cases, sequence diagrams
   - Safety and security
3. Modeling in the design activities
   - Structure, behavior, and data flow
   - Class diagrams, statecharts
4. Model-driven security for access control (Part I)
   - SecureUML as a language for access control
   - Combining Design Modeling Languages with SecureUML
   - Semantics, i.e., what does it all mean,
   - Generation
   - Examples and experience
5. Model-driven security (Part II)
   - Continuation of above topics
6. Security patterns (design and implementation)
7. Implementation-level security
   - Buffer overflows
   - Input checking
   - Injection attacks
8. Code scanning
   - Static code analysis basics
   - Theoretical and practical challenges
   - Analysis algorithms
   - Common bug pattern search and specification
   - Dataflow analysis
9. Testing
   - Overview and basics
   - Model-based testing
   - Testing security properties
10. Risk analysis and management
    - "Risk": assets, threats, vulnerabilities, risk
    - Risk assessment: quantitative and qualitative
    - Safeguards
    - Generic risk analysis procedure
    - The OCTAVE approach
    - Example of qualitative risk assessment
11. Threat modeling
    - Overview
    - Safety engineering basics: FMEA and FTA
    - Security impact analysis in the design phase
    - Modeling security threats: attack trees
    - Examples and experience
12. Evaluation criteria
    - NIST special papers
    - ISO/IEC 27000
    - Common criteria
    - BSI baseline protection
13. Guest lecture
    - TBA

Literature
- Further relevant books and journal/conference articles will be announced in the lecture.

Prerequisites / notice
Prerequisite: Class on Information Security

252-1414-00L System Security  W  7 credits  2V+2U+2A  S. Capkun, S. Shinde

Abstract
The first part of the course covers general security concepts and hardware-based support for security. In the second part, the focus is on system design and methodologies for building secure systems.

Objective
In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.
The first part of the lecture covers hardware-based security concepts. Topics include the concept of physical and software-based side channel attacks on hardware resources, architectural support for security (e.g., memory management and permissions, disk encryption), and trusted execution environments (Intel SGX, ARM TrustZone, AMD SEV, and RISC-V Keystone).

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: common software faults (e.g., buffer overflows, etc.), bug-detection, writing secure software (design, architecture, QA, testing), compiler-supported security (e.g., control-flow integrity), and language-supported security (e.g., memory safety).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

### Competencies

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<thead>
<tr>
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### Content
- **Objective**: Students are familiar with fundamental network-security concepts.
- **Method-specific Competencies**: Students can implement network-security protocols based on cryptographic libraries.
- **Method-specific Competencies**: Students can identify and assess vulnerabilities in software systems and network protocols.
- **Method-specific Competencies**: Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- **Method-specific Competencies**: Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- **Method-specific Competencies**: Students can implement network-security protocols based on cryptographic libraries.

### Prerequisites / notice

This course is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will cover topics spanning four broad themes with a focus on the first two themes:
- **Objective**: Students are familiar with fundamental network-security concepts.
- **Objective**: Students can implement network-security protocols based on cryptographic libraries.
- **Objective**: Students can identify and assess vulnerabilities in software systems and network protocols.
- **Objective**: Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- **Objective**: Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

### Competencies

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<td>assessment</td>
<td>Integrity and Work Ethics</td>
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<td>assessment</td>
<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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### Content

- **Content**: The later parts of the course will focus on applications to machine learning.
- **Content**: The first half of the course will cover topics from cryptography such as secure multiparty computation, zero-knowledge proofs, PIR, ORAM, anonymous communication, etc.
- **Content**: The second part will cover statistical notions of privacy, in particular differential privacy, and selected topics in machine learning privacy.
- **Content**: Students are familiar with fundamental network-security concepts.
- **Content**: Students can implement network-security protocols based on cryptographic libraries.
- **Content**: Students can identify and assess vulnerabilities in software systems and network protocols.
- **Content**: Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- **Content**: Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.

### Lecture notes

Lecture notes will be posted on Moodle.

### Literature

Boneh & Shoup - A Graduate Course in Applied Cryptography

References to relevant research papers will be provided.
Prerequisites / notice

Basic knowledge in cryptography, probability and machine learning is recommended but not required.

## Electives

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0575-00L</td>
<td>Advanced Topics in Communication Networks</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>L. Vanbever</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course covers advanced topics and technologies in computer networks, both theoretically and practically. It is offered each Fall. Repetition for credit is possible with the consent of the instructor.</td>
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<tr>
<td>Objective</td>
<td>The goals of this course is to provide students with a deeper understanding of the existing and upcoming Internet technologies used in large-scale computer networks such as Internet Service Providers (e.g., Swisscom or Deutsche Telekom), Content Delivery Networks (e.g., Netflix) and Data Centers (e.g., Google). Besides covering the fundamentals, the course will be &quot;hands-on&quot; and will enable students to play with the technologies in realistic network environments.</td>
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<tr>
<td>Content</td>
<td>In 2023, the course will cover advanced topics in communication networks such as: - Advanced Internet routing (convergence, optimality, scalability, flexibility); - Network programmability (OpenFlow, P4); - Traffic engineering / Load Balancing; - Network verification and synthesis; - Network measurements; - Network security; - Upcoming transport protocols and technologies; - Adaptive video streaming; and - Network sustainability.</td>
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<tr>
<td>Lecture notes</td>
<td>The course will be composed of lectures and practical exercises (some of which including labs).</td>
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<tr>
<td>Literature</td>
<td>Relevant references will be made available through the course website.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Communication Networks (227-0120-00L) or equivalents / programming skills (in any language) are expected (some of the exercises will involve coding).</td>
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</table>
| Competencies  | Subject-specific Competencies
| Concept and Theories | assessed |
| Techniques and Technologies | assessed |
| Method-specific Competencies
| Analytical Competencies | assessed |
| Decision-making | assessed |
| Problem-solving | assessed |
| Project Management | assessed |
| Social Competencies
| Communication | assessed |
| Cooperation and Teamwork | assessed |
| Personal Competencies
| Adaptability and Flexibility | assessed |
| Creative Thinking | assessed |
| Critical Thinking | assessed |

| 227-0579-00L  | Hardware Security                             | W    | 8     | 2V+2U+2A       | K. Razavi   |
| Abstract      | This course covers the security of commodity computer hardware (e.g., CPU, DRAM, etc.) with a special focus on cutting-edge hands-on research. The aim of the course is familiarizing the students with hardware security and more specifically microarchitectural and circuit-level attacks and defenses through lectures and implementing some of these advanced attacks. |
| Objective     | By the end of the course, the students will be familiar with the state of the art in commodity computer hardware attacks and defenses. More specifically, the students will learn about: - security problems of commodity hardware that we use everyday and how you can defend against them. - relevant computer architecture and operating system aspects of these issues. - hands-on techniques for performing hardware attacks. |
| Literature    | Slides, relevant literature and manuals will be made available during the course. |
| Prerequisites / notice | Experience with Linux, low-level systems programming and computer architecture. |
| Competencies  | Subject-specific Competencies
| Concept and Theories | assessed |
| Techniques and Technologies | assessed |
| Method-specific Competencies
| Analytical Competencies | assessed |
| Decision-making | fostered |
| Media and Digital Technologies | fostered |
| Problem-solving | assessed |
| Project Management | fostered |
| Social Competencies
| Cooperation and Teamwork | fostered |
| Personal Competencies
| Adaptability and Flexibility | fostered |
| Creative Thinking | fostered |
| Critical Thinking | assessed |
| Integrity and Work Ethics | fostered |
| Self-direction and Self-management | fostered |

| 252-0811-00L  | Applied Security Laboratory                  | W    | 8     | 7P             | D. Basin    |
| Abstract      | Hands-on course on applied aspects of information security. Applied information security, operating system security, OS hardening, computer forensics, web application security, project work, design, implementation, and configuration of security mechanisms, risk analysis, system review. |
| Objective     | The Applied Security Laboratory addresses four major topics: operating system security (hardening, vulnerability scanning, access control, logging), application security with an emphasis on web applications (web server setup, common web exploits, authentication, session handling, code security), computer forensics, and risk analysis and risk management. |
This course emphasizes applied aspects of Information Security. The students will study a number of topics in a hands-on fashion and carry out experiments in order to better understand the need for secure implementation and configuration of IT systems and to assess the effectiveness and impact of security measures. This part is based on a book and virtual machines that include example applications, questions, and answers.

The students will also complete an independent project: based on a set of functional requirements, they will design and implement a prototypical IT system. In addition, they will conduct a thorough security analysis and devise appropriate security measures for their systems. Finally, they will carry out a technical and conceptual review of another system. All project work will be performed in teams and must be properly documented.

### Lecture notes


### Literature

Recommended reading includes:

- Various: OWASP Guide to Building Secure Web Applications, available online
- Frisch: Essential System Administration, O'Reilly & Associates.
- NIST: Risk Management Guide for Information Technology Systems, available online as PDF
- BSI: IT-Grundschutzhandbuch, available online

### Prerequisites / notice

- The lab allows flexible working since there are only few mandatory meetings during the semester.
- The lab covers a variety of different techniques. Thus, participating students should have a solid foundation in the following areas: information security, operating system administration (especially Unix/Linux), and networking. Students are also expected to have a basic understanding of HTML, PHP, JavaScript, and MySQL because several examples are implemented in these languages.
- Students must be prepared to spend more than three hours per week to complete the lab assignments and the project. This applies particularly to students who do not meet the recommended requirements given above. Successful participants of the course receive 8 credits as compensation for their effort.
- All participants must sign the lab's charter and usage policy during the introduction lecture.

### 252-1411-00L Security of Wireless Networks

#### Abstract

This course discusses physical layer aspects of wireless communication and a wide range of security-related topics in the domain of wireless technologies. It mainly targets computer science students. Though useful, a background in signal processing or physical layer concepts is not required. A basic understanding of security (e.g. as taught in 252-0211.00L Information Security) is recommended.

#### Objective

After this course, students should be able to describe and classify security goals of and attacks on various wireless networks and technologies, with an emphasis on physical layer aspects.

#### Content

- Introduction to wireless communication
- Physical layer security schemes
- Spreading techniques and their application in jamming-resistant communication and Global Navigation Satellite Systems (GNSSs)
- Secure ranging with Ultra-Wide Band (UWB)
- Security aspects of cellular networks, WiFi, and Bluetooth Low Energy (BLE)

#### Competencies

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### 263-4657-00L Advanced Encryption Schemes

This course focuses on the practical aspects of encryption schemes and their applications in real-world scenarios. The course emphasizes the relationship between theoretical cryptography and practical implementation.

#### Abstract

Public-Key Encryption has had a significant impact by enabling remote parties to communicate securely via an insecure channel. Latest schemes go further by providing a fine-grained access to the encrypted data.

#### Objective

The student is comfortable with formal security definitions and proof techniques used to analyze the security of the latest encryption schemes with advanced features. This prepares the student to start reading research papers on the field.

#### Content

We will start by presenting the notion of Public-Key Encryption with its various security guarantees and some constructions. Then we will look into encryption schemes with fine-grained access control to the encrypted data, such as identity-based encryption or attribute-based encryption and present different methodologies to prove their security.

#### Literature

Links to relevant research papers will be given in the course materials.

#### Prerequisites / notice

It is recommended for students to have prior exposure to cryptography, e.g. the D-INFK course "Digital Signatures" or "Applied Cryptography".

### 263-4665-00L Zero-Knowledge Proofs

This course focuses on the theoretical foundations of zero-knowledge proof systems and their practical applications in computer security.

#### Abstract

Zero-knowledge proofs are protocols which allow a prover to convince a verifier that a statement is true without leaking any information beyond that fact. This course is a detailed introduction to zero-knowledge proof protocols.

#### Objective

- To understand what it means for a zero-knowledge proof to be secure
- To construct and analyse various types of zero-knowledge proofs
- To understand some applications of zero-knowledge proofs

#### Content

The course will discuss interactive zero-knowledge proofs based on various cryptographic assumptions, and their applications in cryptography and the real world. The course may also describe some more advanced constructions of non-interactive proofs.

#### Lecture notes

The course notes will be written in English.

#### Prerequisites / notice

Students should have taken a first course in Cryptography (as taught in the Information Security course at Bachelor’s level), Experience with algebra (groups and finite fields) and probability is highly recommended.

#### Competencies

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### Seminar

#### Number

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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 612 of 2653
Abstract
The seminar covers various topics in information security: security protocols (models, specification & verification), trust management, access control, non-interference, side-channel attacks, identity-based cryptography, host-based attack detection, anomaly detection in backbone networks, key-management for sensor networks.

Objective
The main goals of the seminar are the independent study of scientific literature and assessment of its contributions as well as learning and practicing presentation techniques.

Content
The seminar covers various topics in information security, including network security, cryptography and security protocols. The participants are expected to read a scientific paper and present it in a 35-40 min talk. At the beginning of the semester a short introduction to presentation techniques will be given.

Selected Topics
- security protocols: models, specification & verification
- trust management, access control and non-interference
- side-channel attacks
- identity-based cryptography
- host-based attack detection
- anomaly detection in backbone networks
- key-management for sensor networks

Literature
The reading list will be published on the course web site.

Semester Project
The Semester Project provides students with the opportunity to apply acquired knowledge and skills.

Objective
The students can gain hand-on experience by solving independently a technical-scientific problem.

Data Management Systems
The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations.

Objective
Do you want to be able to query your own data productively and efficiently in your future semester projects, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This course teaches you how to do so as well as the dos and don'ts. "Big Data" refers to the case when the amount of data is very large (100 GB and more), or when the data is not completely structured (or messy). The Big Data revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it are needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each one of your projects efficiently and consistently.
The main source of information for the course will be articles and research papers describing the architecture of the systems discussed.

Course textbook: https://ghislainfourny.github.io/big-data-textbook/

- physical storage: distributed file systems (HDFS), object storage (S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, …)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Large scale analytics and machine learning are outside of the scope of this course.

Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

The lecture is hybrid, meaning you can attend with us in the lecture hall, or on Zoom, or watch the recordings on YouTube later. Exercise sessions are in presence.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departments interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2023

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.
The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

## Elective Courses

### Number 252-0535-00L
#### Title Advanced Machine Learning

**Type:** W  
**ECTS:** 10 credits  
**Hours:** 3V+2U+4A  
**Lecturers:** C. Cotrini Jimenez

**Abstract**

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real-world data.

**Content**

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

**Topics covered in the lecture include:**

- **Fundamentals:**
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- **Supervised learning:**
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- **Unsupervised learning:**
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

**Lecture notes**

No lecture notes, but slides will be made available on the course webpage.

**Literature**


### Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution. PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

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### Number 252-1414-00L
#### Title System Security

**Type:** W  
**ECTS:** 7 credits  
**Hours:** 2V+2U+2A  
**Lecturers:** S. Capkun, S. Shinde

**Abstract**

The first part of the course covers general security concepts and hardware-based support for security. In the second part, the focus is on system design and methodologies for building secure systems.

**Objective**

In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

**Content**

The first part of the lecture covers hardware-based security concepts. Topics include the concept of physical and software-based side channel attacks on hardware resources, architectural support for security (e.g., memory management and permissions, disk encryption), and trusted execution environments (Intel SGX, ARM TrustZone, AMD SEV, and RISC-V Keystone).

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: common software faults (e.g., buffer overflows, etc.), bug detection, writing secure software (design, architecture, QA, testing), compiler-supported security (e.g., control-flow integrity), and language- supported security (e.g., memory safety).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

**Competencies**

**Subject-specific Competencies**

- Concepts and Theories: assessed

**Method-specific Competencies**

- Analytical Competencies: fostered
  - Decision-making: fostered
  - Problem-solving: fostered

**Social Competencies**

- Communication: fostered

**Personal Competencies**

- Adaptability and Flexibility: fostered
  - Critical Thinking: fostered

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### Number 263-2800-00L
#### Title Design of Parallel and High-Performance Computing

**Type:** W  
**ECTS:** 9 credits  
**Hours:** 2V+2U+4A  
**Lecturers:** T. Hoefler

**Abstract**

Advanced topics in parallel and high-performance computing.
Objective
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

Content
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

Prerequisites / notice
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

263-3210-00L Deep Learning W 8 credits 3V+2U+2A T. Hofmann
Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below.

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://ml2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/ss19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18

★★★ Machine Intelligence
★★★ Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td></td>
<td>10</td>
<td>3V+2U+4A</td>
<td>C. Cotrini Jimenez</td>
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Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real-world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:
Fundamentals:
What is data?
Bayesian Learning
Computational learning theory
Supervised learning:
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks
Unsupervised learning:
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation
Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

### Prerequisites / notice
263-3210-00L Deep Learning

**Abstract**
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

**Objective**
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

**Prerequisites / notice**
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

- Advanced Machine Learning
  [https://ml2.inf.ethz.ch/courses/aml/](https://ml2.inf.ethz.ch/courses/aml/)

- Computational Intelligence Lab

- Introduction to Machine Learning
  [https://las.inf.ethz.ch/teaching/introml-S19](https://las.inf.ethz.ch/teaching/introml-S19)

- Statistical Learning Theory
  [http://ml2.inf.ethz.ch/courses/slt/](http://ml2.inf.ethz.ch/courses/slt/)

- Computational Statistics

- Probabilistic Artificial Intelligence
  [https://las.inf.ethz.ch/teaching/pai-f18](https://las.inf.ethz.ch/teaching/pai-f18)

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### Probabilistic Artificial Intelligence

**Abstract**
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

**Objective**
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

**Content**
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bands and Bayesian optimization
- Reinforcement learning

**Prerequisites / notice**
Solid basic knowledge in statistics, algorithms and programming.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Media and Digital Technologies</th>
<th>Problem-solving</th>
<th>Project Management</th>
<th>Communication</th>
<th>Cooperation and Teamwork</th>
<th>Creative Thinking</th>
<th>Critical Thinking</th>
<th>Integrity and Work Ethics</th>
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### Elective Courses

<table>
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<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tr>
<td>263-2400-00L</td>
<td>Reliable and Trustworthy Artificial Intelligence</td>
<td>W</td>
<td>6</td>
<td>2V+2U+1A</td>
<td>M. Vechev</td>
</tr>
</tbody>
</table>

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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 617 of 2653
Abstract
Creating reliable, secure, robust, and fair machine learning models is a core challenge in artificial intelligence and one of fundamental importance. The goal of the course is to teach both the mathematical foundations of this new and emerging area as well as to introduce students to the latest and most exciting research in the space.

Objective
Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of engineering and research problems. To facilitate deeper understanding, the course includes a group coding project where students will build a system based on the learned material.

Content
The course is split into 4 parts:

Robustness of Machine Learning
- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

Privacy of Machine Learning
- Threat models (e.g., data poisoning, membership inference, etc.).
- Attacking federated machine learning (across vision, natural language, and tabular data).
- Differential privacy for defending machine learning.
- AI Regulations and checking model compliance.

Fairness of Machine Learning
- Introduction to fairness (motivation, definitions).
- Enforcing individual fairness (for both vision and tabular data).
- Enforcing group fairness (e.g., demographic parity, equalized odds).

Robustness, Privacy and Fairness of Foundation Models
- We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).

Prerequisites / notice
While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in "Intro to ML" classes at most institutions (e.g., "Introduction to Machine Learning" at ETH).

The coding project will utilize Python and PyTorch. Thus some programming experience in Python is expected. Students without prior knowledge of PyTorch are expected to acquire it early in the course by solving exercise sheets.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

263-5005-00L Artificial Intelligence in Education

Abstract
Artificial Intelligence (AI) methods have shown to have a profound impact in educational technologies, where the great variety of tasks and data types enable us to get benefit of AI techniques in many different ways. We will review relevant methods and applications of AI in various educational technologies, and work on problem sets and projects to solve problems in education with the help of AI.

Objective
The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

Content
This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical and neural networks. This class is appropriate for advanced undergraduates and master students in Computer Science as well as PhD students in other departments.

Literature
Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

263-5056-00L Applications of Deep Learning on Graphs

Abstract
Graphs are an incredibly versatile abstraction to represent arbitrary structures such as molecules, relational knowledge or social and traffic networks. This course provides a practical overview of deep (representation) learning on graphs and their applications.


- We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).

- Enforcing group fairness (for both vision and tabular data).
- Differential privacy for defending machine learning.
- AI Regulations and checking model compliance.

- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

- Threat models (e.g., data poisoning, membership inference, etc.).
- Attacking federated machine learning (across vision, natural language, and tabular data).
- Differential privacy for defending machine learning.
- AI Regulations and checking model compliance.

- Introduction to fairness (motivation, definitions).
- Enforcing individual fairness (for both vision and tabular data).
- Enforcing group fairness (e.g., demographic parity, equalized odds).

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The coding project will utilize Python and PyTorch. Thus some programming experience in Python is expected. Students without prior knowledge of PyTorch are expected to acquire it early in the course by solving exercise sheets.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

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- AI Regulations and checking model compliance.

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While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in "Intro to ML" classes at most institutions (e.g., "Introduction to Machine Learning" at ETH).

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Subject-specific Competencies
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Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

263-5005-00L Artificial Intelligence in Education

Abstract
Artificial Intelligence (AI) methods have shown to have a profound impact in educational technologies, where the great variety of tasks and data types enable us to get benefit of AI techniques in many different ways. We will review relevant methods and applications of AI in various educational technologies, and work on problem sets and projects to solve problems in education with the help of AI.

Objective
The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

Content
This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical and neural networks. This class is appropriate for advanced undergraduates and master students in Computer Science as well as PhD students in other departments.

Literature
Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

263-5056-00L Applications of Deep Learning on Graphs

Abstract
Graphs are an incredibly versatile abstraction to represent arbitrary structures such as molecules, relational knowledge or social and traffic networks. This course provides a practical overview of deep (representation) learning on graphs and their applications.

Objective

Many established deep learning methods require dense input data with a well-defined structure (e.g. an image, a sequence of word embeddings). However, many practical applications deal with sparsely connected and complex data structures, such as molecules, knowledge graphs or social networks. Graph Neural Networks (GNNs) and general representation learning on graphs have recently experienced a surge in popularity because it addresses the challenge to effectively learn representations over such structures. In this course, we aim to understand the fundamental principles of deep (representation) learning on graphs, the similarities and differences to other concepts in deep learning, as well as the unique challenges from a practical point of view. Finally, we provide an overview of recent applications of graph neural networks.

Content

Introduction to GNN concepts: 1) problem-solving on graphs (node-, edge-, graph-level objectives), structural priors (inductive biases) of graph data, applications for graph learning. 2) Graph Neural Networks: convolutional, attentional, message passing; overview on the zoo of published operators. Relations to Transformers and DeepSets. 3) Expressivity of GNNs. 4) Scalability of Graph Neural Networks: Subsampling, Clustering (Pooling). 5) Augmentations and self-supervised learning on Graphs Application: Drug Discovery, Knowledge graphs, Temporal GNNs. Geometric GNNs, Deep Generative Models for Graphs.

Prerequisites / notice

263-3210-00 Depp Learning or 263-0008-00 Computational Intelligence Lab; 252-0220-00 Introduction to Machine Learning; Statistics-Probability; Programming in Python; Unix Command Line.

263-5300-00L Guarantees for Machine Learning

Does not take place this semester.

W 7 credits 3V+1U+2A F. Yang

Abstract

This course is aimed at advanced master and doctorate students who want to conduct independent research on theory for modern machine learning (ML). It teaches standard methods in statistical learning theory commonly used to prove theoretical guarantees for ML algorithms. The knowledge is then applied in independent project work to understand and follow-up on recent theoretical ML results.

Objective

By the end of the semester students should be able to

- understand a good fraction of theory papers published in the typical ML venues. For this purpose, students will learn common mathematical techniques from statistical learning in the first part of the course and apply this knowledge in the project work

- critically examine recently published work in terms of relevance and find impactful (novel) research problems. This will be an integral part of the project work and involves experimental as well as theoretical questions

- outline a possible approach to prove a conjectured theorem by e.g. reducing to more solvable subproblems. This will be practiced in in-person exercises, homeworks and potentially in the final project

- effectively communicate and present the problem motivation, new insights and results to a technical audience. This will be primarily learned via the final presentation and report as well as during peer-grading of peer talks.

Content

This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning algorithms. It touches on the following topics

- concentration bounds
- uniform convergence and empirical process theory
- regularization for non-parametric statistics (e.g. in RKHS, neural networks)
- high-dimensional learning
- computational and statistical learnability (information-theoretic, PAC, SQ)
- overparameterized models, implicit bias and regularization

The project work focuses on current theoretical ML research that aims to understand modern phenomena in machine learning, including but not limited to

- how overparameterized models generalize (statistically) and converge (computationally)
- complexity measures and approximation theoretic properties of randomly initialized and trained neural networks
- generalization of robust learning (adversarial or distribution-shift robustness)
- private and fair learning

Prerequisites / notice

Students should have very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as “Introduction to Machine Learning”, “Regression”/ “Statistical Modelling”. In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

Competencies

Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

263-5351-00L Machine Learning for Genomics

The course reviews solutions provided by machine learning to the most challenging questions in human genomics.

W 6 credits 2V+2U+1A V. Boeva

Abstract

Over the last few years, the parallel development of machine learning methods and molecular profiling technologies for human cells, such as sequencing, created an extremely powerful tool to get insights into the cellular mechanisms in healthy and diseased contexts. In this course, we will discuss the state-of-the-art machine learning methodology solving or attempting to solve common problems in human genomics. At the end of the course, you will be familiar with (1) classical and advanced machine learning architectures used in genomics, (2) bioinformatics analysis of human genomic and transcriptomic data, and (3) data types used in this field.

Content

- Short introduction to major concepts of molecular biology: DNA, genes, genome, central dogma, transcription factors, epigenetic code, DNA methylation, signaling pathways
- Prediction of transcription factor binding sites, open chromatin, histone marks, promoters, nucleosome positioning (convolutional neural networks, position weight matrices)
- Prediction of variant effects and gene expression (hidden Markov models, topic models)
- Deconvolution of mixed signal (MMF, ICA)
- DNA, RNA and protein folding (RNN, LSTM, transformers)
- Data imputation for single-cell RNA-seq data, clustering and annotation (diffusion and methods on graphs)
- Batch correction (autoencoders, optimal transport)
- Survival analysis (Cox proportional hazard model, regularization penalties, multi-omics, multi-tasking)

Prerequisites / notice

### 252-0535-00L Advanced Machine Learning

**Abstract**

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

**Content**

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- **Fundamentals:** What is data?
- **Bayesian Learning**
- **Computational learning theory**
- **Supervised learning:**
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
- **Unsupervised learning:**
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
- **Learning Dynamical Systems**

**Lecture notes**

No lecture notes, but slides will be made available on the course webpage.

**Literature**


**Prerequisites / notice**

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

### 252-1425-00L Geometry: Combinatorics and Algorithms

**Abstract**

Geometric structures are useful in many areas, and there is a need to understand their structural properties, and to work with them algorithmically. The lecture addresses theoretical foundations concerning geometric structures. Central objects of interest are triangulations. We study combinatorial (Does a certain object exist?) and algorithmic questions (Can we find a certain object efficiently?)

**Objective**

The goal is to make students familiar with fundamental concepts, techniques and results in combinatorial and computational geometry, so as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains. In particular, we want to prepare students for conducting independent research, for instance, within the scope of a thesis project.

**Content**

Planar and geometric graphs, embeddings and their representation (Whitney's Theorem, canonical orderings, DCEL), polygon triangulations and the art gallery theorem, convexity in R^d, planar convex hull algorithms (Jarvis Wrap, Graham Scan, Chan's Algorithm), point set triangulations, Delaunay triangulations (Lawson flips, lifting map, randomized incremental construction), Voronoi diagrams, the Crossing Lemma and incidence bounds, line arrangements (duality, Zone Theorem, ham-sandwich cuts), 3-SUM hardness, counting planar triangulations.

**Lecture notes**

yes
Prerequisites / notice

Each student is expected to collaborate in an international working group with students from the partner universities. Each group works on Projects in Topological Data Analysis. Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations. E.g., having passed the course Algorithms, Probability, and Computing (APC) is recommended, though not required formally. If you are not sure whether you're ready for this course or not, please consult the instructor.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Problem-solving

- **Method-specific Competencies**
  - fostered
  - fostered

**Literature**


**Prerequisites / notice**

Prerequisites: The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH.

Outlook: In the following spring semester there is a seminar "Geometry: Combinatorics and Algorithms" that builds on this course. There are ample possibilities for Seminar-, Bachelor- and Master Thesis projects in the area.

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**Elective Courses**

<table>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<td>227-0417-00L</td>
<td>Information Theory I</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>A. Lapidoth</td>
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<td>263-4513-00L</td>
<td>Structural Graph Theory</td>
<td>W</td>
<td>5 credits</td>
<td>2V+2A</td>
<td>R. M. Steiner</td>
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<tr>
<td>263-4511-00L</td>
<td>Projects in Topological Data Analysis</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>P. Schnider</td>
</tr>
</tbody>
</table>

**Abstract**

- **Information Theory I**
  - This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

- **Structural Graph Theory**
  - Structural graph theory forms, besides extremal graph theory, one of the two main pillars of modern graph theory. While the latter is concerned with maximizing the number of edges or the density of graphs, structural graph theory focuses on understanding the structural nature of all members of a class of graphs. This course will cover several cornerstone results of structural graph theory.

- **Projects in Topological Data Analysis**
  - This seminar complements the course "Introduction to Topological Data Analysis". Students of the seminar will collaborate with students from international universities on concrete projects in topological data analysis, both theoretical and applied. Each student is expected to collaborate in an international working group with students from the partner universities. Each group works on one of the projects suggested by the lecturers, and is assigned a mentor. At the end of the semester, each working group presents their findings in a written report and an oral presentation.

**Objective**

- **Information Theory I**
  - The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

- **Structural Graph Theory**
  - The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the source-channel coding theorem, feedback capacity

- **Projects in Topological Data Analysis**
  - Each student is expected to collaborate in an international working group with students from the partner universities. Each group works on one of the projects suggested by the lecturers, and is assigned a mentor. At the end of the semester, each working group presents their findings in a written report and an oral presentation.

**Content**

- **Information Theory I**
  - The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

- **Structural Graph Theory**
  - Graph minors: Connectivity and versions of Menger's theorem, Planar graphs, Wagner's theorem, Tree-width, algorithmic applications of tree-width and Courcelle's theorem, balanced separators and Alon-Seymour-Thomas theorem, Grid Minor Theorem, Erdős–Pósa property and algorithmic applications, Graph Minor Structure Theorem, Membership complexity, Wagner's conjecture

- **Projects in Topological Data Analysis**
  - Successful participation in the course "Introduction to Topological Data Analysis" or equivalent background in topological data analysis is required.

**Overview**

**Literature**


**Prerequisites / notice**

Prerequisites: The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH.
Companions | Subject-specific Competencies | Concepts and Theories | fostered
Method-specific Competencies | Analytical Competencies | fostered
Social Competencies | Communication | assessed

263-5300-00L | Guarantees for Machine Learning | W | 7 credits | 3V+1U+2A | F. Yang

Abstract
This course is aimed at advanced master and doctorate students who want to conduct independent research on theory for modern machine learning (ML). It teaches standard methods in statistical learning theory commonly used to prove theoretical guarantees for ML algorithms. The knowledge is then applied in independent project work to understand and follow-up on recent theoretical ML results.

Objective
By the end of the semester students should be able to
- understand a good fraction of theory papers published in the typical ML venues. For this purpose, students will learn common mathematical techniques from statistical learning in the first part of the course and apply this knowledge in the project work
- critically examine recently published work in terms of relevance and find impactful (novel) research problems. This will be an integral part of the project work and involves experimental as well as theoretical questions
- outline a possible approach to prove a conjectured theorem by e.g. reducing to more solvable subproblems. This will be practiced in individual exercises, homeworks and potentially in the final project
- effectively communicate and present the problem motivation, new insights and results to a technical audience. This will be primarily learned via the final presentation and report as well as during peer-grading of peer talks.

Content
This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning algorithms. It touches on the following topics
- concentration bounds
- uniform convergence and empirical process theory
- regularization for non-parametric statistics (e.g. in RKHS, neural networks)
- high-dimensional learning
- computational and statistical learnability (information-theoretic, PAC, SQ)
- overparameterized models, implicit bias and regularization

The project work focuses on current theoretical ML research that aims to understand modern phenomena in machine learning, including but not limited to
- how overparameterized models generalize (statistically) and converge (computationally)
- complexity measures and approximation theoretic properties of randomly initialized and trained neural networks
- generalization of robust learning (adversarial or distribution-shift robustness)
- private and fair learning

Prerequisites
Students should have a very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as “Introduction to Machine Learning”, “Regression”/“Statistical Modelling”. In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

Competencies
- Subject-specific Competencies
  - Concepts and Theories | fostered

Method-specific Competencies
- Analytical Competencies | fostered
- Problem-solving | assessed

Social Competencies
- Communication | assessed
- Cooperation and Teamwork | assessed

Personal Competencies
- Creative Thinking | assessed
- Critical Thinking | assessed

401-3055-64L | Algebraic Methods in Combinatorics | W | 5 credits | 2V+1U | not available

Abstract
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

Objective
The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

Content
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):
- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 622 of 2653
### Visual and Interactive Computing

#### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0543-01L</td>
<td>Computer Graphics</td>
<td>W</td>
<td>8</td>
<td>3V+2U+2A</td>
<td>M. Gross, M. Papas</td>
</tr>
</tbody>
</table>

**Abstract**

This course covers fundamental and advanced concepts of modern computer graphics. Students will learn the fundamentals of digital scene representations, advanced physically-based light transport algorithms for generating photorealistic images from these scene representations, and inverse rendering methods for recovering digital scene representations from captured images.

**Objective**

At the end of the course, the students will be able to build a rendering system based on path-tracing algorithms. The students will learn the principles of physically-based rendering and computer graphics. In addition, the course is intended to stimulate the student's curiosity to explore the field of computer graphics in subsequent classes or on their own.
Content

We will begin with an introduction to light emission and radiometric quantities, followed by an exploration of geometry representations and texture mapping. Next, we will mathematically formulate the physics of light transport and appearance modeling. Subsequently, we will introduce relevant concepts from Monte Carlo integration and develop path-tracing algorithms to solve these equations by simulating light transport for direct and global illumination due to hard surfaces and participating media, such as fog, smoke, and translucent objects.

Moreover, we will present techniques for significantly improving path-tracing efficiency, including importance sampling, multiple importance sampling, stratified sampling, denoising, and acceleration data structures. The course lectures will conclude with an overview of image-based capture and rendering methods. Topics covered will include geometry reconstruction, material acquisition, differentiable rendering, and image-based rendering.

Lecture notes

no

Literature

Books:
Physically Based Rendering: From Theory to Implementation
High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting
Multiple view geometry in Computer Vision

Prerequisites / notice

Fundamentals of calculus and linear algebra, basic concepts of algorithms and data structures, programming skills in C++, and the Visual Computing course are recommended.

The programming assignments will be in C++. This will not be taught in the class.

Competencies

Subject-specific Competencies
Concepts and Theories
Concepts and Theories

Techniques and Technologies
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Analytical Competencies

Decision-making
Decision-making

Media and Digital Technologies
Media and Digital Technologies

Problem-solving
Problem-solving

Project Management
Project Management

Social Competencies
Communication
Communication

Leadership and Responsibility
Leadership and Responsibility

Personal Competencies
Creative Thinking
Creative Thinking

Critical Thinking
Critical Thinking

Integrity and Work Ethics
Integrity and Work Ethics

Self-direction and Self-management
Self-direction and Self-management

263-5902-00L

Computer Vision

W

8 credits

3V+1U+3A

M. Pollefeys, S. Tang, F. Yu

Objective

The objectives of this course are:

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

Prerequisites / notice

It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

Elective Courses

Number

227-0560-00L

Computer Vision and Artificial Intelligence for Autonomous Cars

Up until FS2022 offered as Deep Learning for Autonomous Driving

Type

W

ECTS

6 credits

3V+2P

C. Sakaridis

Abstract

This course introduces the core computer vision techniques and algorithms that autonomous cars use to perceive the semantics and geometry of their driving environment, localize themselves in it, and predict its dynamic evolution. Emphasis is placed on techniques tailored for real-world settings, such as multi-modal fusion, domain-adaptive and outlier-aware architectures, and multi-agent methods.

Objective

Students will learn about the fundamentals of autonomous cars and of the computer vision models and methods these cars use to analyze their environment and navigate themselves in it. Students will be presented with state-of-the-art representations and algorithms for semantic, geometric and temporal visual reasoning in automated driving and will gain hands-on experience in developing computer vision algorithms and architectures for solving such tasks.

After completing this course, students will be able to:

1. understand the operating principles of visual sensors in autonomous cars
2. differentiate between the core architectural paradigms and components of modern visual perception models and describe their logic and the role of their parameters
3. systematically categorize the main visual tasks related to automated driving and understand the primary representations and algorithms which are used for solving them
4. critically analyze and evaluate current research in the area of computer vision for autonomous cars
5. practically reproduce state-of-the-art computer vision methods in automated driving
6. independently develop new models for visual perception
The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including:

1. Fundamentals
   (a) Fundamentals of autonomous cars and their visual sensors
   (b) Fundamental computer vision architectures and algorithms for autonomous cars

2. Semantic perception
   (a) Semantic segmentation
   (b) Object detection
   (c) Instance segmentation and panoptic segmentation

3. Geometric perception and localization
   (a) Depth estimation
   (b) 3D reconstruction
   (c) Visual localization
   (d) Unimodal visual/lidar 3D object detection

4. Robust perception: multi-modal, multi-domain and multi-agent methods
   (a) Multi-modal 2D and 3D object detection
   (b) Visual grounding and verbo-visual fusion
   (c) Domain-adaptive and outlier-aware semantic perception
   (d) Vehicle-to-vehicle communication for perception

5. Temporal perception
   (a) Multiple object tracking
   (b) Motion prediction

The practical projects involve implementing complex computer vision architectures and algorithms and applying them to real-world, multi-modal driving datasets. In particular, students will develop models and algorithms for:

1. Semantic segmentation and depth estimation
2. Sensor calibration for multi-modal 3D driving datasets
3. 3D object detection using lidars

Lecture notes
Lecture slides are provided in PDF format.

Prerequisites / notice
Students are expected to have a solid basic knowledge of linear algebra, multivariate calculus, and probability theory, and a basic background in computer vision and machine learning. All practical projects will require solid background in programming and will be based on Python and libraries of it such as PyTorch.

Competencies
Subject-specific Competencies
   Concepts and Theories assessed
   Techniques and Technologies assessed
Method-specific Competencies
   Analytical Competencies assessed
   Media and Digital Technologies fostered
   Problem-solving assessed
Social Competencies
   Communication fostered
   Cooperation and Teamwork fostered
Personal Competencies
   Creative Thinking assessed
   Critical Thinking assessed

262-0546-00L Physically-Based Simulation in Computer Graphics

Abstract
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Objective
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Content
The lecture covers topics in physically-based modeling, such as particle systems, mass-spring models, finite difference and finite element methods. These approaches are used to represent and simulate deformable objects or fluids with applications in animated movies, 3D games and medical systems. Furthermore, the lecture covers topics such as rigid body dynamics, collision detection, and object animation.

Prerequisites / notice
Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++. Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

263-5905-00L Mixed Reality

Abstract
The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human machine interaction, as well as gaming technology.

Objective
After attending this course, students will:
1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.

Content
The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including:
- Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introduction to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course are student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision(graphics/HMI research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D, other platforms are also possible to use, such as tablets and phones.

Prerequisites / notice
Prerequisites include:
- Good programming skills (C# / C++ / Java etc.)
- Computer graphics/vision experience: Students should have taken, at a minimum, Visual Computing. Higher level courses are recommended, such as Introduction to Computer Graphics, 3D Vision, Computer Vision.

> Interfocus Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-0006-00L</td>
<td>Algorithms Lab</td>
<td>W</td>
<td>8</td>
<td>4P+3A</td>
<td>A. Steger</td>
</tr>
</tbody>
</table>
Abstract Students learn how to solve algorithmic problems given by a textual description (understanding problem setting, finding appropriate modeling, choosing suitable algorithms, and implementing them). Knowledge of basic algorithms and data structures is assumed; more advanced material and usage of standard libraries for combinatorial algorithms are introduced in tutorials.

Objective The objective of this course is to learn how to solve algorithmic problems given by a textual description. This includes appropriate problem modeling, choice of suitable (combinatorial) algorithms, and implementing them using C/C++, STL, CGAL, and BGL.


263-0009-00L Information Security Lab W 8 credits 2V+1U+3P+1A S. Shinde, D. Basin, S. Capkun, K. Paterson

Abstract This InterFocus Course will provide a broad, hands-on introduction to Information Security, introducing adversarial thinking and security by design as key approaches to building secure systems.

Objective This course will introduce key concepts from Information Security, both from attack and defence perspectives. Students will gain an appreciation of the complexity and challenge of building secure systems.

Content The course is organised in three-week segments. In each segment, a new concept from Information Security will be introduced. The overall scope will be broad, including cryptography, protocol design, system security, and privacy.

Lecture notes Will be made available during the semester.

Literature Paul C. van Oorschot, Computer Security and the Internet: Tools and Jewels.
Dan Boneh and Victor Shoup, A Graduate Course in Applied Cryptography.

Prerequisites / notice Ideally, students will have taken the D-INFK Bachelors course “Information Security” or an equivalent course at Bachelors level.

Competencies

<table>
<thead>
<tr>
<th>Competency Area</th>
<th>Competency Type</th>
<th>Assessed/Fostered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
</tr>
</tbody>
</table>

Free Electives Students can individually chose from the entire Master course offerings in the area of Computer Science (or a closely related field), from ETH Zurich, EPF Lausanne, the University of Zurich and - but only with the consent of the Director of Studies - from all other Swiss universities.

Course Catalogue of ETH Zurich

Science in Perspective

See Science in Perspective: Language Courses ETH/UZH
See Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-INFK

Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>260-0700-00L</td>
<td>Internship</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>external organisers</td>
</tr>
</tbody>
</table>

Abstract An internship provides opportunities to gain experience in an industrial environment and it creates a network of contacts.

Objective see above

Master’s Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
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<tr>
<td>260-0800-00L</td>
<td>Master’s Thesis</td>
<td>O</td>
<td>30</td>
<td>64D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Abstract Only students who fulfill the following criteria are allowed to begin with their master thesis:
a. successful completion of the bachelor programme;
b. fulfilling of any additional requirements necessary to gain admission to the master programme.

Objective The Master's thesis concludes the study program and demonstrates the students' ability to use the knowledge and skills acquired during Master's studies to solve a complex cyber security problem.

Cyber Security Master - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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Key for Hours

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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

Key for ECTS

<table>
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<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Special students and auditors need special permission from the lecturers.</td>
</tr>
</tbody>
</table>
Nonparametric tests, randomization tests, jackknife and bootstrap, as well as asymptotic properties of estimators.

This course focusses on nonparametric estimation of probability densities and regression functions. These recent methods allow modelling without restrictive assumptions such as 'linear function'. These smoothing methods require a weight function and a smoothing parameter. Focus is on one dimension, higher dimensions and samples of curves are treated briefly. Exercises at the computer.


Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

For classical parametric models there exist optimal statistical estimators and test statistics whose distributions can often be determined exactly. The methods covered in this course allow for finding statistical procedures for more general models and to derive exact or approximate distributions of complicated estimators and test statistics.

This course is part of the programme for the certificate and diploma in Advanced Studies in Applied Statistics. It is given every second year in the winter semester break.

In the workshop each participant gives a short talk about a recent statistical problem encountered in their daily work.

Presentation of a statistical problem, getting to know different applications of statistical methodology.

Nonparametric tests, randomization tests, jackknife and bootstrap, as well as asymptotic properties of estimators.

Nonparametric tests, randomization tests, jackknife and bootstrap, as well as asymptotic properties of estimators.

Understanding of the choice of weight function and of the smoothing parameter, also done automatically.

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In the workshop each participant gives a short talk about a recent statistical problem encountered in their daily work.

Practical application on data sets at the computer.


Practical application on data sets at the computer.

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In the workshop each participant gives a short talk about a recent statistical problem encountered in their daily work.

Presentation of a statistical problem, getting to know different applications of statistical methodology.
We will learn how to describe business/scientific problems as probabilistic models, apply Bayes rules to draw inference from data, and use assessed generation and structure of repeated measures. Planning and realization of corresponding studies. Within- and between-subjects factors.

This course introduces probabilistic deep learning (DL). DL is used for data with complex features like images. We treat DL as probabilistic assessed.

Participants will gain the ability of recognizing repeated measures and to analyze them adequately. They will know how to deal with pseudoreplicates. Generation and structure of repeated measures. Planning and realization of corresponding studies. Within- and between-subjects factors. Common covariance structures. Statistical analyses: graphical methods, summary statistics approach, univariate and multivariate ANOVA, linear mixed effects models.

You will get practical experiences in setting up probabilistic DL models, learn how to tune them, and learn how to control the training procedure. You will learn to model different outcome distributions such as Gaussians, Poissonians, or Multinomial for the task at hand. You will learn about different neural network architectures (e.g. fully connected and convolutional neural networks) and how to choose the appropriate NN architecture for your task at hand.

You will learn to model different outcome distributions such as Gaussians, Poissonians, or Multinomial for the task at hand.

You will learn how to describe business/scientific problems as probabilistic models, apply Bayes rules to draw inference from data, and use the probabilistic programming language STAN to obtain samples from posterior distributions. There will be examples of applications from various fields: insurance, meteorology, marketing, etc.

"Bayes Rules! An Introduction to Applied Bayesian Modeling", Alicia A. Johnson, Miles Q. Ott, Mine Dogucu - CRC Press 2022

- introductory statistics
- applied regression
- R

- R
Competencies

### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

### Method-specific Competencies
- Analytical Competencies: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed

### Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

### Personal Competencies
- Negotiation: fostered
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### Method-specific Competencies
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

### Personal Competencies
- Negotiation: fostered
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### Competencies

<table>
<thead>
<tr>
<th>Competency</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject-specific Competencies</td>
<td></td>
<td>Concepts and Theories: assessed</td>
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<td></td>
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<td>Techniques and Technologies: assessed</td>
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<td>Method-specific Competencies</td>
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<td>Analytical Competencies: fostered</td>
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<td>Media and Digital Technologies: fostered</td>
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<td>Problem-solving: assessed</td>
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<td>Personal Competencies</td>
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<td>Creative Thinking: fostered</td>
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<td>Decision-making: assessed</td>
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<td>Media and Digital Technologies: fostered</td>
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<td>Problem-solving: assessed</td>
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<td>Self-presentation and Social Influence: fostered</td>
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<td>Sensitivity to Diversity: fostered</td>
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<tr>
<td></td>
<td></td>
<td>Self-direction and Self-management: fostered</td>
</tr>
</tbody>
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**447-6191-00L Statistical Analysis of Financial Data**

Special Students "University of Zurich (UZH)" in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to registrar@ethz.ch. The Registrar's Office will then register you for the course.

**Abstract**

**Objective**
Getting to know the typical properties of financial data and appropriate statistical models, incl. the corresponding functions in R.

---

**447-6255-00L Analysis of High-Dimensional Data**

Special Students "University of Zurich (UZH)" in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to registrar@ethz.ch. The Registrar's Office will then register you for the course.

**Abstract**
Block course on analysis of high-dimensional data with a focus on prediction and feature assessment.

**Objective**
The goal of this course is to gain a good understanding of the concepts discussed during the lecture and to apply the new methods on real data examples using the software "R". The topics covered in the lecture are:

1. **Part 1: Linear regression in the high-dimensional context; Overfitting, prediction and the bias-variance tradeoff; Model selection; Ridge and Lasso regularization**
2. **Part 2: Logistic regression and regularization; Classification based on decision trees, Random Forest and AdaBoost; Multiple testing; P-value adjustment and variance shrinkage**

**Content**
Course on Analysis of High-Dimensional Data with focus on Prediction and Feature Assessment.

1. **Part 1: Linear regression in the high-dimensional context; Overfitting, prediction and the bias-variance tradeoff; Model selection; Ridge and Lasso regularization**
2. **Part 2: Logistic regression and regularization; Classification based on decision trees, Random Forest and AdaBoost; Multiple testing; P-value adjustment and variance shrinkage**

**Lecture notes**
The block course is based on lecture notes (https://bookdown.org/staedler_n/highdimstats/).

**Literature**

**Prerequisites / notice**
The exercises are done exclusively with the (free, open source) software "R" (http://www.r-project.org). A final exam will also happen at the computers, using R (and your brains!).

---

**447-6233-00L Spatial Statistics**

Special Students "University of Zurich (UZH)" in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to registrar@ethz.ch. The Registrar's Office will then register you for the course.

**Abstract**

**Objective**

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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 629 of 2653
Abstract
In many research fields, spatially referenced data are collected. When analysing such data the focus is either on exploring their structure (dependence on explanatory variables, autocorrelation) and/or on spatial prediction. The course provides an introduction to geostatistical methods that are useful for such purposes.

Objective
The course will provide an overview of the basic concepts and stochastic models that are commonly used to model geostatistical data sets. In addition, the participants will learn a number of geostatistical techniques and acquire some familiarity with software that is useful for analysing spatial data.

Content
After an introductory discussion of the types of problems and the kind of data that arise in environmental research, an introduction into linear geostatistics (models: stationary random processes, modelling large-scale spatial patterns by regression, modelling autocorrelation by variogram; kriging: mean-square prediction of spatial data) will be taught. The lectures will be complemented by data analyses that the participants have to do themselves.

Lecture notes
Slides, descriptions of the problems for the data analyses and worked-out solutions to them will be provided.

Literature

Competencies
<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
<td></td>
</tr>
<tr>
<td>Analytical Competencies</td>
<td></td>
</tr>
<tr>
<td>Decision-making</td>
<td></td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
<td></td>
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<tr>
<td>Project Management</td>
<td></td>
</tr>
</tbody>
</table>

Social Competencies
| Communication                  | fostered |
| Cooperation and Teamwork      | fostered |
| Customer Orientation          | fostered |
| Leadership and Responsibility | fostered |
| Self-presentation and Social Influence | fostered |
| Sensitivity to Diversity      | fostered |
| Negotiation                   | fostered |

Personal Competencies
| Adaptability and Flexibility  | fostered |
| Creative Thinking             | fostered |
| Critical Thinking             | fostered |
| Integrity and Work Ethics     | fostered |
| Self-awareness and Self-reflection | fostered |
| Self-direction and Self-management | fostered |

Diploma Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>447-1990-00L</td>
<td>Diploma Thesis</td>
<td>O</td>
<td>2</td>
<td>4D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Abstract
The diploma thesis typically consists of a data analysis of data from a participant's own field of work. The thesis requires a time expenditure of about one or two weeks. Thesis work should prove the participants' capability to apply useful and modern statistical methods to address appropriate questions properly and effectively.

Objective
Thesis work should prove the participants' capability to apply useful and modern statistical methods to address appropriate questions properly and effectively.

DAS in Applied Statistics - Key for Type

<table>
<thead>
<tr>
<th>W</th>
<th>Eligible for credits</th>
<th>Dr</th>
<th>Suitable for doctorate</th>
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<tbody>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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</table>

Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
DAS in Cyber Security

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-1414-00L</td>
<td>System Security</td>
<td>O</td>
<td>7</td>
<td>2V+2U+2A</td>
<td>S. Capkun, S. Shinde</td>
</tr>
<tr>
<td>Abstract</td>
<td>The first part of the course covers general security concepts and hardware-based support for security. In the second part, the focus is on system design and methodologies for building secure systems.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>The first part of the lecture covers hardware-based security concepts. Topics include the concept of physical and software-based side channel attacks on hardware resources, architectural support for security (e.g., memory management and permissions, disk encryption), and trusted execution environments (Intel SGX, ARM TrustZone, AMD SEV, and RISC-V Keystone).</td>
<td></td>
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</tbody>
</table>

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: common software faults (e.g., buffer overflows, etc.), bug detection, writing secure software (design, architecture, QA, testing), compiler-supported security (e.g., control-flow integrity), and language-supported security (e.g., memory safety).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

| Competencies                      | 
|----------------------------------|-----------------------------------|
| Subject-specific Competencies    | Concepts and Theories assessed |
|                                  | Techniques and Technologies assessed |
| Method-specific Competencies     | Analytical Competencies fostered |
|                                  | Decision-making fostered         |
|                                  | Problem-solving fostered         |
| Social Competencies              | Communication fostered           |
| Personal Competencies            | Adaptability and Flexibility fostered |
|                                  | Creative Thinking fostered        |
|                                  | Critical Thinking fostered        |

263-4640-00L Network Security O 8 credits 2V+2U+3A P. De Vaere, S. Frei, K. Paterson, A. Perrig

Abstract Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems. This course provides an in-depth study of network attack techniques and methods to defend against them.

Objective Students are familiar with fundamental network-security concepts.

- Students can implement network-security protocols based on cryptographic libraries.

Content The course will cover topics spanning four broad themes with a focus on the first two themes:

1. network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. analysis and inference topics such as traffic monitoring and network forensics; and
4. new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

Prerequisites / notice This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

Competencies

| Competencies                      | 
|----------------------------------|-----------------------------------|
| Subject-specific Competencies    | Concepts and Theories assessed |
|                                  | Techniques and Technologies assessed |
| Method-specific Competencies     | Analytical Competencies fostered |
|                                  | Decision-making fostered         |
|                                  | Media and Digital Technologies assessed |
|                                  | Problem-solving assessed         |
|                                  | Project Management assessed      |
| Social Competencies              | Communication fostered           |
|                                  | Cooperation and Teamwork fostered |
|                                  | Customer Orientation fostered     |
|                                  | Leadership and Responsibility fostered |
|                                  | Self-presentation and Social Influence fostered |
|                                  | Sensitivity to Diversity fostered |
|                                  | Negotiation fostered             |
| Personal Competencies            | Adaptability and Flexibility fostered |
|                                  | Creative Thinking assessed        |
|                                  | Critical Thinking assessed        |
|                                  | Integrity and Work Ethics fostered |
|                                  | Self-awareness and Self-reflection fostered |
|                                  | Self-direction and Self-management assessed |

268-0101-00L Introduction to Information Security O 5 credits 4G P. Schaller, S. Matetic

Abstract In this course, the goal is to introduce the fundamentals of information/cyber security from a technical point of view. Along with theory, hands-on experiments are an important building block of the course and help to deepen the students' understanding of the theory parts.

Objective Graduates of the course know the technical foundations of information security and understand the difficulty and complexity involved when trying to build secure systems.
In this new course, the goal is to introduce the fundamentals of information/cyber security from a technical point of view. Along with theory, hands-on experiments are an important building block of the course and help to deepen the students' understanding of the theory parts.

### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: fostered
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: fostered

#### Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0463-00L</td>
<td>Security Engineering</td>
<td>W</td>
<td>7 credits</td>
<td>2V+2U+2A</td>
<td>D. Basin, S. Krstic</td>
</tr>
</tbody>
</table>

**Abstract**
Subject of the class are engineering techniques for developing secure systems. We examine concepts, methods and tools, applied within the different activities of the SW development process to improve security of the system. Topics: security requirements & risk analysis, system modeling & model-based development methods, implementation-level security, and evaluation criteria for secure systems.

**Objective**
Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software.

Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include:
- security requirements & risk analysis,
- system modeling and model-based development methods,
- implementation-level security, and
- evaluation criteria for the development of secure systems.
Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software. Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems

Modules taught:

1. Introduction
   - Introduction of Infsec group and speakers
   - Security meets SW engineering: an introduction
   - The activities of SW engineering, and where security fits in
   - Overview of this class
2. Requirements Engineering: Security Requirements and some Analysis
   - Overview: functional and non-functional requirements
   - Use cases, misuse cases, sequence diagrams
   - Safety and security
3. Modeling in the design activities
   - Structure, behavior, and data flow
   - Class diagrams, statecharts
4. Model-driven security for access control (Part I)
   - SecureUML as a language for access control
   - Combining Design Modeling Languages with SecureUML
   - Semantics, i.e., what does it all mean,
   - Generation
   - Examples and experience
5. Model-driven security (Part II)
   - Continuation of above topics
6. Security patterns (design and implementation)
7. Implementation-level security
   - Buffer overflows
   - Input checking
   - Injection attacks
8. Code scanning
   - Static code analysis basics
   - Theoretical and practical challenges
   - Analysis algorithms
   - Common bug pattern search and specification
   - Dataflow analysis
9. Testing
   - Overview and basics
   - Model-based testing
   - Testing security properties
10. Risk analysis and management
    - "Risk": assets, threats, vulnerabilities, risk
    - Risk assessment: quantitative and qualitative
    - Safeguards
    - Generic risk analysis procedure
    - The OCTAVE approach
    - Example of qualitative risk assessment
11. Threat modeling
    - Overview
    - Safety engineering basics: FMEA and FTA
    - Security impact analysis in the design phase
    - Modeling security threats: attack trees
    - Examples and experience
12. Evaluation criteria
    - NIST special papers
    - ISO/IEC 27000
    - Common criteria
    - BSI baseline protection
13. Guest lecture
    - TBA

Literature
- Further relevant books and journal/conference articles will be announced in the lecture.

Prerequisites / notice
Prerequisite: Class on Information Security

252-1411-00L Security of Wireless Networks

W 6 credits 2V+1U+2A S. Capkun, K. Kostiainen

Abstract
This course discusses physical layer aspects of wireless communication and a wide range of security-related topics in the domain of wireless technologies. It mainly targets computer science students. Though useful, a background in signal processing or physical layer concepts is not required. A basic understanding of security (e.g. as taught in 252-0211.00L Information Security) is recommended.

Objective
After this course, students should be able to describe and classify security goals of and attacks on various wireless networks and technologies, with an emphasis on physical layer aspects.
<table>
<thead>
<tr>
<th>Content</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Introduction to wireless communication</td>
<td>- Physical layer security schemes</td>
</tr>
<tr>
<td>- Spreading techniques and their application in jamming-resilient</td>
<td>- Secure ranging with Ultra-Wide Band (UWB)</td>
</tr>
<tr>
<td>communication and Global Navigation Satellite Systems (GNSSs)</td>
<td>- Security aspects of cellular networks, WiFi, and Bluetooth</td>
</tr>
<tr>
<td>- Secure ranging with Ultra-Wide Band (UWB)</td>
<td>Low Energy (BLE)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Competencies</th>
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<tbody>
<tr>
<td>Subject-specific Competencies</td>
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<tr>
<td>Techniques and Technologies assessed</td>
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<tr>
<td>Method-specific Competencies</td>
</tr>
<tr>
<td>Analytical Competencies assessed</td>
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<tr>
<td>Problem-solving assessed</td>
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<tr>
<td>Social Competencies</td>
</tr>
<tr>
<td>Cooperation and Teamwork fostered</td>
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<tr>
<td>Personal Competencies</td>
</tr>
<tr>
<td>Critical Thinking fostered</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>268-0201-00L Information Security Seminar and Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
</tr>
<tr>
<td>Participants of the seminar are assigned a recent topic in cyber security.</td>
</tr>
<tr>
<td>They are expected to become acquainted with the assigned issue and to</td>
</tr>
<tr>
<td>prepare a corresponding presentation in the context of the seminar.</td>
</tr>
<tr>
<td>Objective</td>
</tr>
<tr>
<td>Participants have understood and presented a publication or report on a</td>
</tr>
<tr>
<td>present topic in information security. By attending other</td>
</tr>
<tr>
<td>participants presentations students get further introduced to additional</td>
</tr>
<tr>
<td>current information security related topics/incidents.</td>
</tr>
<tr>
<td>Content</td>
</tr>
<tr>
<td>Participants of the seminar are assigned a recent topic in cyber security.</td>
</tr>
<tr>
<td>They are expected to become acquainted with the assigned issue and to</td>
</tr>
<tr>
<td>prepare a corresponding presentation in the context of the seminar.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>268-0202-00L Contemporary Topics in Cyber Security</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
</tr>
<tr>
<td>This course is composed of various sub-modules related to Cyber Security</td>
</tr>
<tr>
<td>taught by experts on the relevant fields.</td>
</tr>
<tr>
<td>Objective</td>
</tr>
<tr>
<td>Students are expected to see behind the curtain of current research and</td>
</tr>
<tr>
<td>engineering activities related to Cyber Security. At the same time students</td>
</tr>
<tr>
<td>are introduced to contemporary challenges in cyber security by renowned</td>
</tr>
<tr>
<td>experts.</td>
</tr>
<tr>
<td>Content</td>
</tr>
<tr>
<td>The lectures cover contemporary aspects and challenges in Cyber Security.</td>
</tr>
<tr>
<td>The goal is to present current fields of research/engineering and the</td>
</tr>
<tr>
<td>latest results. By way of example, Cyber Security Policy is one of sub-</td>
</tr>
<tr>
<td>modules presented by researchers of the Center for Security Studies at ETH.</td>
</tr>
<tr>
<td>Besides faculty members of the computer science department, there will be</td>
</tr>
<tr>
<td>guest lecturers from industry presenting Cyber Security related challenges</td>
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<tr>
<td>in their field of activity.</td>
</tr>
<tr>
<td>Literature</td>
</tr>
<tr>
<td>Will be announced during the course.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DAS in Cyber Security - Key for Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
</tr>
<tr>
<td>Eligible for credits</td>
</tr>
<tr>
<td>Dr</td>
</tr>
<tr>
<td>Suitable for doctorate</td>
</tr>
<tr>
<td>E-</td>
</tr>
<tr>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>O</td>
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<tr>
<td>Compulsory</td>
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<tr>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W+</td>
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<tr>
<td>Eligible for credits and recommended</td>
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</table>

<table>
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<tr>
<th>Key for Hours</th>
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<tbody>
<tr>
<td>V</td>
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<tr>
<td>lecture</td>
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<td>P</td>
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<tr>
<td>practical/laboratory course</td>
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<td>A</td>
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<td>exercise</td>
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<td>diploma thesis</td>
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<td>seminar</td>
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<td>revision course / private study</td>
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<td>K</td>
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<tr>
<td>colloquium</td>
</tr>
</tbody>
</table>

| ECTS                                                                       |
| European Credit Transfer and Accumulation System                           |
| Special students and auditors need special permission from the lecturers.  |
**DAS in Data Science**

**Core Courses**

**Foundations Courses**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0105-00L</td>
<td>Introduction to Estimation and Machine Learning</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
</tbody>
</table>

**Abstract**
Mathematical basics of estimation and machine learning, with a view towards applications in signal processing.

**Objective**
Students master the basic mathematical concepts and algorithms of estimation and machine learning.

**Content**
Review of probability theory; basics of statistical estimation; least squares and linear learning; Hilbert spaces; singular-value decomposition; kernel methods, neural networks, and more

**Lecture notes**
Lecture notes will be handed out as the course progresses.

**Prerequisites / notice**
solid basics in linear algebra and probability theory

**Capstone Project**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>266-0100-00L</td>
<td>Capstone Project</td>
<td>O</td>
<td>8</td>
<td>17A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

**Abstract**
The capstone project is part of the DAS in Data Science and is an opportunity to apply the knowledge acquired in the program in an independent, real-world project.

**Objective**
To apply the knowledge acquired in the program in an independent, real-world project.

**Content**
The capstone project can be done under the supervision of the Swiss Data Science Center, or of any core or adjunct faculty of Data Science. The project has to be finished within 6 months. Deadline for a project the following semester conducted at the SDSC is mid June/mid December.

**Specialisation Track**

**Hardware for Machine Learning**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0155-00L</td>
<td>Machine Learning on Microcontrollers</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>M. Magno</td>
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</tbody>
</table>

**Abstract**
Registration in this class requires the permission of the instructors. Preference is given to students in the MSc EEIT.

Machine Learning (ML) and artificial intelligence are pervading the digital society. Today, even low power embedded systems are incorporating ML, becoming increasingly "smart". This lecture gives an overview of ML methods and algorithms to process and extract useful near-sensor information in end-nodes of the "internet-of-things", using low-power microcontrollers/processors (ARM-Cortex-M; RISC-V).

**Objective**
Learn how to Process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ExG bio-signals, cameras…). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers.

**Content**
The final goal of the course is a deep understanding of machine learning and its practical implementation on single- and multi-core microcontrollers, coupled with performance and energy efficiency analysis and optimization. The main topics of the course include:

- Sensors and sensor data acquisition with low power embedded systems
- Machine Learning: Overview of supervised and unsupervised learning and in particular supervised learning (Bayes Decision Theory, Decision Trees, Random Forests, kNN-Methods, Support Vector Machines, Convolutional Networks and Deep Learning)
- Low-power embedded systems and their architecture. Low Power microcontrollers (ARM-Cortex M) and RISC-V-based Parallel Ultra Low Power (PULP) systems-on-chip.
- Low power smart sensor system design: hardware-software tradeoffs, analysis, and optimization. Implementation and performance evaluation of ML in battery-operated embedded systems.

The laboratory exercised will show how to address concrete design problems, like motion, gesture recognition, emotion detection, image and sound classification, using real sensors data and real MCU boards.

**Lecture notes**
Script and exercise sheets. Books will be suggested during the course.

**Prerequisites / notice**
Prerequisites: C language programming. Basics of Digital Signal Processing. Basics of processor and computer architecture. Some exposure to machine learning concepts is also desirable

**Image Analysis & Computer Vision**

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>263-5902-00L</td>
<td>Computer Vision</td>
<td>W</td>
<td>8</td>
<td>3V+1U+3A</td>
<td>M. Pollefeys, S. Tang, F. Yu</td>
</tr>
</tbody>
</table>

**Abstract**
The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

**Objective**
The objectives of this course are:

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.
Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al., 2015, Silver et al., 2018), ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalized problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g., recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today's neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to 'error backpropagation' in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

The participation in the course is subject to the following conditions:
1) The number of participants is limited to 120 students (MSc and PhDs).
2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

Neural Information Processing

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>227-0421-00L</td>
<td>Learning in Deep Artificial and Biological Neuronal Networks</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>B. Grewe</td>
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</table>

Neuromorphic Engineering I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-1033-00L</td>
<td>Neuromorphic Engineering I</td>
<td>W</td>
<td>6</td>
<td>2+3U</td>
<td>T. Delbrück, G. Indiveri, S.-C. Liu, M. Payvand</td>
</tr>
</tbody>
</table>

Neuromorphic Engineering I

Registration in this class requires the permission of the instructors. Class size will be limited to available lab spots. Preference is given to students that require this class as part of their major.

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module IN1404 at UZH. Please mind the ETH enrolment deadlines for UZH students: https://ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

The course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Understanding of the characteristics of neuromorphic circuit elements.

Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audio, and real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS TRANSISTOR, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Particular: The course is highly recommended for those who intend to take the spring semester course 'Neuromorphic Engineering II', that teaches the conception, simulation, and physical layout of such circuits with chip design tools.

Statistics

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Prerequisites / notice
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

Statistics

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<th>Lecturers</th>
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</table>

Prerequisites: Background in basics of semiconductor physics helpful, but not required.
401-0625-01L Applied Analysis of Variance and Experimental Design

Abstract Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial designs and fractional designs, power.

Objective Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Content Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial designs and fractional designs, power.

Prerequisites / notice The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Competencies

<table>
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<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td></td>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Critical Thinking</td>
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<td></td>
<td>assessed</td>
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Lecture notes A script will be available.


401-0649-00L Applied Statistical Regression

Abstract This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

Objective The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

Content The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

Prerequisites / notice The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

Competencies

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<tbody>
<tr>
<td></td>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Adaptable and Flexibility</td>
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</table>

Lecture notes A script will be available.

Literature

- Fox (2008): Applied Regression Analysis and GLMs
- Faraway (2005): Linear Models with R
- Faraway (2006): Extending the Linear Model with R
- Draper & Smith (1998): Applied Regression Analysis
- Montgomery et al. (2006): Introduction to Linear Regression Analysis
- Montgomery et al. (2006): Introduction to Linear Regression Analysis
- Montgomery et al. (2006): Introduction to Linear Regression Analysis

401-3612-00L Stochastic Simulation

Abstract This course provides an introduction to statistical Monte Carlo methods. This includes applications of simulations in various fields (Bayesian statistics, statistical mechanics, operations research, financial mathematics), algorithms for the generation of random variables (accept-reject, importance sampling), estimating the precision, variance reduction, introduction to Markov chain Monte Carlo.

Objective Stochastic simulation (also called Monte Carlo method) is the experimental analysis of a stochastic model by implementing it on a computer. Probabilities and expected values can be approximated by averaging simulated values, and the central limit theorem gives an estimate of the error of this approximation. The course shows examples of the many applications of stochastic simulation and explains different algorithms used for simulation. These algorithms are illustrated with the statistical software R.


Lecture notes A script will be available in English.
The aim of this course is to gain insight into the main statistical ideas and concepts. The course considers classical low-dimensional models, with pointers towards today’s highly complex models.

Competencies

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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Creative Thinking</td>
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**401-3620-00L Statistical Modelling**

The course offers an introduction into analyzing time series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

Objective

The goal of the course is to gain insight into the main statistical ideas and concepts. The course considers classical low-dimensional models, with pointers towards today’s highly complex models.

Competencies

<table>
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<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Creative Thinking</td>
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**401-4632-10L Causality**

In statistics, we are used to search for the best predictors of some random variable. In many situations, however, we are interested in predicting a system’s behavior under manipulations. For such an analysis, we require knowledge about the underlying causal structure of the system. In this course, we study concepts and theory behind causal inference.
Objective

After this course, you should be able to
- understand the language and concepts of causal inference
- know the assumptions under which one can infer causal relations from observational and/or interventional data
- describe and apply different methods for causal structure learning
- given data and a causal structure, derive causal effects and predictions of interventional experiments

Content

The material covered in this course has a significant overlap with the material that has been covered in 401-3620-22L Student Seminar in Statistics: Causality FS2023.

Literature

Parts of this course will be based on the book “Elements of Causal Inference” (MIT Press, open access). More details will follow.

Prerequisites / notice

Prerequisites: basic knowledge of probability theory and regression

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

➡️ Machine Learning and Artificial Intelligence

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0689-00L</td>
<td>System Identification</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>R. Smith</td>
</tr>
<tr>
<td>Abstract</td>
<td>Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.</td>
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<tr>
<td>Objective</td>
<td>To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.</td>
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<tr>
<td>Literature</td>
<td>“System Identification; Theory for the User” Lennart Ljung, Prentice Hall (2nd Ed), 1999. Additional papers will be available via the course Moodle.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Control systems (227-0216-00L) or equivalent.</td>
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| 252-0535-00L | Advanced Machine Learning | W    | 10 credits | 3V+2U+4A | C. Cotrini Jimenez |
| Abstract     | Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects. |
| Objective    | Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data. |
| Content      | The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data. Topics covered in the lecture include: Fundamentals: What is data? Bayesian Learning Computational learning theory Supervised learning: Ensembles: Bagging and Boosting Max Margin methods Neural networks Unsupervised learning: Dimensionality reduction techniques Clustering Mixture Models Non-parametric density estimation Learning Dynamical Systems |
| Literature   | No lecture notes, but slides will be made available on the course webpage. |
| Prerequisites / notice | The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least “Introduction to Machine Learning” or an equivalent course offered by another institution. |
|             | PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points. |

| 252-3005-00L | Natural Language Processing | W    | 7 credits | 3V+3U+1A | R. Cotterell |
|             | The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least “Introduction to Machine Learning” or an equivalent course offered by another institution. |
|             | PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points. |
Abstract
This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Objective
The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

Content
This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Literature
Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

263-2400-00L Reliable and Trustworthy Artificial Intelligence W 6 credits 2V+2U+1A M. Vechev
Abstract
Creating reliable, secure, robust, and fair machine learning models is a core challenge in artificial intelligence and one of fundamental importance. The goal of the course is to teach both the mathematical foundations of this new and emerging area as well as to introduce students to the latest and most exciting research in the space.

Objective
Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of engineering and research problems. To facilitate deeper understanding, the course includes a group coding project where students will build a system based on the learned material.

Content
The course is split into 4 parts:
Robustness of Machine Learning
- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

Privacy of Machine Learning
- Threat models (e.g., stealing data, poisoning, membership inference, etc.).
- Attacking federated machine learning (across vision, natural language and tabular data).
- Differential privacy for defending machine learning.
- AI Regulations and checking model compliance.

Fairness of Machine Learning
- Introduction to fairness (motivation, definitions).
- Enforcing individual fairness (for both vision and tabular data).
- Enforcing group fairness (e.g., demographic parity, equalized odds).

Robustness, Privacy and Fairness of Foundation Models
- We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).

Prerequisites / notice
While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in “Intro to ML” classes at most institutions (e.g., “Introduction to Machine Learning” at ETH).

The coding project will utilize Python and PyTorch. Thus some programming experience in Python is expected. Students without prior knowledge of PyTorch are expected to acquire it early in the course by solving exercise sheets.

Competencies
Subject-specific Competencies
Concepts and Theories assessed

Method-specific Competencies
Techniques and Technologies assessed
Analytical Competencies assessed
Problem-solving assessed

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

263-3240-00L Deep Learning W 8 credits 3V+2U+2A T. Hofmann
Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is to provide an understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.
Prerequisites / notice

This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

  Advanced Machine Learning
  https://ml2.inf.ethz.ch/courses/aml/

  Computational Intelligence Lab
  http://da.inf.ethz.ch/teaching/2019/CIL/

  Introduction to Machine Learning
  https://ias.inf.ethz.ch/teaching/introml-S19

  Statistical Learning Theory
  http://ml2.inf.ethz.ch/courses/slt/

  Computational Statistics
  https://stat.ethz.ch/lectures/ss19/comp-stats.php

  Probabilistic Artificial Intelligence
  https://las.inf.ethz.ch/teaching/pai-f18

263-5210-00L Probabilistic Artificial Intelligence W 8 credits 3V+2U+2A A. Krause

Abstract
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit “intelligent” behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice
Solid basic knowledge in statistics, algorithms and programming.
The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed
Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management assessed
Social Competencies
- Communication fostered
Personal Competencies
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics fostered

263-5300-00L Guarantees for Machine Learning W 7 credits 3V+1U+2A F. Yang

Does not take place this semester.

Abstract
This course is aimed at advanced master and doctorate students who want to conduct independent research on theory for modern machine learning (ML). It teaches standard methods in statistical learning theory commonly used to prove theoretical guarantees for ML algorithms. The knowledge is then applied in independent project work to understand and follow-up on recent theoretical ML results.

Objective
By the end of the semester students should be able to
- understand a good fraction of theory papers published in the typical ML venues. For this purpose, students will learn common mathematical techniques from statistical learning in the first part of the course and apply this knowledge in the project work
- critically examine recently published work in terms of relevance and find impactful (novel) research problems. This will be an integral part of the project work and involves experimental as well as theoretical questions
- outline a possible approach to prove a conjectured theorem by e.g. reducing to more solvable subproblems. This will be practiced in in-person exercises, homeworks and potentially in the final project
- effectively communicate and present the problem motivation, new insights and results to a technical audience. This will be primarily learned via the final presentation and report as well as during peer-grading of peer talks.
This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning algorithms. It touches on the following topics:
- concentration bounds
- uniform convergence and empirical process theory
- regularization for non-parametric statistics (e.g. in RKHS, neural networks)
- high-dimensional learning
- computational and statistical learnability (information-theoretic, PAC, SQ)
- overparameterized models, implicit bias and regularization

The project work focuses on current theoretical ML research that aims to understand modern phenomena in machine learning, including but not limited to:
- how overparameterized models generalize (statistically) and converge (computationally)
- complexity measures and approximation theoretic properties of randomized initialized and trained neural networks
- generalization of robust learning (adversarial or distribution-shift robustness)
- private and fair learning

Students should have a very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as “Introduction to Machine Learning”, “Regression”/“Statistical Modelling”. In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

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<th>Competencies</th>
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<th>Personal Competencies</th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Problem-solving</td>
<td>Communication</td>
<td>Creative Thinking</td>
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</table>

Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

Big Data Systems

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10 credits</td>
<td>3V+2U+4A</td>
<td>C. Cotrini Jimenez</td>
</tr>
</tbody>
</table>

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:
- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory
- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
- Neural networks
- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature

Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.
Students should have followed at least “Introduction to Machine Learning” or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

252-0834-00L Information Systems for Engineers W 4 credits 2V+1U G. Fourny

Abstract
This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).
Objective

Do you want to be able to query your own data productively and efficiently in your future semester projects, bachelor’s thesis, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This courses teaches you how to do so as well as the dos and don'ts.

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook

Literature

- Lecture material (slides).
- Book: "Database Systems: The Complete Book", H. Garcia-Molina, J.D. Ullman, J. Widom (It is not required to buy the book, as the library has it)

Prerequisites / notice

For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logic
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python
### Course Information

<table>
<thead>
<tr>
<th>263-2800-00L</th>
<th>Design of Parallel and High-Performance Computing</th>
<th>W</th>
<th>9 credits</th>
<th>2V+2U+4A</th>
<th>T. Hoefler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Advanced topics in parallel and high-performance computing.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become familiar with important technical concepts and with concurrency folklore.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses &quot;Parallele Programmierung (parallel programming)&quot; and &quot;Algorithmen und Datenstrukturen (algorithm and data structures)&quot; or equivalent courses.</td>
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</table>

<table>
<thead>
<tr>
<th>263-3010-00L</th>
<th>Big Data</th>
<th>W</th>
<th>10 credits</th>
<th>3V+2U+4A</th>
<th>G. Fourny</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The key challenge of the information society is to turn data into information, knowledge into knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations.</td>
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<tr>
<td>Objective</td>
<td>Do you want to be able to query your own data productively and efficiently in your future semester projects, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This courses teaches you how to do so as well as the dos and don'ts.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>&quot;Big Data&quot; refers to the case when the amount of data is very large (100 GB and more), or when the data is not completely structured (or messy). The Big Data revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the &quot;fourth paradigm&quot;.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Literature</td>
<td>Large scale analytics and machine learning are outside of the scope of this course.</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Papers from scientific conferences and journals. References will be given as part of the course material during the semester.</td>
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</tbody>
</table>
The course will cover the implementation aspects of data management systems using relational database engines as a starting point to foster the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.

**Prerequisites / notice**
The lecture is hybrid, meaning you can attend with us in the lecture hall, or on Zoom, or watch the recordings on YouTube later. Exercise sessions are in presence.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departaments interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2023

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

### Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-3210-00L</td>
<td>Deep Learning</td>
<td>W 8 credits 3V+2U+2A</td>
<td>T. Hofmann</td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://mi2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/ss19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/mai-f18

263-3845-00L Data Management Systems W 8 credits 3V+1U+3A G. Alonso

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<th>Abstract</th>
<th>The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.</th>
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<tr>
<td>Objective</td>
<td>The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.</td>
</tr>
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<td>Content</td>
<td>The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understating these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.</td>
</tr>
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<td>Literature</td>
<td>The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.</td>
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<td>Prerequisites / notice</td>
<td>The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.</td>
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https://las.inf.ethz.ch/teaching/mai-f18
**Key for Type**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

**Key for Hours**

- **V**: lecture
- **G**: lecture with exercise
- **U**: exercise
- **S**: seminar
- **K**: colloquium
- **P**: practical/laboratory course
- **A**: independent project
- **D**: diploma thesis
- **R**: revision course / private study

**ECTS**

- European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
DAS in Information Technology and Electrical Engineering

Subjects of Specialization

Subjects are to be chosen from the courses offered in the master degree program in electrical engineering and information technology. The director of studies decides on exceptions, upon consultation with the tutor.

Course offer from the Master Program in Electrical Engineering and Information Technology

Diploma Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1101-00L</td>
<td>How to Write Scientific Texts</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>U. Koch</td>
</tr>
</tbody>
</table>

**Abstract**

This four-hour course covers the basics of writing and presenting scientific work. The focus lies on the structure and the main elements of a scientific text. Formatting guidelines, citation rules, good practice of scientific writing and hints to convince the audience are part of the course.

**Objective**

- You can write scientific texts using the correct structure
- You can convincingly present scientific work
- You can differentiate the scientific style from novels and news
- You can adhere to citation rules and scientific integrity

**Content**

The block course covers the following topics:

- Structure of Scientific Texts
- Structure of Scientific Presentations
- Formatting of Scientific Elements (figures, equations, tables)
- Citation Rules and Scientific Integrity

The lecture will be given in two parts on two afternoons. Some exercises will be built into the lecture.

**Literature**

Scientific Integrity, see https://ethz.ch/en/research/ethics-and-animal-welfare/research-integrity.html

**Prerequisites / notice**

You should be writing either a bachelor/semester/master thesis or a scientific publication in the immediate future.

**Competencies**

Subject-specific Competencies

Method-specific Competencies

Social Competencies

Personal Competencies

- Concepts and Theories assessed
- Media and Digital Technologies fostered
- Communication fostered
- Critical Thinking assessed
- Self-awareness and Self-reflection fostered

**227-3001-00L Diploma Thesis**

Registration for the diploma thesis requires the successful completion of 18 credits ECTS from subjects of specialization.

**Abstract**

The Diploma of Advanced Studies finishes with a 3-months diploma thesis which is directed by a professor of the department ITET. Students prove their ability to conduct independent scientific research on a specific research problem, using skills and knowledge acquired during the program. The thesis includes a written report and an oral presentation.

**Objective**

see above
# DAS in Military Sciences

The DAS in Military Sciences programme is executed every second year. 

Takes place in Autumn Semester 2023. 

Next start: Autumn Semester 2025.

<table>
<thead>
<tr>
<th>Key for Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>Z</td>
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</tbody>
</table>

## Key for Hours

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<td>lecture with exercise</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Regenerative Materials

**Compulsory Module Essentials**

*Wird im Frühjahrssemester angeboten.*

**Electives**

**Elective Module Structural Specialisation**

*Wird ab Herbstsemester 2024 angeboten*

**Elective Module Hygrothermal Specialisation**

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>136-0201-00L</td>
<td>General Knowledge on Hygrothermal Building Physics</td>
<td>W</td>
<td>2 credits</td>
<td>3G</td>
<td>G. Habert</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong> Regenerative Materials can be used to build high-quality envelopes and high-comfort environments. The course present the basics of hygrothermal building physics and the state of the art in this field. It gives an overview of the type of earth- and bio-based materials that can be used and their hygrothermal properties.</td>
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<tr>
<td></td>
<td><strong>Objective</strong> - Learn the diversity of regenerative materials used for high-quality envelopes and high-comfort environments - Learn how to distinguish earth- and bio-based materials based on their hygrothermal properties - Ensure an efficient and durable impact on participants' professional development</td>
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<tr>
<td></td>
<td><strong>Content</strong> The course present which Regenerative Materials can be used to build high-quality envelopes and high-comfort environments. It details the basics of hygrothermal building physics: Evolution of standards and models; Strength and weaknesses of Regenerative Materials; State of the art and market evolution. It also gives an overview of the diversity of earth-based materials (plasters, blocks, monolith walls), bio-based materials with fibers (straw bales, wool and rigid panels, bulk fibers) and low-impact composites (light mixes combining mineral binder to bio-sourced materials) from resource to implementation, with a synthesis of their hygrothermal properties and their impact on comfort and energy savings.</td>
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</tbody>
</table>

| 136-0202-00L | Constructive Details & Implementation of Regenerative Envelops |
|         | W 2 credits 3G G. Habert |
|         | **Abstract** The course is focused on constructive details for regenerative materials used to build high-quality envelopes and high-comfort environments. The participant are mainly learning through a hands-on workshop during which they will produce different prototypes in small groups. |
|         | **Objective** - Apply knowledge from previous course on high-quality envelopes built with regenerative materials - Learn how to compare different constructive systems built with regenerative materials to conventional building techniques considering thermal insulation, thermal mass, moisture regulation and air tightness - Ensure an efficient and durable impact on participants’ professional development |
|         | **Content** Small groups producing different prototypes during a hands-on workshop. Each group design and realize a prototype to explore a specific constructive technique using Regenerative Materials and considering thermal insulation, thermal mass, moisture regulation and air tightness. Monitoring devices will be installed in each prototype. These prototypes are compared to reference prototypes built with conventional building techniques. |

<p>| 136-0203-00L | Advanced Knowledge on Hygrothermal Assessment |
|         | W 2 credits 3G G. Habert |
|         | <strong>Abstract</strong> This course offers advanced knowledge on HAM (Heat Air and Moisture) modeling. The most up-to-date simulation models will be presented and used by the participants on real-case projects during simulation workshops. |
|         | <strong>Objective</strong> - Learn how to use the most up-to-date HAM simulation models - Learn how to analyse the transient hygrothermal behaviour of an envelope - Learn how to run a digital parametric iteration to optimize an envelope - Ensure an efficient and durable impact on participants’ professional development |
|         | <strong>Content</strong> Advanced knowledge on HAM modeling are presented during simulation workshops: Transient hygrothermal behaviour: Presentation of relevant software by experts users or developers. Presentation of a case study by the HVAC engineers in charge of the calculation. Calculation exercises based on this case study. Digital parametric iteration: Presentation of relevant software by experts users or developers. Presentation of a case study by the HVAC engineers in charge of the calculation. Calculation exercises based on this case study. |</p>
<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<tr>
<td></td>
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<td>Analytical Competencies</td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Social Competencies</td>
<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Creative Thinking</td>
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</table>

### 136-0250-00L Project Work on Hygrothermal Validation

**W** 6 credits 3G

G. Habert

**Abstract**

Based on the content of previous courses, the participant are asked to simulate to analyze the hygrothermal behaviour of a building built with the same constructive technique as their prototype. In addition, they have to reproduce the monitoring conditions of their prototypes and compare measurements to simulation results. The result and discussion is presented in front of a jury.

**Objective**

- Apply knowledge from previous courses on a case study
- Learn how to compare measurements to simulation results
- Enhance communication skills concerning high-quality envelopes built with regenerative materials

### Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<td></td>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
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<td></td>
<td>Critical Thinking</td>
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#### Diploma Thesis

Wird im Frühjahrssemester angeboten.  
Start FS 2024

### DAS in Regenerative Materials - Key for Type

<table>
<thead>
<tr>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
<th>W</th>
<th>Eligible for credits</th>
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<td>Dr</td>
<td>Suitable for doctorate</td>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
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<td>Z</td>
<td>Courses outside the curriculum</td>
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### Key for Hours

<table>
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<tr>
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<th>P</th>
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<tr>
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<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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</table>

### ECTS

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
DAS Preparation for the Swiss Federal Examination in Pharmacy

First Series of Courses (Group A)

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
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<td>535-0810-00L</td>
<td>Gene Technology</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>J. Scheuermann, N. Grob</td>
</tr>
</tbody>
</table>

Abstract
The course gives a description and summary of the field of gene technology and its pharmaceutical applications. The course focuses on important methods and technologies and their application for genomic, transcriptomic and proteomic analyses in human biology.

Objective
The course gives an overview of current state-of-the-art and advancement in the fields of gene technology. Herein, the course focuses on genomic, transcriptomic and proteomic analysis and their uses in drug discovery and biomedical applications. The course is structured into lectures and practical examples drawn from the research field. Upon completion, the students are familiar and know current state-of-the art of methods and applications, but are also able to classify, contrast and apply different strategies and methods within the field of gene technology. The course is suited for advanced undergraduate and early graduate students in pharmaceutical sciences or related fields.

Content
I) Genomics and transcriptomics
Methods and Techniques:
- Recombinant DNA technology
- Next generation sequencing methods, sequencing of genomes
- CRISPR technology
Application to human biology:
- Functional genomics/transcriptomics
- Principles of cancer, genetic diseases
- Therapies: cell-based therapies/gene therapies/DNA and RNA vaccination

II) Proteomics
Methods and Techniques:
- Protein cloning and expression
- The antibody molecule
- Measurement and determination of biomolecular interactions
- Protein characterization and engineering
- Modifications and radioactive labelling
Application to human biology:
- Protein therapeutics
- Proteomic approaches for identification of novel disease-related targets and biomarkers

III) Drug discovery: Protein-based libraries
Methods and Techniques:
- Immune repertoire mining
- Display and selection technologies
  1. antibody phage display
  2. other polypeptide display technologies
  3. small-molecules display: DNA-encoded chemical libraries

Lecture notes
The lecture series follows the above-described content, and the students are provided with the lecture slides and additional notes. The additional notes are needed for the in-depth study of the individual topics, and to set the frame and content of the in-class group work of the chosen examples.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Decision-making assessed
Problem-solving assessed
Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

<table>
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<tr>
<td>535-0830-00L</td>
<td>Pharmaceutical Immunology I</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>C. Hallin Winter</td>
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</table>

Abstract
Get Students familiar with basic Immunological concepts of pharmaceutical relevance.

Objective
Get Students familiar with basic Immunological concepts of pharmaceutical relevance.

Content
Janeway's Immunobiology, by Kenneth Murphy et al. (9th or 10th Edition; W.W. Norton & Company).

Literature
Janeway's Immunobiology, by Kenneth Murphy et al. (9th or 10th Edition; W.W. Norton & Company)
Paperback
[www.garlandscience.com]

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies fostered
Personal Competencies
Critical Thinking fostered

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<tr>
<td>535-0421-00L</td>
<td>Galenical Pharmacy I</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>J.-C. Leroux, E. Giger</td>
</tr>
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</table>

Abstract
Principles and technologies for the manufacturing of dosage forms and drug delivery systems. Knowledge of pharm. excipients, materials, containers, liquid and semi-solid dosage forms, their production, function, quality and application. Comprehension of molecular interactions in solution and colloidal systems. Comprehension of interfacial phenomena and stabilization measures in dosage forms.

Objective
Knowledge of the most important pharmaceutical excipients, materials, containers, liquid and semi-solid dosage forms, of their production, function, quality, stability and application. Comprehension of the molecular interactions in solution and colloidal systems. Comprehension of interfacial phenomena and stabilization measures in dispense dosage forms.

Content
Introduction and overview of important fundamentals, principles and technologies for the development and manufacturing of dosage forms and drug delivery systems. Overview of the most important pharmaceutical excipients and polymers, their structure, properties and processing; importance of materials properties for containers. Pharmaceutical solvents, fundamentals of solubility and solubilization of drugs. Water treatment processes, sterilization techniques and quality requirements of pharmaceutical water. Parenteral dosage forms and liquid ophthalmics. Surfactants, micelle formation and colloidal systems. Liquid suspensions and emulsions. Stabilization measures in dosage forms.
Abstract
The course places the basic pharmaceutical knowledge acquired to date, particularly in pharmacology, in an applied therapeutic context and encourages interdisciplinary thinking in pharmacy. Weekly practical sessions present and discuss common pharmaceutical case studies that may arise in a pharmacist's daily work.

Objective
Students
• are able to independently analyze, present, explain, and discuss simple case studies from pharmacy practice based on their basic knowledge of pharmacy, particularly pharmacology.
• deepen their knowledge of therapeutic classes, drugs, and treatment guidelines.
• are able to analyze the pharmacological profiles of selected drugs in a therapeutic context (e.g., with regard to adverse drug reactions and interactions).
• are able to compare different drugs and derive therapy-relevant characteristics.

Content
Pharmaceutical case studies from different therapeutic fields comprehend following subject areas:
• Indication
• Dosage Form
• Adverse Drug Reactions
• Interactions
• Contraindications

Lecture notes
Is made available via Moodle.

Literature
As stated in the cases.

Prerequisites / notice
The lecture Pharmacology and Toxicology I (535-0521-00L) must be attended in parallel to or prior to this course.

The course takes place weekly. For each lesson, group work is prepared and submitted in advance, presented by one group at a time, and discussed in plenary.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
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<tr>
<td>Subject-specific Competencies</td>
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<tr>
<td>Method-specific Competencies</td>
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<td>Social Competencies</td>
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<tr>
<td>Personal Competencies</td>
<td>fostered</td>
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</tbody>
</table>

535-0525-00L Pharmaceutical Cases

O 1 credit 1G
D. Stämpfli, S. Erni, E. Kunt Bacs, P. Obrist

Abstract
This two-semester lecture course provides a detailed understanding of the fundamentals of drug action and the therapeutic use of important classes of drugs. The lectures are intended for students of pharmaceutical sciences.

Objective
The lectures provide a comprehensive survey of pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiological and clinical aspects.

Content
Topics include disease-relevant macroscopic, microscopic, pathobiochemical and functional disturbances of specific organs and organ systems. The lectures integrate disease pathology with mechanisms of drug action, usage, metabolism, pharmacokinetics, side effects, toxicology, contraindications and dosage of relevant drugs. Basic principles of clinical pharmacology and pharmacotherapy will be covered.
Lecture notes

A script is provided for each lecture. Scripts define important course contents but do not replace the lectures.

Literature

Recommended reading:

Klaus Aktories, Veit Flockerzi, Ulrich Förstermann, Franz Hofmann.
Allgemeine und spezielle Pharmakologie und Toxikologie.
13. Auflage (2022)
Urban & Fischer (Elsevier)
ISBN: 978-3-437-42622-3

The classic textbook in Pharmacology:

Goodman and Gilman’s The Pharmacological Basis of Therapeutics
Laurence Brunton, Bjorn Knollman.
14th edition (2022)
ISBN-10: 1264258070

Prerequisites / notice

Voraussetzungen: Abschluss Grundstudium

Competencies

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving

Project Management

Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Second Series of Courses (Group A)

Compulsory Courses I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract

This course provides basic clinical and pharmaceutical knowledge and skills for triage, diagnostics and therapy support of the most common diseases.

Objective

Students

- know and understand the pathomechanisms and clinical lead and warning symptoms (red flags) of the most common diseases in the fields listed below.
- can use this knowledge to triage patients: i.e. analyse simple symptoms and diseases, make a tentative diagnosis and recommend suitable medication or further examinations or measures.
- know the therapeutic guidelines, classes of active ingredients and selected, practice-relevant drugs (including indications and the most frequent and important adverse drug reactions, interactions and contraindications).

Content

"Pharmaceutical Care" und "Health Care";
Häufigste Erkrankungen und Therapien der
- Allergologie
- Angiologie und Hämatologie
- Dermatologie
- Endokrinologie und Diabetologie
- Gastroenterologie
- Infektiologie
- Kardiologie
- Neurologie
- Ophthalmologie
- Otorhinolaryngologie
- Pneumologie
- Psychiatrie
- Rheumatologie
- Urologie

Lecture notes

Provided via moodle.

Literature

As stated in the lecture notes.
The course is divided into three parts. The first part provides an overview of drugs used for the pharmacotherapy of infectious diseases, osteoporosis, autoimmune diseases and cancer. The second part is focused on pharmacogonomics of drug metabolism and basic concepts of toxicology. The third part addresses advanced knowledge in pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiological and clinical aspects of drug therapy in the fields of infectious diseases, osteoporosis, autoimmune diseases and cancer. The course also provides an overview of the fields of medical virology, toxicology, and pharmacogonomics with a special focus on the role of genetic polymorphisms in drug response and adverse effects.

Topics include the pharmacology and pharmacotherapy of infectious diseases, osteoporosis, autoimmune diseases and cancer. Medical virology covers important viral infections and their pharmacotherapy with different classes of antiviral drugs. In the field of pharmacogonomics, the course is focused on examples of genetic variability of drug metabolism and drug responses, and the relevance of pharmacogonomics and toxicogenomics for clinical drug development. Finally, basic concepts of toxicology are introduced.

A script is provided for each lecture. The scripts define important and exam-relevant contents of the lectures. Scripts do not replace the handouts to the lectures. 

Please note that the assessment of this course must be passed (not compensable). The performance assessment of the course takes place in two written on campus online partial examinations. The overall grade results from the average of the grades of both partial examinations. If the overall grade is unsatisfactory, both partial examinations must be repeated.
Literature

Recommended reading:
The classic textbook in Pharmacology:
Goodman and Gilman’s The Pharmacological Basis of Therapeutics
Laurence Brunton, Bjorn C. Knollman.
14th edition (2022)
ISBN-10: 1264258070

or

Klaus Aktories, Veit Flockerzi, Ulrich Förstermann, Franz Hofmann.
Allgemeine und spezielle Pharmakologie und Toxikologie.
13th edition (2022)
Urban & Fischer (Elsevier)

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Leadership: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: fostered

Content

- Historical landmarks of drug safety
- Pharmacovigilance and causality assessment
- Drug safety in premarketing clinical trials
- Descriptive, cohort and case-control drug safety study designs; Data analysis and control of confounding
- Pharmacoepidemiology and regulatory decision making in drug safety; Risk management plans (RMPs)
- Medication errors, clinical pharmacology / clinical pharmacy
- Clinical Decision Support Systems, Interventional Pharmacoepidemiology
- Pharmacoepidemiological databases, ‘Big Data’
- Interactive discussion of many real-life examples for each topic

Lecture notes

This course will be a combination of formal lectures, group discussions and self-directed studies. Course material will be taught through seminars, case studies in small groups. Reading material and scripts will be provided for each week.

Literature

Recommended literature
- Rothman: Introduction to Epidemiology
- Strom, Kimmel, Hennessy: Textbook of Pharmacoepidemiology
- Gigerenzer: Risk Savvy - How to Make Good Decisions

Second Series of Courses (Group B)

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>535-0050-00L</td>
<td>Pharmacoepidemiology and Drug Safety</td>
<td>W</td>
<td>3</td>
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<td>A. Burden, S. Russmann</td>
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<td>535-0137-00L</td>
<td>Clinical Chemistry II</td>
<td>W</td>
<td>1</td>
<td>1V</td>
<td>M. Hersberger</td>
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</tbody>
</table>

Prerequisites / notice

Requirement: basic knowledge in clinical chemistry and laboratory diagnostics
This course provides basic clinical and pharmaceutical knowledge and skills for triage, diagnostics and therapy support of the most common diseases.

**Objective**

- know and understand the pathomechanisms and clinical lead and warning symptoms (red flags) of the most common diseases in the fields listed below;
- can use this knowledge to triage patients: i.e. analyse simple symptoms and diseases, make a tentative diagnosis and recommend suitable medication or further examinations or measures;
- know the therapeutic guidelines, classes of active ingredients and selected, practice-relevant drugs (including indications and the most frequent and important adverse drug reactions, interactions and contraindications).

**Content**

- "Pharmaceutical Care" und "Health Care'';
- Häufigste Erkrankungen und Therapien der
  - Allergologie
  - Angiologie und Hämatologie
  - Dermatologie
  - Endokrinologie und Diabetologie
  - Gastroenterologie
  - Infektiologie
  - Kardiologie
  - Neurologie
  - Ophthalmologie
  - Otorhinolaryngologie
  - Pneumologie
  - Psychiatrie
  - Rheumatologie
  - Urologie

**Lecture notes**

Provided via moodle.

**Literature**

As stated in the lecture notes.

**Prerequisites / notice**

Please note that the assessment of this course must be passed (not compensable).

The performance assessment of the course takes place in two written on campus online partial examinations. The overall grade results from the average of the grades of both partial examinations. If the overall grade is unsatisfactory, both partial examinations must be repeated.

The courses Pharmacology and Toxicology I and II and Pathobiology provide indispensable basics which students must master at the beginning of the semester in order to successfully complete the course.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies
- **Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Problem-solving
- **Social Competencies**
  - Communication
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
- **Personal Competencies**
  - Adaptability and Flexibility
  - Critical Thinking
  - Self-awareness and Self-reflection

---

**Clinical Chemistry II**

**Abstract**

Detailed knowledge on particular aspects of clinical chemistry and medical laboratory diagnostics concerning quality control, point-of-care analytics, analytics of kidney stones, tumor markers, diagnosis of HIV and hepatitis, pharmacogenetics, thyroid function, bone metabolism and laboratory diagnosis of hypertension.

**Objective**

Detailed knowledge on the implementation and interpretation of clinical laboratory diagnostic tests. Competence to interprete selected tests.

**Content**

Internal and external quality control, point-of-care analytics, analytics of kidney stones, use of tumor marker determinations, diagnosis of HIV and hepatitis, pharmacogenetics, thyroid function, bone metabolism and laboratory diagnosis of hypertension.

**Lecture notes**

Documentation will be available before the lectures electronically.

**Literature**

- Jürgen Hallbach, Klinische Chemie und Hämatologie für den Einstieg, Thieme Verlag
- Harald Renz, Praktische Labordiagnostik, de Gruyter Verlag
- Walter Guder, Das Laborbuch für Klinik und Praxis, Elsevier Verlag
- Lothar Thomas, Labor und Diagnose, TH Books
- William Marshall, Clinical Chemistry, Mosby Ltd.
- Alan H.B. Wu, Tietz, Clinical Guide to Laboratory Tests, Saunders

**Prerequisites / notice**

Requirement: basic knowledge in clinical chemistry and laboratory diagnostics

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**Third Series of Courses (Group A and B)**

**Practical Pharmacy and Compensatory Courses**

**Number**

<table>
<thead>
<tr>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
</table>

**Abstract**

This course provides basic knowledge relevant to pharmacy and its application in nephrology, phytotherapy, complementary medicine, wound care and pharmaceutical care.
Objective
Students know and understand the therapeutic concepts of the mentioned topics and their application in practice.

(for detailed learning objectives see the guidelines)

Content
- complementary medicine
- phytotherapy
- wound care
- pharmaceutical care 2
- nephrology

Lecture notes
Provided via myStudies.

Literature
As specified in the lecture notes

Competencies

<table>
<thead>
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<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<td>Techniques and Technologies</td>
<td>Communication</td>
<td>Critical Thinking</td>
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<tr>
<td>Analytical Competencies</td>
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<td>Cooperation and Teamwork</td>
<td>Self-awareness and Self-reflection</td>
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<tr>
<td>Problem-solving</td>
<td>fostered</td>
<td>fostered</td>
<td></td>
</tr>
<tr>
<td>assessed</td>
<td></td>
<td>fostered</td>
<td></td>
</tr>
</tbody>
</table>

535-5522-00L Therapeutic Skills II

Abstract
This course provides basic clinical and pharmaceutical knowledge and its application for triage, diagnostics and therapy support for the most common diseases in geriatrics, women's health, oncology, paediatrics and neurology (epilepsy). In addition, the role of nutrition in special life situations and in selected health disorders is taught.

Objective
- know and understand the pathomechanisms and the clinical lead and warning symptoms (red flags) of the most common diseases in the fields listed.
- can triage patients by applying this knowledge: i.e. analyse simple symptoms and disease patterns, make a tentative diagnosis and recommend suitable medication or further examinations or measures.
- know the therapeutic guidelines, drug classes and selected, practice-relevant drugs (including indications and the most frequent and important dosages, adverse drug reactions, interactions and contraindications).

(for detailed learning objectives, see the guideline)

Content
- nutrition
- geriatrics
- neurology (epilepsy)
- oncology
- paediatrics
- women's health

Lecture notes
Provided via myStudies.

Literature
As specified in the lecture notes

535-5502-00L Pharmaceutical Manufacturing in Small Quantities

Number Title Type ECTS Hours Lecturers
535-5502-00L Pharmaceutical Manufacturing in Small Quantities (Compounding) O 3 credits 5G P. G. Tiefenböck, A. Romagna
Abstract
Pharmaceutical Manufacturing relevant for the community pharmacy considering the "GMP-Regeln in kleinen Mengen" of the Pharmacopoeia: The preparation of extemporaneous products covering the most common forms under consideration of their Risks and Quality Assurance.

Objective
The students are able to produce pharmaceutical relevant drug Systems without further assistance, lege arts, applying the right techniques and material. The production and packaging has to follow GMP rules and tailored for the patients need. The quality control and correct documentation have to be followed. The students know the most relevant specifications, concentration and dosing ranges of common APIs and excipients. The students are familiar with the relevant literature (Pharmaceutical and legal basis) regarding the Pharmaceutical manufacturing relevant for the community pharmacies.

Content
Vermittlung der wichtigsten Kenntnisse, Arbeitsschritte und -techniken im Bereich der Arzneimittelherstellung in kleinen Mengen (Formula) mit Fokus auf der Herstellung, Qualitätssicherung und Risikobeurteilung einschliesslich der patientenspezifischen Abgabepraxis.

In den Praktika: Anhand praxis-relevanter Beispiele wird die Aufgabenplanung, die Fertigung einschliesslich die korrekte Verwendung der Gerätschaften, die Inprozesskontrolle, die Verpackung und die Qualitätssicherung diverser Rezepte und Arzneiformen geübt. Unter Einbezug risikoadaptierter Massnahmen erfolgt die Qualitätssicherung, -kontrolle und Einhaltung von Hygienerichtlinien genümt der geltenden Arzneibüchern. Die Studierenden vertiefen damit ihre GMP-relevanten Kenntnisse und Fertigkeiten.

Prerequisites / notice
Safety conceptt: https://chab.ethz.ch/studium/bachelor1.html

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Problem-solving</th>
<th>Communication</th>
<th>Cooperation and Teamwork</th>
<th>Sensitivity to Diversity</th>
<th>Adaptability and Flexibility</th>
<th>Creative Thinking</th>
<th>Critical Thinking</th>
<th>Integrity and Work Ethics</th>
<th>Self-awareness and Self-reflection</th>
<th>Self-direction and Self-management</th>
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<tr>
<td>Institutional Pharmacy</td>
<td>O</td>
<td>2 credits</td>
<td>3G</td>
<td>P. Wiedemeier, M. Lutters, E. Martinelli, I. S. Vogel Kahmann</td>
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</table>

535-5526-00L Injection Techniques and Vaccinations

Does not take place this semester.

Abstract
Die Studierenden erlernen die praktische Durchführung von subkutanen (s.c.) und intramuskulären (i.m.) Injektionen. Sie wissen, wie in Notfallsituationen vorzugehen ist.

Die Besonderheiten von häufig eingesetzten parenteral zu verabreichenden Medikamenten, insbesondere von Impfungen, sind bekannt.

Objective
Die Studierenden erwerben das theoretische Wissen und die praktischen Fähigkeiten, welche für die s.c. und i.m. Verabreichung von Medikamenten erforderlich sind. Sie sind fähig, Risikopatienten zu identifizieren und sind geschult, bei Notfällen (z.B. Anaphylaxie) korrekt zu handeln.

Die Studierenden kennen die in der Schweiz zur Verfügung stehenden Impfungen, den schweizerischen Impfplan und sind vertraut mit der Anwendung von elektronischen Hilfsmitteln bei Fragestellungen rund um das Impfen.

Die Studierenden kennen die rechtlichen Grundlagen und regulatorischen Aspekte bezüglich der Verabreichung von Impfungen. Sie fördern den Einsatz von elektronischen Hilfsmitteln zur Verwaltung und Überwachung der Impfungen.

Die Studierenden kennen das konzeptionelle und praktische Vorgehen bei der Durchführung von subkutanen Injektionen und intramuskulären Injektionen.

Die Studierenden können verschiedene Verbandmaterialien und können diese anwenden, um akute Wunden zu versorgen.

Content
Die Lernziele und Inhalte entsprechen dem Fähigkeitsprogramm FPh Impfen und Blutentnahme von PharmaSuisse (ausser venöse Blutentnahmen)

- BLS-AED-SRC Komplettkurs (siehe https://www.slrg.ch)
- Vorgehen bei Notfällen (z.B. Herzinkarst, Schlaganfall, Anaphylaxie u.a.) in der Apotheke
- Vorgehen bei der Versorgung akuter Wunden
- Injektionstechniken: Materialkunde, Hygienevorschriften und Desinfektion, Kommunikation mit Patienten, Vor- und Nachbereitung einer Injektion, praktische Durchführung von subkutanen Injektionen und intramuskulären Injektionen
- Theorie und praktische Aspekte der Durchführung von subkutanen Blutentnahmen
- Impfungen (z.B. Lesen von Impfausweisen, Erstellen eines individuellen Impfschemas, Impfdebate)

Lecture notes
Wird auf mystudies veröffentlicht.

Literature
Wird im Skript angegeben.

Prerequisites / notice
Die Impfungen werden an Mittelstuderenden durchgeführt.

Deshalb müssen sich alle Studierenden gegen Hepatitis B impfen und eine Titerbestimmung nach der 3. Impfung durchführen lassen. (Ziel: Titer über 100 UI/).

Der Nachweis über den ausreichenden Titer muss am ersten Kurstag mitgebracht werden.

Die praktischen Übungen werden in Kleingruppen durchgeführt. Die Zuteilung muss eingehalten werden. Unterschiedliche Anfangszeiten beachten!

Film und Tonaufnahmen während der Lehrveranstaltung sind strikt untersagt.

Schutzkonzept: https://chab.ethz.ch/studium/bachelor1.html
### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed

#### Social Competencies
- Communication: fostered
- Customer Orientation: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Critical Thinking: assessed
- Customer Orientation: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

### DAS Preparation for the Swiss Federal Examination in Pharmacy - Key for Type

<table>
<thead>
<tr>
<th>Dr</th>
<th>Suitable for doctorate</th>
<th>W</th>
<th>Eligible for credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
</tbody>
</table>

### Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</tr>
</tbody>
</table>

### ECTS

- European Credit Transfer and Accumulation System
  - Special students and auditors need special permission from the lecturers.
Data Science Master

Master Studies (Programme Regulations 2023)

Core Courses

Data Analysis

### Core Courses

#### Data Analysis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10 credits</td>
<td>3V+2U+4A</td>
<td>C. Cotrini Jimenez</td>
</tr>
</tbody>
</table>

**Abstract**

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

**Content**

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

**Lecture notes**

No lecture notes, but slides will be made available on the course webpage.

**Literature**


**Prerequisites / notice**

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

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### Core Courses

#### Probabilistic Artificial Intelligence

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>263-5210-00L</td>
<td>Probabilistic Artificial Intelligence</td>
<td>W</td>
<td>8 credits</td>
<td>3V+2U+2A</td>
<td>A. Krause</td>
</tr>
</tbody>
</table>

**Abstract**

This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

**Objective**

How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

**Content**

Topics covered:

- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

**Prerequisites / notice**

Solid basic knowledge in statistics, algorithms and programming.

The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed
  - Project Management: assessed

- Social Competencies
  - Communication: fostered
  - Cooperation and Teamwork: fostered

- Personal Competencies
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered

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Data: 15.06.2024 12:39   Autumn Semester 2024   Page 660 of 2653
Abstract
Mostly self-contained, but fast-paced, introductory masters level course on various theoretical aspects of algorithms that aim to extract information from data.

Objective
Introduction to various mathematical aspects of Data Science.

Content
These topics lie in overlaps of Mathematics with: Computer Science, Electrical Engineering, Statistics, and/or Operations Research. Most lectures will feature Mathematical Open Problems. The main mathematical tools used will be Probability and Linear Algebra, and a basic familiarity with these subjects is required. There will also be some (although knowledge of these tools is not assumed) Graph Theory, Representation Theory, Applied Harmonic Analysis, among others. The topics treated will include Dimension reduction, Manifold learning, Sparse recovery, Random Matrices, Approximation Algorithms, Community detection in graphs, and several others.

Lecture notes

Prerequisites / notice
The main mathematical tools used will be Probability, Linear Algebra (and real analysis), and a working knowledge of these subjects is required. In addition to these prerequisites, this class requires a certain degree of mathematical maturity--including abstract thinking and the ability to understand and write proofs.

We encourage students who are interested in mathematical data science to take both this course and "227-0434-10L Mathematics of Information" taught by Prof. H. Bölcskei. The two courses are designed to be complementary.

A. Bandeira and H. Bölcskei

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Sensitivity to Diversity: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Data Management

Number Title Type ECTS Hours Lecturers
263-3010-00L Big Data W 10 3V+2U+4A G. Fourny

Abstract
The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations.

Objective
Do you want to be able to query your own data productively and efficiently in your future semester projects, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This courses teaches you how to do so as well as the dos and don'ts.

"Big Data" refers to the case when the amount of data is very large (100 GB and more), or when the data is not completely structured (or messy). The Big Data revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it are needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each one of your projects efficiently and consistently.
Content

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage (S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)

Large scale analytics and machine learning are outside of the scope of this course.

Literature

Course textbook: https://ghislainfourny.github.io/big-data-textbook/

Prerequisites / notice

The lecture is hybrid, meaning you can attend with us in the lecture hall, or on Zoom, or watch the recordings on YouTube later. Exercise sessions are in presence.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departements interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2023

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

Competencies

Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies

- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving fostered

Social Competencies

- Communication fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies

- Creative Thinking fostered
- Critical Thinking assessed

263-3845-00L Data Management Systems

Abstract

The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.

Objective

The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.

Content

The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understating these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

Literature

The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.
The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

263-4500-00L Advanced Algorithms
W 9 credits
3V+2U+3A J. Lengler, B. Häupler, M. Probst

This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms, sketching and streaming algorithms, and online algorithms.

Objective
This course familiarizes the students with some of the main tools and techniques in modern subareas of algorithm design.

Content
The lectures will cover modern topics in algorithm design and analysis, including the following: graph sparsifications while preserving cuts or distances, various approximation algorithms techniques and concepts, metric embeddings and probabilistic tree embeddings, online algorithms, multiplicative weight updates, streaming algorithms, sketching algorithms.

Lecture notes
https://people.inf.ethz.ch/~aroeyskoe/AA23

Prerequisites / notice
This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations. E.g., having passed the course Algorithms, Probability, and Computing (APC) is recommended, though not required formally. If you are not sure whether you're ready for this class or not, please consult the instructor.

252-3005-00L Natural Language Processing
W 7 credits
3V+3U+1A R. Cotterell

This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Objective
The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

Content
This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Literature
Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

263-2400-00L Reliable and Trustworthy Artificial Intelligence
W 6 credits
2V+2U+1A M. Vechev

Creating reliable, secure, robust, and fair machine learning models is a core challenge in artificial intelligence and one of fundamental importance. The goal of the course is to teach both the mathematical foundations of this new and emerging area as well as to introduce students to the latest and most exciting research in the space.

Objective
Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of engineering and research problems. To facilitate deeper understanding, the course includes a group coding project where students will build a system based on the learned material.
Content

The course is split into 4 parts:

Robustness of Machine Learning

- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

Privacy of Machine Learning

- Threat models (e.g., stealing data, poisoning, membership inference, etc.).
- Attack federated machine learning (across vision, natural language and tabular data).
- Differential privacy for defending machine learning.
- AI Regulations and checking model compliance.

Fairness of Machine Learning

- Introduction to fairness (motivation, definitions).
- Enforcing individual fairness (for both vision and tabular data).
- Enforcing group fairness (e.g., demographic parity, equalized odds).

Robustness, Privacy and Fairness of Foundation Models

We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).


Prerequisites / notice

While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in “Intro to ML” classes at most institutions (e.g., “Introduction to Machine Learning” at ETH).

Competencies

The coding project will utilize Python and PyTorch. Thus some programming experience in Python is expected. Students without prior knowledge of PyTorch are expected to acquire it early in the course by solving exercise sheets.

Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies

- Analytical Competencies: assessed
- Problem-solving: assessed

Personal Competencies

- Creative Thinking: assessed
- Critical Thinking: assessed

263-3210-00L Deep Learning W 8 credits 3V+2U+2A T. Hofmann

Abstract

Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective

In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice

This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://mil2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/ss19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18

263-5005-00L Artificial Intelligence in Education W 3 credits 1V+0.5U M. Sachan

Abstract

Artificial Intelligence (AI) methods have shown to have a profound impact in educational technologies, where the great variety of tasks and data types enable us to get benefit of AI techniques in many different ways. We will review relevant methods and applications of AI in various educational technologies, and work on problem sets and projects to solve problems in education with the help of AI.

Objective

The course will be centered around exploring methodological and system-focused perspectives on designing AI systems for education and analyzing educational data using AI methods. Students will be expected to a) engage in presentations and active in-class and asynchronous discussion, and b) work on problem-sets exemplifying the use of educational data mining techniques.
Introduction to GNN concepts: 1) problem-solving on graphs (node-, edge-, graph-level objectives), structural priors (inductive biases) of assessed 6 credits

2G+1A

The course will start with an introduction to data mining techniques (e.g., prediction, structured discovery, visualization, and relationship mining) relevant to analyzing educational data. We will then continue with topics on personalization in AI in educational technologies (e.g., learner modeling and knowledge tracing, self-improving AIED systems) while showcasing exemplary applications in areas such as content curation and dialog-based tutoring. Finally, we will cover ethical challenges associated with using AI in student-facing settings. Face-to-face meetings will be held every fortnight, although students will be expected to work individually on weekly tasks (e.g., discussing relevant literature, working on problems, preparing seminar presentations).

Lecture notes
Lecture slides will be made available at the course Web site.

Prerequisites / Literature
No textbook is required, but there will be regularly assigned readings from research literature, linked to the course website.

Content
Graphs are an incredibly versatile abstraction to represent arbitrary structures such as molecules, relational knowledge or social and traffic networks. This course provides a practical overview of deep (representation) learning on graphs and their applications.

Objective
Many established deep learning methods require dense input data with a well-defined structure (e.g., an image, a sequence of word embeddings). However, many practical applications deal with sparsely connected and complex data structures, such as molecules, knowledge graphs or social networks. Graph Neural Networks (GNNs) and general representation learning on graphs have recently experienced a surge in popularity because it addresses the challenge to effectively learn representations over said structures. In this course, we aim to understand the fundamental principles of deep (representation) learning on graphs, the similarities and differences to other concepts in deep learning, as well as the unique challenges from a practical point of view. Finally, we provide an overview of recent applications of graph neural networks.

Content
Introduction to GNN concepts: 1) problem-solving on graphs (node-, edge-, graph-level objectives), structural priors (inductive biases) of graph data, applications for graph learning. 2) Graph Neural Networks: convolutional, attentional, message passing; overview on the zoo of published operators. Relations to Transformers and DeepSets. 3) Expressivity of GNNs. 4) Scalability of Graph Neural Networks: Subsampling, Clustering (Pooling). 5) Augmentations and self-supervised learning on Graphs Application: Drug Discovery, Knowledge graphs, Temporal GNNs, Geometric GNNs, Deep Generative Models for Graphs.

Prerequisites / notice
There are no prerequisites for this class. However, it will help if the student has taken an undergraduate or graduate level class in statistics, data science or machine learning. This class is appropriate for advanced undergraduates and master students in Computer Science as well as PhD students in other departments.

263-5056-00L Applications of Deep Learning on Graphs

Abstract
Graphs are an incredibly versatile abstraction to represent arbitrary structures such as molecules, relational knowledge or social and traffic networks. This course provides a practical overview of deep (representation) learning on graphs and their applications.

Objective
Many established deep learning methods require dense input data with a well-defined structure (e.g., an image, a sequence of word embeddings). However, many practical applications deal with sparsely connected and complex data structures, such as molecules, knowledge graphs or social networks. Graph Neural Networks (GNNs) and general representation learning on graphs have recently experienced a surge in popularity because it addresses the challenge to effectively learn representations over said structures. In this course, we aim to understand the fundamental principles of deep (representation) learning on graphs, the similarities and differences to other concepts in deep learning, as well as the unique challenges from a practical point of view. Finally, we provide an overview of recent applications of graph neural networks.

Content
Introduction to GNN concepts: 1) problem-solving on graphs (node-, edge-, graph-level objectives), structural priors (inductive biases) of graph data, applications for graph learning. 2) Graph Neural Networks: convolutional, attentional, message passing; overview on the zoo of published operators. Relations to Transformers and DeepSets. 3) Expressivity of GNNs. 4) Scalability of Graph Neural Networks: Subsampling, Clustering (Pooling). 5) Augmentations and self-supervised learning on Graphs Application: Drug Discovery, Knowledge graphs, Temporal GNNs, Geometric GNNs, Deep Generative Models for Graphs.

Prerequisites / notice
263-3210-00 Depp Learning or 263-0008-00 Computational Intelligence Lab; 252-0220-00 Introduction to Machine Learning; Statistics/Probability; Programming in Python; Unix Command Line.

263-5300-00L Guarantees for Machine Learning

Abstract
This course is aimed at advanced master and doctorate students who want to conduct independent research on theory for modern machine learning (ML). It teaches standard methods in statistical learning theory commonly used to prove theoretical guarantees for ML algorithms. The knowledge is then applied in independent project work to understand and follow-up on recent theoretical ML results.

Objective
By the end of the semester students should be able to
- understand a good fraction of theory papers published in the typical ML venues. For this purpose, students will learn common mathematical techniques from statistical learning in the first part of the course and apply this knowledge in the project work
- critically examine recently published work in terms of relevance and find impactful (novel) research problems. This will be an integral part of the project work and involves experimental as well as theoretical questions
- outline a possible approach to prove a conjectured theorem by e.g. reducing to more solvable subproblems. This will be practiced in in-person exercises, homeworks and potentially in the final project
- effectively communicate and present the problem motivation, new insights and results to a technical audience. This will be practiced in final presentations and report as well as during peer-grading of peer talks.

Content
This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning algorithms. It touches on the following topics
- concentration bounds
- uniform convergence and empirical process theory
- regularization for non-parametric statistics (e.g. in RKHS, neural networks)
- high-dimensional learning
- computational and statistical learnability (information-theoretic, PAC, SQ)
- overparameterized models, implicit bias and regularization

Prerequisites / notice
The project work focuses on current theoretical ML research that aims to understand modern phenomena in machine learning, including but not limited to
- how overparameterized models generalize (statistically) and converge (computationally)
- complexity measures and approximation theoretic properties of randomly initialized and trained neural networks
- generalization of robust learning (adversarial or distribution-shift robustness)
- private and fair learning

Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

263-5351-00L Machine Learning for Genomics

Abstract
The course reviews solutions provided by machine learning to the most challenging questions in human genomics.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed
Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

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Machine Learning on Microcontrollers

Abstract
Machine Learning (ML) and artificial intelligence are pervading the digital society. Today, even low power embedded systems are incorporating ML, becoming increasingly “smart”. This lecture gives an overview of ML methods and algorithms to process and extract useful near-sensor information in end-nodes of the “internet-of-things”, using low-power microcontrollers/processors (ARM-Cortex-M; RISC-V).

Objective
Learn how to Process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ExG bio-signals, cameras,…). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers.

Content
- Low power smart sensor system design: hardware-software tradeoffs, analysis, and optimization. Implementation and performance evaluation of ML in battery-operated embedded systems.
- Low power smart sensor system design: hardware-software tradeoffs, analysis, and optimization. Implementation and performance evaluation of ML in battery-operated embedded systems.

Lecture notes
Script and exercise sheets. Books will be suggested during the course.

Prerequisites / notice

Computer Vision

Abstract
The laboratory exercises will show how to address concrete design problems, like motion, gesture recognition, emotion detection, image evaluation of ML in battery-operated embedded systems.

Objective
- Sensors and sensor data acquisition with low power embedded systems
- Machine Learning: Overview of supervised and unsupervised learning and in particular supervised learning (Bayes Decision Theory, Decision Trees, Random Forests, kNN-Methods, Support Vector Machines, Convolutional Networks and Deep Learning)
- Low-power embedded systems and their architecture. Low Power microcontrollers (ARM-Cortex M) and RISC-V-based Parallel Ultra Low Power (PULP) systems-on-chip.
- Low power smart sensor system design: hardware-software tradeoffs, analysis, and optimization. Implementation and performance evaluation of ML in battery-operated embedded systems.

Content
The final goal of the course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective
The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Prerequisites / notice
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

Information Theory I

Abstract
This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

Objective
The fundamentals of Information Theory including Shannon’s source coding and channel coding theorems

Content
- The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

Literature
T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

Computer Vision and Artificial Intelligence for Autonomous Cars

Abstract
This course introduces the core computer vision techniques and algorithms that autonomous cars use to perceive the semantics and geometry of their driving environment, localize themselves in it, and predict its dynamic evolution. Emphasis is placed on techniques tailored for real-world settings, such as multi-modal fusion, domain-adaptive and outlier-aware architectures, and multi-agent methods.

Objective
- Computer Vision: Invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition
- Social Competencies
- Introduction to Machine Learning, Statistics/Probability, Programming in Python, Unix Command Line

Content
- Short introduction to major concepts of molecular biology: DNA, genes, genome, central dogma, transcription factors, epigenetic code, DNA methylation, signaling pathways
- Prediction of transcription factor binding sites, open chromatin, histone marks, promoters, nucleosome positioning (convolutional neural networks, position weight matrices)
- Prediction of variant effects and gene expression (hidden Markov models, topic models)
- Deconvolution of mixed signal (NMF, ICA)
- DNA, RNA and protein folding (RNN, LSTM, transformers)
- Data imputation for single-cell RNA-seq data, clustering and annotation (diffusion and methods on graphs)
- Batch correction (autoencoders, optimal transport)
- Survival analysis (Cox proportional hazard model, regularization penalties, multi-omics, multi-tasking)

Prerequisites / notice
Introduction to Machine Learning, Statistics/Probability, Programming in Python, Unix Command Line

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Communication

Social Competencies
- fostered
- assessed

263-5902-00L

Abstract
The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective
The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Prerequisites / notice
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

227-0155-00L

Abstract
Registration in this class requires the permission of the instructors. Preference is given to students in the MSc EEIT.

Objective
Learn how to Process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ExG bio-signals, cameras,…). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers.

Content
The final goal of the course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective
The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Prerequisites / notice
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

277-0417-00L

Abstract
This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

Objective
The fundamentals of Information Theory including Shannon’s source coding and channel coding theorems

Content
- The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

Literature
T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

227-0560-00L

Abstract
This course introduces the core computer vision techniques and algorithms that autonomous cars use to perceive the semantics and geometry of their driving environment, localize themselves in it, and predict its dynamic evolution. Emphasis is placed on techniques tailored for real-world settings, such as multi-modal fusion, domain-adaptive and outlier-aware architectures, and multi-agent methods.

Objective
- Computer Vision: Invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition
- Social Competencies
- Introduction to Machine Learning, Statistics/Probability, Programming in Python, Unix Command Line

Content
- Short introduction to major concepts of molecular biology: DNA, genes, genome, central dogma, transcription factors, epigenetic code, DNA methylation, signaling pathways
- Prediction of transcription factor binding sites, open chromatin, histone marks, promoters, nucleosome positioning (convolutional neural networks, position weight matrices)
- Prediction of variant effects and gene expression (hidden Markov models, topic models)
- Deconvolution of mixed signal (NMF, ICA)
- DNA, RNA and protein folding (RNN, LSTM, transformers)
- Data imputation for single-cell RNA-seq data, clustering and annotation (diffusion and methods on graphs)
- Batch correction (autoencoders, optimal transport)
- Survival analysis (Cox proportional hazard model, regularization penalties, multi-omics, multi-tasking)

Prerequisites / notice
Introduction to Machine Learning, Statistics/Probability, Programming in Python, Unix Command Line

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Communication

Social Competencies
- fostered
- assessed

263-5902-00L

Abstract
The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective
The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Prerequisites / notice
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

227-0155-00L

Abstract
Registration in this class requires the permission of the instructors. Preference is given to students in the MSc EEIT.

Objective
Learn how to Process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ExG bio-signals, cameras,…). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers.

Content
The final goal of the course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective
The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Prerequisites / notice
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

277-0417-00L

Abstract
This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

Objective
The fundamentals of Information Theory including Shannon’s source coding and channel coding theorems

Content
- The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

Literature
T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

227-0560-00L

Abstract
This course introduces the core computer vision techniques and algorithms that autonomous cars use to perceive the semantics and geometry of their driving environment, localize themselves in it, and predict its dynamic evolution. Emphasis is placed on techniques tailored for real-world settings, such as multi-modal fusion, domain-adaptive and outlier-aware architectures, and multi-agent methods.
Objective

Students will learn about the fundamentals of autonomous cars and of the computer vision models and methods these cars use to analyze their environment and navigate themselves in it. Students will be presented with state-of-the-art representations and algorithms for semantic, geometric and temporal visual reasoning in automated driving and will gain hands-on experience in developing computer vision algorithms and architectures for solving such tasks.

After completing this course, students will be able to:
1. understand the operating principles of visual sensors in autonomous cars
2. differentiate between the core architectural paradigms and components of modern visual perception models and describe their logic and the role of their parameters
3. systematically categorize the main visual tasks related to automated driving and understand the primary representations and algorithms which are used for solving them
4. critically analyze and evaluate current research in the area of computer vision for autonomous cars
5. practically reproduce state-of-the-art computer vision methods in automated driving
6. independently develop new models for visual perception

Content

The content of the lectures consists in the following topics:

1. Fundamentals
   (a) Fundamentals of autonomous cars and their visual sensors
   (b) Fundamental computer vision architectures and algorithms for autonomous cars

2. Semantic perception
   (a) Semantic segmentation
   (b) Object detection
   (c) Instance segmentation and panoptic segmentation

3. Geometric perception and localization
   (a) Depth estimation
   (b) 3D reconstruction
   (c) Visual localization
   (d) Unimodal visual/lidar 3D object detection

4. Robust perception: multi-modal, multi-domain and multi-agent methods
   (a) Multi-modal 2D and 3D object detection
   (b) Visual grounding and verbo-visual fusion
   (c) Domain-adaptive and outlier-aware semantic perception
   (d) Vehicle-to-vehicle communication for perception

5. Temporal perception
   (a) Multiple object tracking
   (b) Motion prediction

The practical projects involve implementing complex computer vision architectures and algorithms and applying them to real-world, multi-modal driving datasets. In particular, students will develop models and algorithms for:
1. Semantic segmentation and depth estimation
2. Sensor calibration for multi-modal 3D driving datasets
3. 3D object detection using lidars

Lecture notes
Lecture slides are provided in PDF format.

Prerequisites / notice
Students are expected to have a solid basic knowledge of linear algebra, multivariate calculus, and probability theory, and a basic background in computer vision and machine learning. All practical projects will require solid background in programming and will be based on Python and libraries of it such as PyTorch.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

227-0689-00L System Identification W 4 credits 2V+1U R. Smith

Abstract
Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.

Objective
To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.

Content
Introduction to modeling: Black-box and grey-box models; Parametric and non-parametric models; ARX, ARMAX (etc.) models.

Predictive, open-loop, black-box identification methods. Time and frequency domain methods. Subspace identification methods.

Optimal experimental design, Cramer-Rao bounds, input signal design.

Parametric identification methods. On-line and batch approaches.

Closed-loop identification strategies. Trade-off between controller performance and information available for identification.


Literature
Additional papers will be available via the course Moodle.

Prerequisites / notice
Control systems (227-0216-00L) or equivalent.

401-0625-01L Applied Analysis of Variance and Experimental Design W 5 credits 2V+1U L. Meier
Subject-specific Competencies

Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by assessing

Literature


Analytical Competencies

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has not available

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the

Critical Thinking

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial designs and fractional designs, power.

Prerequisites

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Competencies

Subject-specific Competencies

Concepts and Theories - assessed

Techniques and Technologies - assessed

Method-specific Competencies

Analytical Competencies - assessed

Decision-making - assessed

Personal Competencies

Critical Thinking - assessed

401-3054-14L

Probabilistic Methods in Combinatorics

W 5 credits 2V+1U B. Sudakov

Abstract

This course provides a gentle introduction to the Probabilistic Method, with an emphasis on methodology. We will try to illustrate the main ideas by showing the application of probabilistic reasoning to various combinatorial problems.

Content

The topics covered in the class will include (but are not limited to): linearity of expectation, the second moment method, the local lemma, correlation inequalities, martingales, large deviation inequalities, Janson and Talagrand inequalities and pseudo-randomness.

Literature

- Graph Coloring and the Probabilistic Method, by M. Molloy and B. Reed, Springer, 2002.

401-3055-64L

Algebraic Methods in Combinatorics

W 5 credits 2V+1U not available

Abstract

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

Content

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lecture notes

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Prerequisites

Students are expected to have a mathematical background and should be able to write rigorous proofs.

401-3601-00L

Probability Theory

W 9 credits 4V+1U V. Tassion

Abstract

Basics of probability theory and the theory of stochastic processes in discrete time

Objective

This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- measure theory formalism and probability theory, Dynkin's lemma and independence, convergence of series of independent random variables, law of large numbers, conditional expectation, martingale convergence theorems, uniform integrability, optional stopping theorem for martingales, the Bienaymé-Galton-Watson process and its R-number, convergence in distribution and the central limit theorem.
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- measure theory formalism and probability theory,
- Dynkin's lemma and independence,
- convergence of series of independent random variables,
- law of large numbers,
- conditional expectation,
- martingale convergence theorems,
- uniform integrability,
- optional stopping theorem for martingales,
- the Bienaymé–Galton-Watson process and its R-number,
- convergence in distribution and the central limit theorem.

The course will be available in electronic form.

**Lecture notes**


**Prerequisites / notice**

- Basic notions in probability theory (probability space, conditional probability, Borel Cantelli, Dynkin Lemma, random variables, expectation, variance, law of large numbers).
- Measure Theory

**Competencies**

- Subject-specific Competencies: Concepts and Theories
- Techniques and Technologies
- Personal Competencies: Creative Thinking

**401-3612-00L Stochastic Simulation**

**Abstract**

This course provides an introduction to statistical Monte Carlo methods. This includes applications of simulations in various fields (Bayesian statistics, statistical mechanics, operations research, financial mathematics), algorithms for the generation of random variables (accept-reject, importance sampling), estimating the precision, variance reduction, introduction to Markov chain Monte Carlo.

**Objective**

Stochastic simulation (also called Monte Carlo method) is the experimental analysis of a stochastic model by implementing it on a computer. Probabilities and expected values can be approximated by averaging simulated values, and the central limit theorem gives an estimate of the error of this approximation. The course shows examples of the many applications of stochastic simulation and explains different algorithms used for simulation. These algorithms are illustrated with the statistical software R.

**Content**

Examples of simulations in different fields (computer science, statistics, statistical mechanics, operations research, financial mathematics).


**Literature**


**Prerequisites / notice**

- Familiarity with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

**401-3622-00L Statistical Modelling**

**Abstract**

In regression, the dependency of a random response variable on other variables is examined. We consider the theory of linear regression with one or more covariates, high-dimensional linear models, nonlinear models and generalized linear models, robust methods, model choice and nonparametric models. Several numerical examples will illustrate the theory.

**Objective**

Introduction into theory and practice of a broad and popular area of statistics, from a modern viewpoint.

**Content**


**Prerequisites / notice**

- This is the course unit with former course title "Regression".
- Credits cannot be recognised for both courses 401-3622-00L Statistical Modelling and 401-0649-00L Applied Statistical Regression in the Mathematics Bachelor and Master programmes (to be precise: one course in the Bachelor and the other course in the Master is also forbidden).

**401-3621-00L Fundamentals of Mathematical Statistics**

**Abstract**

In this course we study the basics of theoretical statistics. The course includes methods for designing estimators, confidence intervals and tests, and various ways to evaluate the accuracy of estimators, confidence intervals and tests. We consider optimality criteria such as admissibility and minimaxity, as well as Bayesian criteria. We will also present the asymptotic point of view.

**Objective**

The aim of this course is to gain insight into the main statistical ideas and concepts.

**Competencies**

- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies
- Personal Competencies: Creative Thinking

**401-4623-00L Time Series Analysis**

**Abstract**

The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

**Objective**

The goal of the course is to have a good overview of the different types of time series and the approaches used in their statistical analysis.
This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exhibited by time series is the dependence between successive observations.

The key topics which will be covered as:

- Stationarity
- Autocorrelation
- Trend estimation
- Elimination of seasonality
- Spectral analysis, spectral densities
- Forecasting

ARIMA, ARIMA, Introduction into GARCH models

The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis

Basic knowledge in probability and statistics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-4632-15L</td>
<td>Causality</td>
<td>W</td>
<td>5</td>
<td>3G</td>
<td>J. Peters</td>
</tr>
<tr>
<td>Abstract</td>
<td>In statistics, we are used to search for the best predictors of some random variable. In many situations, however, we are interested in predicting a system's behavior under manipulations. For such an analysis, we require knowledge about the underlying causal structure of the system. In this course, we study concepts and theory behind causal inference.</td>
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<tr>
<td>Objective</td>
<td>After this course, you should be able to</td>
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<tr>
<td></td>
<td>- understand the language and concepts of causal inference</td>
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<tr>
<td></td>
<td>- know the assumptions under which one can infer causal relations from observational and/or interventional data</td>
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<tr>
<td></td>
<td>- describe and apply different methods for causal structure learning</td>
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<td></td>
<td>- given data and a causal structure, derive causal effects and predictions of interventional experiments</td>
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<tr>
<td>Content</td>
<td>The material covered in this course has a significant overlap with the material that has been covered in 401-3620-22L Student Seminar in Statistics: Causality FS2023.</td>
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<tr>
<td>Literature</td>
<td>Parts of this course will be based on the book &quot;Elements of Causal Inference&quot; (MIT Press, open access). More details will follow.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: basic knowledge of probability theory and regression</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0563-01L</td>
<td>Dynamic Programming and Optimal Control</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>R. D'Andrea</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to Dynamic Programming and Optimal Control.</td>
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<tr>
<td>Objective</td>
<td>Covers the fundamental concepts of Dynamic Programming &amp; Optimal Control.</td>
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<tr>
<td>Content</td>
<td>Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.</td>
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Other courses that overlap with this course are:

- 151-0563-01L Dynamic Programming and Optimal Control
- 261-5112-00L Algorithms and Data Structures for Population Scale Genomics
- 263-5351-00L Machine Learning for Genomics

The course reviews solutions provided by machine learning to the most challenging questions in human genomics.

Over the last few years, the parallel development of machine learning methods and molecular profiling technologies for human cells, such as sequencing, created an extremely powerful tool to get insights into the cellular mechanisms in healthy and diseased contexts. In this course, we will discuss the state-of-the-art machine learning methodology solving or attempting to solve common problems in human genomics. At the end of the course, you will be familiar with (1) classical and advanced machine learning architectures used in genomics, (2) bioinformatics analysis of human genomic and transcriptomic data, and (3) data types used in this field.
### 636-0017-00L Computational Biology

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<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td></td>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Creative Thinking</td>
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<tr>
<td></td>
<td>Communication</td>
<td>Decision-making</td>
<td>Critical Thinking</td>
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</table>

**Abstract**
The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

**Objective**
Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:
- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics
- epidemiology
- pathogen evolution
- macromutation of species

**Content**
The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS.

Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylogenetics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

**Lecture notes**
Lecture slides will be available on moodle.

**Literature**
The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:
- Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.

**Prerequisites / notice**

**Computationally continuous performance assessments.** In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place in Basel before the start of the semester.

### 252-1411-00L Security of Wireless Networks

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<th>Competencies</th>
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<th>Social Competencies</th>
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<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Cooperation and Teamwork</td>
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<td>fostered</td>
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<td>Techniques and Technologies</td>
<td>Decision-making</td>
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<td>Problem-solving</td>
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**Abstract**
This course discusses physical layer aspects of wireless communication and a wide range of security-related topics in the domain of wireless technologies. It mainly targets computer science students. Though useful, a background in signal processing or physical layer concepts is not required. A basic understanding of security (e.g. as taught in 252-0211.00L Information Security) is recommended.

**Objective**
After this course, students should be able to describe and classify security goals of and attacks on various wireless networks and technologies, with an emphasis on physical layer aspects.

**Content**
- Introduction to wireless communication
- Physical layer security schemes
- Spreading techniques and their application in jamming-resistant communication and Global Navigation Satellite Systems (GNSSs)
- Secure ranging with Ultra-Wide Band (UWB)
- Security aspects of cellular networks, WiFi, and Bluetooth Low Energy (BLE)

**Computationally continuous performance assessments.** In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place in Basel before the start of the semester.

**Prerequisites / notice**

**Computationally continuous performance assessments.** In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place in Basel before the start of the semester.

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**Data:** 15.06.2024 12:39

**Autumn Semester 2024**

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In 2023, the course will cover advanced topics in communication networks such as:

- Advanced Internet routing (convergence, optimality, scalability, flexibility);
- Network programmability (OpenFlow, P4);
- Traffic engineering / Load Balancing;
- Network verification and synthesis;
- Network measurements;
- Network security;
- Upcoming transport protocols and technologies;
- Adaptive video streaming; and
- Network sustainability.

The course will be composed of lectures and practical exercises (some of which including labs).

<table>
<thead>
<tr>
<th>Competencies</th>
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<tbody>
<tr>
<td>- Students are familiar with fundamental network-security concepts.</td>
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<td>- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.</td>
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<td>- Students can identify and assess vulnerabilities in software systems and network protocols.</td>
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<tr>
<td>- Students have an in-depth understanding of a range of important state-of-the-art security technologies.</td>
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<tr>
<td>- Students can implement network-security protocols based on cryptographic libraries.</td>
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</table>

The course will cover topics spanning four broad themes with a focus on the first two themes:

1. network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. analysis and inference topics such as traffic monitoring and network forensics; and
4. new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
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<tbody>
<tr>
<td>This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course. The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.</td>
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<table>
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<td>- Students can implement network-security protocols based on cryptographic libraries.</td>
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</table>

263-4640-00L **Network Security**

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<thead>
<tr>
<th>Objective</th>
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<tr>
<td>This course provides an in-depth study of network attack techniques and methods to defend against them.</td>
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<tr>
<td>This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course. The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.</td>
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401-3913-01L **Mathematical Foundations for Finance**

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<th>Objective</th>
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<tbody>
<tr>
<td>First introduction to main modelling ideas and mathematical tools from mathematical finance</td>
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<tr>
<th>Prerequisites / notice</th>
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<tbody>
<tr>
<td>This course gives a first introduction to the main modelling ideas and mathematical tools from mathematical finance. It mainly aims at non-mathematicians who need an introduction to the main tools from stochastics used in mathematical finance. However, mathematicians who want to learn some basic modelling ideas and concepts for quantitative finance (before continuing with a more advanced course) may also find this of interest. The main emphasis will be on ideas, but important results will be given with (sometimes partial) proofs.</td>
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<tr>
<th>Competencies</th>
<th>Content</th>
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</table>
Topics to be covered include:

- financial market models in finite discrete time
- absence of arbitrage and martingale measures
- valuation and hedging in complete markets
- basics about Brownian motion
- stochastic integration
- stochastic calculus: Itô’s formula, Girsanov transformation, Itô’s representation theorem
- Black-Scholes formula

Lecture notes

See information on course homepage

Prerequisites:

Prerequisites: Results and facts from probability theory as in the book “Probability Essentials” by J. Jacod and P. Protter will be used freely. Especially participants without a direct mathematics background are strongly advised to familiarise themselves with those tools before (or very quickly during) the course. (A possible alternative to the above English textbook are the (German) lecture notes for the standard course “Wahrscheinlichkeitsrechnung”.)

For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.

Competencies

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<tr>
<th>Subject-specific Competencies</th>
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<tbody>
<tr>
<td>Analytical Competencies</td>
<td>Decision-making</td>
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<tr>
<td>Problem-solving</td>
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<td>Fostered</td>
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<tr>
<td>Adaptable and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Fostered</td>
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<tr>
<td>Integrity and Work Ethics</td>
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401-3922-00L Life Insurance Mathematics

Abstract

The classical life insurance model is presented together with the important insurance types (insurance on one and two lives, term and endowment insurance and disability). Besides that the most important terms such as mathematical reserves are introduced and calculated. The profit and loss account and the balance sheet of a life insurance company is explained and illustrated.

401-3925-00L Non-Life Insurance: Mathematics and Statistics

Abstract

Does not take place this semester.

Objective

The student is familiar with the basics in non-life insurance mathematics and statistics. This includes the basic mathematical models for insurance liability modeling, pricing concepts, stochastic claims reserving models and ruin and solvency considerations.

Content

The following topics are treated:

- Collective Risk Modeling
- Claim Counts Models
- Individual Claim Size Modeling
- Censoring and Truncation
- Approximations for Compound Distributions
- Ruin Theory in Discrete Time
- Premium Calculation Principles
- Tarification
- Generalized Linear Models and Neural Networks
- Bayesian Models and Credibility Theory
- Claims Reserving
- Solvency Considerations

Lecture notes

M.V. Wüthrich, Non-Life Insurance: Mathematics & Statistics
http://ssrn.com/abstract=2319328

Literature

M.V. Wüthrich, M. Merz. Statistical Foundations of Actuarial Learning and its Applications

Prerequisites:

The exams ONLY take place during the official ETH examination period (no semester end exams), and only in person exams (i.e. no remote exams).

This course will be held in English and counts towards the diploma of “Aktuar SAV”. For the latter, see details under www.actuaries.ch.

Competencies

<table>
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<tr>
<th>Subject-specific Competencies</th>
<th>Methods and Technologies</th>
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<tbody>
<tr>
<td>Analytical Competencies</td>
<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<tr>
<td>Project Management</td>
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261-5111-00L Asset Management: Advanced Investments (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: MFOEC207

Mind the enrolment deadlines at UZH:

Abstract

Comprehension and application of advanced portfolio theory

Objective

Comprehension and application of advanced portfolio theory
The theoretical part of the lecture consists of the topics listed below.

- Standard Markowitz Model and Extensions MV Optimization, MV with Liabilities and CAPM.
- The Crux with MV
- Resampling, regression, Black-Litterman, Bayesian, shrinkage, constrained and robust optimization.
- Downside and Coherent Risk Measures
- Definition of risk measures, MV optimization under VaR and ES constraints.
- Risk Budgeting
- Equal risk contribution, most diversified portfolio and other concentration indices
- Regime Switching and Asset Allocation

An introduction to regime switching models and its intuition.

- Strategic Asset Allocation
Introducing a continuous-time framework, solving the HJB equation and the classical Merton problem.

401-4889-00L Mathematical Finance W 10 credits 4V+2U B. Acciaio

Abstract
Advanced course on mathematical finance:
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- additional topics

Objective
Advanced course on mathematical finance, presupposing good knowledge in probability theory and stochastic calculus (for continuous processes).

Content
This is an advanced course on mathematical finance for students with a good background in probability. We want to give an overview of main concepts, questions and approaches, and we do this mostly in continuous-time models.

Topics include
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- and probably others

Lecture notes
The course is based on different parts from different books as well as on original research literature.

Literature
While there are many textbooks on mathematical finance, none of them is ideal to cover the contents of this course. References include the following books:

Prerequisites / notice
Prerequisites are the standard courses
- Probability Theory (for which lecture notes are available)
- Brownian Motion and Stochastic Calculus (for which lecture notes are available)
Those students who already attended "Introduction to Mathematical Finance" will have an advantage in terms of ideas and concepts.

This course is the second of a sequence of two courses on mathematical finance. The first course "Introduction to Mathematical Finance" (MF I), 401-3888-00, focuses on models in finite discrete time. It is advisable that the course MF I is taken prior to the present course, MF II.

For an overview of courses offered in the area of mathematical finance, see https://www.math.ethz.ch/imsf/education/education-in-stochastic-finance/overview-of-courses.html.

103-0227-00L Application Development in Cartography W 6 credits 4G A. Neumann

Abstract
This course introduces concepts and techniques in 3D cartography and web application development. Practical experience will be gained in a map project.

Objective
Students acquire general knowledge about the foundations and best practices in 3D cartography and modern web application development. They learn to plan, design and implement an interactive and animated 3D web map.
Content
- 3D cartography
- Web mapping
- Data processing
- Animations and interactions
- Map and UI design
- Web application development
- Programming (JavaScript).

Lecture notes
Handouts of the lectures and exercise documents are available on Moodle.

Prerequisites / notice
Cartography II or Introduction to Web Cartography Part 1+2 (MOOC) or similar knowledge in mapping with JavaScript.

Competencies

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<th>Competencies</th>
<th>Techniques and Technologies</th>
<th>Analytical Competencies</th>
<th>Media and Digital Technologies</th>
<th>Problem-solving</th>
<th>Project Management</th>
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<th>Self-direction and Self-management</th>
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<td>Subject-specific Competencies</td>
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Abstract
Geoinformationstechnologien und -analysen für Fortgeschrittene: Mobile GIS; Web-GIS & Geo-Web-Services; Spatial Big Data; Zeittliche Aspekte in GIS; Analyse von Bewegungsdaten; Benutzerschnittstellen

Objective

Content
- Mobile GIS
- Web-GIS & Geo-Web-Services
- Spatial Big Data
- Zeitliche Aspekte in GIS
- Analyse von Bewegungsdaten
- Benutzerschnittstellen

Competencies

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Abstract
Independent study project with novel geoinformation technologies. Information on past projects: http://gis-lab.ethz.ch/

Objective
This lab focuses on presenting spatial, temporal, and open data in tangible ways. Students will learn how to work with novel geoinformation technologies such as virtual/mixed reality or mobile applications. They will engage in teamwork, application design, programming and presenting their results.

Competencies

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Abstract
Building a Robot Judge: Data Science for Decision-Making

Does not take place this semester.
Deep-Learning (DL) is a brain-inspired weak form of AI that allows training of large artificial neuronal networks (ANNs), similar to those found in the human brain. ANNs are trained using algorithms that are inspired by the way the brain learns, which involves adjusting the strength of connections between neurons based on experience. This allows them to learn from data and improve their performance over time. However, ANNs are not without limitations. They require large amounts of training data, and their performance can be limited in certain domains without sufficient data.

The workshop and lecture series will present a mix of speakers who represent the wide range of current social science research methods ranging from single synapses to entire networks. To achieve this, the lectures and exercises will merge ideas, concepts, and methods from machine learning and neuroscience. Personal Competencies will be developed through presentation skills, professional behavior, and the ability to work in teams. Social Competencies will be developed through presentation skills, professional behavior, and the ability to work in teams. Also, participants will develop a diverse skill set that is required to understand learning in large, hierarchical neuronal networks. This includes the ability to simulate spiking neuronal networks that learn simple (e.g., digit classification) tasks in a supervised manner.

Objective

After the workshop and lecture series, participants should be acquainted with interdisciplinary approaches towards intellectual property, innovation, antitrust, privacy, and technology policy research. They should also have an overview of current topics of international research in these areas.

Content

The workshop and lecture series will present a mix of speakers who represent the wide range of current social science research methods ranging from single synapses to entire networks. To achieve this, the lectures and exercises will merge ideas, concepts, and methods from machine learning and neuroscience. Personal Competencies will be developed through presentation skills, professional behavior, and the ability to work in teams. Social Competencies will be developed through presentation skills, professional behavior, and the ability to work in teams. Also, participants will develop a diverse skill set that is required to understand learning in large, hierarchical neuronal networks. This includes the ability to simulate spiking neuronal networks that learn simple (e.g., digit classification) tasks in a supervised manner.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is it that the defendant will commit another crime? How much additional revenue will this new tax law collect? Students will be introduced to emerging applied research in this vein. In a semester paper, students (individually or in groups) will conceive and implement an applied data-science research project.
Prerequisites / notice
This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:

1) The number of participants is limited to 120 students (MSc and PhDs).

2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

227-1033-00L  Neuroromophic Engineering I

Registration in this class requires the permission of the instructors. Class size will be limited to available lab spots. Preference is given to students that require this course as part of their major.

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module INI404 at UZH.
Please mind the ETH enrolment deadlines for UZH students: https://ethz.ch/en/studies/non-degree-courses/special-students/university-of-zurich.html

Abstract
This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Objective
Understanding of the characteristics of neuromorphic circuit elements.

Content
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Literature
S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

Prerequisites / notice
Particular: This course is highly recommended for those who intend to take the spring semester course 'Neuromorphic Engineering II', that teaches the conception, simulation, and physical layout of such circuits with chip design tools.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

227-1037-00L  Introduction to Neuroinformatics

The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.

Abstract
Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

Content
This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.

227-1051-00L  Systems Neuroscience (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI415

Mind the enrolment deadlines at UZH:

Abstract
This course focuses on basic aspects of central nervous system physiology, including perception, motor control and cognitive functions.

Objective
To understand the basic concepts underlying perceptual, motor and cognitive functions.

Content
Main emphasis sensory systems, with complements on motor and cognitive functions.

Lecture notes
None

Literature

Prerequisites / notice
none
Network Analysis

Particularly suitable for students of D-INFK, D-MATH.

Abstract
Network science is a distinct domain of data science that is characterized by a specific kind of data being studied. While areas of application range from archaeology to zoology, we concern ourselves with social networks for the most part. Emphasis is placed on descriptive and analytic approaches rather than theorizing, modeling, or data collection.

Objective
Students will be able to identify and categorize research problems that call for network approaches while appreciating differences across application domains and contexts.

In particular, they will be able to evaluate such methods in terms of appropriateness and efficiency.

Content
The following topics will be covered with an emphasis on structural and computational approaches and frequent reference to their suitability with respect to substantive theory:

* Empirical Research and Network Data
* Macro and Micro Structure
* Centrality
* Roles
* Cohesion
* Influence

Lecture notes
Slides and lecture notes are distributed via the associated course moodle.

Literature

Network Modeling

Particularly suitable for students of D-MATH, D-INFK and in the MSc Data Science

Students are required to have basic knowledge in inferential statistics, such as regression models.

Abstract
Social Network Science is a distinct domain of data science that focuses on relational systems. Various models have been proposed to describe structures and dynamics of networks, including statistical and mathematical methods. In this course, the emphasis is placed on the statistical analysis of (social) systems and their connection to social theories and data sources.

Objective
The following topics will be covered:

- Introduction to network models and their applications
- Stylized models:
  * uniform random graph models
  * small world models
  * preferential attachment models
- Models for testing hypotheses while controlling for the network structure:
  * Quadratic assignment procedure regression (QAP regression)
- Models for testing hypotheses on the network structure:
  * Models for one single observation of a network: exponential random graph models (ERGMs)
  * Models for panel network data: stochastic actor-oriented models (SAOMs)

The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.
The following topics will be covered:

- Introduction to network models and their applications
- Stylized models:
  * uniform random graph models
  * small world models
  * preferential attachment models
- Models for testing hypotheses while controlling for the network structure:
  * Quadratic assignment procedure regression (QAP regression)
- Models for testing hypotheses on the network structure:
  * Models for one single observation of a network: exponential random graph models (ERGMs)
  * Models for panel network data: stochastic actor-oriented models (SAOMs)
  * Models for relational event data: dynamic network actor models (DyNAMs)

The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

Students are required to have basic knowledge in inferential statistics and should be familiar with linear and logistic regression models.
This course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based simulation models' current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in groups.

**Objective**
At the end of the course, the students should:
- have an understanding of agent-based modeling
- have an understanding of MATSim
- have an understanding of the process needed to set up an agent-based study
- have practical experience of using MATSim to perform transportation studies

**Content**
This course provides an introduction to agent-based models for transportation policy analysis. Four essential topics are covered:

1. Introduction of agent-based modeling and its comparison to the traditional state of practice modeling
2. MATSim, an open-source agent-based model, developed at ETH Zurich and TU Berlin, and its various parts
3. Setting up an agent-based model simulation, where different statistical methods used in the process will be introduced and explained.
4. Conducting a transport policy study. The case study will be performed in groups and will include a paper-like report.

**Literature**
Agent-based modeling in general

MATSim

**Prerequisites / notice**
There are no strict preconditions regarding which lectures the students should have previously attended. However, experience with at least one high-level programming language (Java, R, Python, or other) is recommended.

For those without object-oriented programming experience, a crash course 101-0491-10 Basics of Java and Best Practices for Scientific Computing before the start of HS is recommended.

**Competencies**

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<td>Techniques and Technologies</td>
<td>Analytical Competencies</td>
<td>Cooperation and Teamwork</td>
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**W 3 credits 2V**

**701-0023-00L Atmosphere**

**Abstract**
Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

**Objective**
Students are able
- to explain the physical structure and chemical composition of the atmosphere
- to quantitatively describe and understand the fundamental physical and chemical process in the atmosphere
- to explain the interactions and feedbacks between atmosphere - ocean - land surface, troposphere - stratosphere and weather - climate.

In the course "Atmosphere", the competencies of process understanding, system understanding and data analysis & interpretation are taught, applied and examined.

**Content**
Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds.

**Lecture notes**
Written information will be supplied.

**Literature**

**Competencies**

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**701-0473-00L Weather Systems**

**Abstract**
Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; Potential Vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer; water isotope

**Objective**
The students are able to
- explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- to discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
- to explain how mountains influence the atmospheric flow on different scales

- basic understanding of stable water isotopes as tracers for moist adiabatic processes in weather systems

**Content**
Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; Potential Vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer; water vapour transport in the atmosphere; water isotope

**Lecture notes**
Lecture notes and slides
The students will learn how to design and implement state-of-the-art algorithms for planning the motion of robots executing challenging tasks in complex environments. This course will cover the algorithmic foundations of motion planning, with an eye to real-world implementation issues. Planning safe and efficient motions for robots in complex environments, often shared with humans and other robots, is a difficult problem combining discrete and continuous mathematics, as well as probabilistic, game-theoretic, and ethical/regulatory aspects. This course will foster the development of tools from data science and social science to a new project, potentially in a group, to develop a paper or app.

**Prerequisites / notice**

Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

**Competencies**

- **Analytical Competencies**
  - Conceptual Thinking
  - Creative Thinking
- **Social Competencies**
  - Cooperation and Teamwork
- **Personal Competencies**
  - Critical Thinking

**Literature**

Prerequisites / notice

Students should have taken basic courses in optimization, control systems, probability theory, and should be familiar with modern programming languages and practices (e.g., Python, and/or C/C++). Previous exposure to robotic systems is a definite advantage.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Decision-making
- Problem-solving

151-0563-01L Dynamic Programming and Optimal Control

Introduction to Dynamic Programming and Optimal Control.

Covers the fundamental concepts of Dynamic Programming & Optimal Control.

Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.


Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

Prerequisites / notice

151-0632-00L Vision Algorithms for Mobile Robotics (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: DINF2039

Mind the enrolment deadlines at UZH:

Abstract

For a robot to be autonomous, it has to perceive and understand the world around it. This course introduces you to the key computer vision algorithms used in mobile robotics, such as feature extraction, structure from motion, dense reconstruction, tracking, and visual-inertial odometry. The course will cover computer vision using a combination of theoretical lectures and practical exercises.

Objective

Learn the fundamental computer vision algorithms used in mobile robotics, in particular: filtering, feature extraction, structure from motion, multiple view geometry, dense reconstruction, tracking, image retrieval, event-based vision, and visual-inertial odometry. The course will cover the algorithms behind Hololens, Oculus Quest, and the NASA Mars rovers.

Content

Each lecture will be followed by a lab session where you will learn to implement a building block of a visual odometry algorithm in Matlab. By the end of the course, you will integrate all these building blocks into a working visual odometry algorithm.

Literature


Lecture notes

Lecture slides will be made available on the course official website: http://rpg.ifi.uzh.ch/teaching.html

Prerequisites / notice

Fundamentals of algebra, geometry, matrix calculus, and Matlab programming.

Note: If you are interested in taking UZH courses, you must register as an incoming mobility student at UZH. For details, see as follows:

UZH course enrollment for ETH student at University of Zurich (UZH) > Mobility within Switzerland – Incoming > Module Mobility: The easiest way to take individual modules/courses to supplement your studies at your home university is with module mobility. This option is not available to students who have dropped out of their home university or have been definitively excluded or banned from the relevant program > Application and Deadlines: Applications are submitted via the UZH application portal (https://www.uzh.ch/cmsssl/en/studies/application/launch.html)

ATTENTION: When you book the course at UZH, you are automatically registered for the exam at UZH and you can unregister until the October deadline. After registering for the course, you as an ETH student need to check out your **“UZH email account”** to receive the related information from the lecturer.

151-0851-00L Robot Dynamics

We will provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing.

The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems. The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

The course consists of three parts: First, we will refresh and deepen the student’s knowledge in kinematics, dynamics, and rotations of multi-body systems. In this context, the learning material will build upon the courses for mechanics and dynamics available at ETH, with the particular focus on their application to robotic systems. The goal is to foster the conceptual understanding of similarities and differences among the various types of robots. In the second part, we will apply the learned material to classical robotic arms as well as legged systems and discuss kinematic constraints and interaction forces. In the third part, focus is put on modeling fixed wing aircraft, along with related design and control concepts. In this context, we also touch aerodynamics and flight mechanics to an extent typically required in robotics. The last part finally covers different helicopter types, with a focus on quadrotors and the coaxial configuration which we see today in many UAV applications. Case studies on all main topics provide the link to real applications and to the state of the art in robotics.

The contents of the following ETH Bachelor lectures or equivalent are assumed to be known: Mechanics and Dynamics, Control, Basics in Fluid Dynamics.

Prerequisites / notice

151-0703-00L Control Systems

Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Objective

Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Note: If you are interested in taking UZH courses, you must register as an incoming mobility student at UZH. For details, see as follows:

UZH course enrollment for ETH student at University of Zurich (UZH) > Mobility within Switzerland – Incoming > Module Mobility: The easiest way to take individual modules/courses to supplement your studies at your home university is with module mobility. This option is not available to students who have dropped out of their home university or have been definitively excluded or banned from the relevant program > Application and Deadlines: Applications are submitted via the UZH application portal (https://www.uzh.ch/cmsssl/en/studies/application/launch.html)

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Content

Literature

Prerequisites / notice
Prerequisites: Signal and Systems Theory II.
MATLAB is used for system analysis and simulation.

Additional Electives
- All courses on master's level from D-INFK, D-ITET and D-MATH
- All courses listed in the Interdisciplinary Electives

Data Science Lab

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<td>10 credits</td>
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<td>A. Ilie, V. Boeva, R. Cotterell, J. Vogt, F. Yang</td>
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Abstract
In this class, we bring together data science applications provided by ETH researchers outside computer science and teams of computer science master’s students. Two to three students will form a team working on data science/machine learning-related research topics provided by scientists in a diverse range of domains such as astronomy, biology, social sciences etc.

Objective
The goal of this class if for students to gain experience of dealing with data science and machine learning applications “in the wild”. Students are expected to go through the full process starting from data cleaning, modeling, execution, debugging, error analysis, and quality/performance refinement.

Prerequisites / notice
Prerequisites: At least 8 KP must have been obtained under Data Analysis and at least 8 KP must have been obtained under Data Management and Processing.

Master Studies (Programme Regulations 2017)

Core Courses

Data Analysis

Information and Learning

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<td>Advanced Machine Learning</td>
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<td>3V+2U+4A</td>
<td>C. Cotrini Jimenez</td>
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Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real-world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
- Computational learning theory
  - Supervised learning:
    - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
  - Unsupervised learning:
    - Dimensionality reduction techniques
    - Clustering
    - Mixture Models
    - Non-parametric density estimation
- Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.
Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
Abstract
The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations.

Objective
Do you want to be able to query your own data productively and efficiently in your future semester projects, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This courses teaches you how to do so as well as the dos and don'ts.

“Big Data” refers to the case when the amount of data is very large (100 GB and more), or when the data is not completely structured (or messy). The Big Data revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it are needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

Content
This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage(S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Large scale analytics and machine learning are outside of the scope of this course.

Course textbook: https://ghislainfourny.github.io/big-data-textbook/

Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

Prerequisites / notice
The lecture is hybrid, meaning you can attend with us in the lecture hall, or on Zoom, or watch the recordings on YouTube later. Exercise sessions are in presence.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departements interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases); this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2023

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.
<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>Decision-making</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Media and Digital Technologies</td>
<td>fostered</td>
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<td>Problem-solving</td>
<td>fostered</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
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<td>fostered</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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<td>fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td></td>
<td>fostered</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
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<td>assessed</td>
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</tbody>
</table>

**263-3845-00L Data Management Systems**

**W 8 credits 3V+1U+3A G. Alonso**

**Abstract**

The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.

**Objective**

The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in-depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.

**Content**

The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place a special emphasis on understanding these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

**Literature**

The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

**Prerequisites / notice**

The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

**Competencies**

- Subject-specific Competencies: Concepts and Theories, Techniques and Technologies
- Fostered Competencies: Information Theory I, Dynamic Programming and Optimal Control

### Core Electives

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0563-01L</td>
<td>Dynamic Programming and Optimal Control</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>R. D’Andrea</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Introduction to Dynamic Programming and Optimal Control</td>
<td>Covers the fundamental concepts of Dynamic Programming &amp; Optimal Control.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.</td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Discrete-Time and Statistical Signal Processing</th>
<th>W</th>
<th>6</th>
<th>4G</th>
<th>H.-A. Loeliger</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>The course is about some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The course is about some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust &quot;inversion&quot; of a linear filter.</td>
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<tr>
<td><strong>Content</strong></td>
<td>1. Discrete-time linear systems and filters: state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.</td>
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<td>2. The discrete Fourier transform and its use for digital filtering.</td>
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<td></td>
<td>3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Lecture Notes</td>
<td></td>
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</tbody>
</table>

**227-0417-00L Information Theory I**

**W 6 credits 4G A. Lapidoth**

**Abstract**

This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

**Objective**

The fundamentals of Information Theory including Shannon’s source coding and channel coding theorems

**Content**

The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

**Literature**

T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

**227-0560-00L Computer Vision and Artificial Intelligence for Autonomous Cars**

**W 6 credits 3V+2P C. Sakaridis**

Up until FS2022 offered as Deep Learning for Autonomous Driving
Abstract
This course introduces the core computer vision techniques and algorithms that autonomous cars use to perceive the semantics and geometry of their driving environment, localize themselves in it, and predict its dynamic evolution. Emphasis is placed on techniques tailored for real-world settings, such as multi-modal fusion, domain-adaptive and outlier-aware architectures, and multi-agent methods.

Objective
Students will learn about the fundamentals of autonomous cars and of the computer vision models and methods these cars use to analyze their environment and navigate themselves in it. Students will be presented with state-of-the-art representations and algorithms for semantic, geometric and temporal visual reasoning in automated driving and will gain hands-on experience in developing computer vision algorithms and architectures for solving such tasks.

After completing this course, students will be able to:
1. understand the operating principles of visual sensors in autonomous cars
2. differentiate between the core architectural paradigms and components of modern visual perception models and describe their logic and the role of their parameters
3. systematically categorize the main visual tasks related to automated driving and understand the primary representations and algorithms which are used for solving them
4. critically analyze and evaluate current research in the area of computer vision for autonomous cars
5. practically reproduce state-of-the-art computer vision methods in automated driving
6. independently develop new models for visual perception

Content
The content of the lectures consists in the following topics:

1. Fundamentals
   (a) Fundamentals of autonomous cars and their visual sensors
   (b) Fundamental computer vision architectures and algorithms for autonomous cars

2. Semantic perception
   (a) Semantic segmentation
   (b) Object detection
   (c) Instance segmentation and panoptic segmentation

3. Geometric perception and localization
   (a) Depth estimation
   (b) 3D reconstruction
   (c) Visual localization
   (d) Unimodal visual/lidar 3D object detection

4. Robust perception: multi-modal, multi-domain and multi-agent methods
   (a) Multi-modal 2D and 3D object detection
   (b) Visual grounding and verbo-visual fusion
   (c) Domain-adaptive and outlier-aware semantic perception
   (d) Vehicle-to-vehicle communication for perception

5. Temporal perception
   (a) Multiple object tracking
   (b) Motion prediction

The practical projects involve implementing complex computer vision architectures and algorithms and applying them to real-world, multi-modal driving datasets. In particular, students will develop models and algorithms for:
1. Semantic segmentation and depth estimation
2. Sensor calibration for multi-modal 3D driving datasets
3. 3D object detection using lidars

Lecture notes
Lecture slides are provided in PDF format.

Prerequisites / notice
Students are expected to have a solid basic knowledge of linear algebra, multivariate calculus, and probability theory, and a basic background in computer vision and machine learning. All practical projects will require solid background in programming and will be based on Python and libraries of it such as PyTorch.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

227-0689-00L System Identification W 4 credits 2V+1U R. Smith
Abstract
Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.

Objective
To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.

Content
Introduction to modeling: Black-box and grey-box models; Parametric and non-parametric models; ARX, ARMAX (etc.) models.

Predictive, open-loop, black-box identification methods. Time and frequency domain methods. Subspace identification methods.

Optimal experimental design, Cramer-Rao bounds, input signal design.

Parametric identification methods. On-line and batch approaches.

Closed-loop identification strategies. Trade-off between controller performance and information available for identification.

Literature

Prerequisites / notice
Control systems (227-0216-00L) or equivalent.

227-2210-00L Computer Architecture W 8 credits 6G+1A S. Sadrosadati, O. Mutlu

Abstract
Autumn Semester 2024
Abstract
Computer architecture is the science & art of designing and optimizing hardware components and the hardware/software interface to create a computer that meets design goals. This course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.

Objective
We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), new paradigms like processing-in-memory, parallel computing systems (including multicore processors, coherence and consistency, GPUs), heterogeneous computing, interconnection networks, specialized systems for major data-intensive workloads (e.g. graph analytics, bioinformatics, machine learning), etc. We will focus on fundamentals as well as cutting-edge research. Significant attention will be given to real-life examples and tradeoffs, as well as critical analysis of modern computing systems.

Content
The principles presented in the lecture are reinforced in the laboratory through 1) the design and implementation of a cycle-accurate simulator, where we will explore different components of a modern computing system (e.g., pipeline, memory hierarchy, branch prediction, prefetching, caches, multithreading), and 2) the extension of state-of-the-art research simulators (e.g., Ramulator) for more in-depth understanding of specific system components (e.g., memory scheduling, prefetching).

See the course website for detailed and complete content of past incarnations of the course: https://safari.ethz.ch/architecture

Lecture notes
All the materials (including lecture slides) will be provided on the course website: https://safari.ethz.ch/architecture/

The video recordings of the lectures are expected to be made available after lectures.

See https://safari.ethz.ch/architecture for past examples.

Literature
We will provide required and recommended readings in every lecture. They will mainly consist of research papers presented in major Computer Architecture and related conferences and journals.

See https://safari.ethz.ch/architecture for past examples.

Prerequisites / notice

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Problem-solving assessed

Social Competencies
- Communication assessed
- Leadership and Responsibility assessed

Personal Competencies
- Adaptability and Flexibility assessed
- Critical Thinking assessed
- Self-direction and Self-management assessed

252-1414-00L System Security W 7 credits 2V+2U+2A S. Capkun, S. Shinde

252-3005-00L Natural Language Processing W 7 credits 3V+3U+1A R. Cotterell

261-5130-00L Research in Data Science W 6 credits 13A Professors
Students learn how to solve algorithmic problems given by a textual description (understanding problem setting, finding appropriate modeling, choosing suitable algorithms, and implementing them). Knowledge of basic algorithms and data structures is assumed; more advanced material and usage of standard libraries for combinatorial algorithms are introduced in tutorials.

The objective of this course is to learn how to solve algorithmic problems given by a textual description. This includes appropriate problem modeling, choice of suitable (combinatorial) algorithms, and implementing them (using C/C++, STL, CGAL, and BGL).


This InterFocus Course will provide a broad, hands-on introduction to Information Security, introducing adversarial thinking and security by design as key approaches to building secure systems.

This course will introduce key concepts from Information Security, both from attack and defense perspectives. Students will gain an appreciation of the complexity and challenge of building secure systems.
The course is organised in three-week segments. In each segment, a new concept from Information Security will be introduced. The overall scope will be broad, including cryptography, protocol design, system security, and privacy.

Will be made available during the semester.

Paul C. van Oorschot, Computer Security and the Internet: Tools and Jewels.
Dan Boneh and Victor Shoup, A Graduate Course in Applied Cryptography.

Ideally, students will have taken the D-INFK Bachelors course “Information Security” or an equivalent course at Bachelors level.

Subject-specific Competencies
Methods-specific Competencies
Personal Competencies

Robustness of Machine Learning
- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

Privacy of Machine Learning
- Threat models (e.g., stealing data, poisoning, membership inference, etc.).
- Attacking federated machine learning (across vision, natural language and tabular data).
- Differential privacy for defending machine learning.
- AI Regulations and checking model compliance.

Fairness of Machine Learning
- Introduction to fairness (motivation, definitions).
- Enforcing individual fairness (for both vision and tabular data).
- Enforcing group fairness (e.g., demographic parity, equalized odds).

Robustness, Privacy and Fairness of Foundation Models
- We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).


While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in "Intro to ML" classes at most institutions (e.g., "Introduction to Machine Learning" at ETH).

The coding project will utilize Python and PyTorch. Thus some programming experience in Python is expected. Students without prior knowledge of PyTorch are expected to acquire it early in the course by solving exercise sheets.

Subject-specific Competencies
Methods-specific Competencies
Personal Competencies

263-2000-00L Design of Parallel and High-Performance Computing W 9 credits 2V+2U+4A T. Höfler

Abstract

Objective

Content

Literature

Prerequisites / notice

Competencies

Assessment

263-0006-00L Algorithms Lab W 8 credits 4P+3A A. Steger

Abstract

Objective

Literature

Prerequisites / notice

Competencies

Assessment

263-0009-00L Information Security Lab W 8 credits 2V+1U+3P+1A S. Shinde, D. Basin, S. Capkun, K. Paterson

Abstract

Objective

Content

Literature

Prerequisites / notice

Competencies

Assessment

263-2400-00L Reliable and Trustworthy Artificial Intelligence W 6 credits 2V+2U+1A M. Vechev

Abstract

Objective

Content

Prerequisites / notice

Competencies

Assessment

263-2800-00L Design of Parallel and High-Performance Computing W 9 credits 2V+2U+4A T. Höfler

Abstract

Objective

Content

Literature

Prerequisites / notice

Competencies

Assessment
The course will start with an introduction to data mining techniques (e.g., prediction, structured discovery, visualization, and relationship mining) relevant to analyzing educational data. We will then continue with topics on personalization in AI in educational technologies (e.g., learner modeling and knowledge tracing, self-improving AIED systems) while showcasing exemplary applications in areas such as content curation and dialog-based tutoring. Finally, we will cover ethical challenges associated with using AI in student-facing settings. Face-to-face meetings will be held every fortnight, although students will be expected to work individually on weekly tasks (e.g., discussing relevant literature, working on problems, preparing seminar presentations).

### 263-5005-00L Artificial Intelligence in Education

**Objective**
The course will be centered around exploring methodological and system-focused perspectives on designing AI systems for education and analyzing educational data using AI methods. Students will be expected to a) engage in presentations and active in-class and asynchronous discussion, and b) work on problem-sets exemplifying the use of educational data mining techniques.

**Content**
The course will start with an introduction to data mining techniques (e.g., prediction, structured discovery, visualization, and relationship mining) relevant to analyzing educational data. We will then continue with topics on personalization in AI in educational technologies (e.g., learner modeling and knowledge tracing, self-improving AIED systems) while showcasing exemplary applications in areas such as content curation and dialog-based tutoring. Finally, we will cover ethical challenges associated with using AI in student-facing settings. Face-to-face meetings will be held every fortnight, although students will be expected to work individually on weekly tasks (e.g., discussing relevant literature, working on problems, preparing seminar presentations).

**Lecture notes**
Lecture slides will be made available at the course Web site.

**Literature**
No textbook is required, but there will be regularly assigned readings from research literature, linked to the course website.

**Prerequisites / notice**
There are no prerequisites for this class. However, it will help if the student has taken an undergraduate or graduate level class in statistics, data science or machine learning. This class is appropriate for advanced undergraduates and master students in Computer Science as well as PhD students in other departments.

### 263-5210-00L Probabilistic Artificial Intelligence

**Objective**
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit “intelligent” behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

**Content**
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

**Prerequisites / notice**
Solid basic knowledge in statistics, algorithms and programming. The material covered in the course “Introduction to Machine Learning” is considered as a prerequisite.
The objectives of this course are:

- understand a good fraction of theory papers published in the typical ML venues. For this purpose, students will learn common mathematical techniques from statistical learning in the first part of the course and apply this knowledge in the project work
- critically examine recently published work in terms of relevance and find impactful (novel) research problems. This will be an integral part of the project work and involves experimental as well as theoretical questions
- outline a possible approach to prove a conjectured theorem by e.g. reducing to more solvable subproblems. This will be practiced in in-person exercises, homeworks and potentially the final project
- effectively communicate and present the problem motivation, new insights and results to a technical audience. This will be primarily learned via the final presentation and report as well as during peer-grading of peer talks.

The project work focuses on current theoretical ML research that aims to understand modern phenomena in machine learning, including but not limited to:
- how overparameterized models generalize (statistically) and converge (computationally)
- complexity measures and approximation theoretic properties of randomly initialized and trained neural networks
- generalization of robust learning (adversarial or distribution-shift robustness)
- private and fair learning

Students should have a very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as “Introduction to Machine Learning”, “Regression”/“Statistical Modelling”. In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve these.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.
**Content**

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

**Literature**


**Prerequisites / notice**

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
  - assessed

- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - assessed

- Personal Competencies
  - Critical Thinking
  - assessed

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**401-3601-00L Probability Theory**

**W**

- 9 credits
- 4V+1U
- V. Tassion

**Objective**

At most one of the three course units (Bachelor Core Courses)

401-3461-00L Functional Analysis I

401-3531-00L Differential Geometry I

401-3601-00L Probability Theory

401-3602-00L Applied Stochastic Processes

This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- Measure theory formalism and probability theory, Dynkin’s lemma and independence, convergence of series of independent random variables, law of large numbers, conditional expectation, martingale convergence theorems, uniform integrability, optional stopping theorem for martingales, the Bienaymé-Galton-Watson process and its R-number, convergence in distribution and the central limit theorem.

**Content**

This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- Measure theory formalism and probability theory, Dynkin’s lemma and independence, convergence of series of independent random variables, law of large numbers, conditional expectation, martingale convergence theorems, uniform integrability, optional stopping theorem for martingales, the Bienaymé-Galton-Watson process and its R-number, convergence in distribution and the central limit theorem.

**Lecture notes**

will be available in electronic form.

**Literature**

- H. Bauer, Probability Theory, de Gruyter 1991
- J. Jacod and P. Protter, Probability essentials, Springer 2004
- D. Williams, Probability with martingales, Cambridge University Press 1991

**Prerequisites / notice**

- Measure Theory
- Basic notions in probability theory (probability space, conditional probability, Borel Cantelli, Dynkin Lemma, random variables, expectation, variance, law of large numbers).

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
  - assessed

- Personal Competencies
  - Creative Thinking
  - assessed

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**401-3612-00L Stochastic Simulation**

**W**

- 5 credits
- 2V+1U
- F. Sigrist

**Objective**

This course provides an introduction to statistical Monte Carlo methods. This includes applications of simulations in various fields (Bayesian statistics, statistical mechanics, operations research, financial mathematics), algorithms for the generation of random variables (accept-reject, importance sampling), estimating the precision, variance reduction, introduction to Markov chain Monte Carlo.

**Content**

Stochastic simulation (also called Monte Carlo method) is the experimental analysis of a stochastic model by implementing it on a computer. Probabilities and expected values can be approximated by averaging simulated values, and the central limit theorem gives an estimate of the error of this approximation. The course shows examples of the many applications of stochastic simulation and explains different algorithms used for simulation. These algorithms are illustrated with the statistical software R.

**Lecture notes**

A script will be available in English.

**Literature**


**Prerequisites / notice**

Familiarity with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

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**401-3627-00L High-Dimensional Statistics**

**W**

- 4 credits
- 2V
- not available

**Abstract**

"High-Dimensional Statistics" deals with modern methods and theory for statistical inference when the number of unknown parameters is of much larger order than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed.

**Objective**

Knowledge of methods and basic theory for high-dimensional statistical inference.
### 401-3622-00L Statistical Modelling

**Abstract**
In regression, the dependency of a random response variable on other variables is examined. We consider the theory of linear regression with one or more covariates, high-dimensional linear models, nonlinear models, and generalized linear models, robust methods, and nonparametric models. Several numerical examples will illustrate the theory.

**Objective**
Introduction into theory and practice of a broad and popular area of statistics, from a modern viewpoint.

**Content**
- Basics of Regression Approaches
- Linear and Generalized Linear Models
- Nonparametric Regression
- Robust Regression Methods
- Model Selection

**Literature**

**Prerequisites / notice**
Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: fostered
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: fostered
- Social Competencies
  - Communication: assessed
  - Cooperation and Teamwork: fostered
  - Sensitivity to Diversity: fostered
- Personal Competencies
  - Adaptability and Flexibility: fostered
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

**Credits**
7 credits

**Lecture notes**
https://people.math.ethz.ch/~abandeira/BandeiraSingerStrohmer-MDS-draft.pdf (see for some Open Problems)

**401-3901-00L Linear & Combinatorial Optimization**

**Abstract**
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

**Objective**
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

**Content**
- Linear programming and polyhedra
- Flows and cuts
- Combinatorial optimization problems and polyhedral techniques
- Equivalence between optimization and separation

**Literature**

**Prerequisites / notice**
Solid background in linear algebra.

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: fostered
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: fostered
- Social Competencies
  - Communication: assessed
  - Cooperation and Teamwork: fostered
  - Sensitivity to Diversity: fostered
- Personal Competencies
  - Adaptability and Flexibility: fostered
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

**Credits**
10 credits

**Lecture notes**

**401-4944-20L Mathematics of Data Science**

**Abstract**
Mostly self-contained, but fast-paced, introductory masters level course on various theoretical aspects of algorithms that aim to extract information from data.

**Objective**
Introduction to various mathematical aspects of Data Science.

**Content**
These topics lie in overlaps of Mathematics with: Computer Science, Electrical Engineering, Statistics, and/or Operations Research. Most lectures will feature Mathematical Open Problems. The main mathematical tools used will be Probability and Linear Algebra, and a basic familiarity with these subjects is required. There will also be some (although knowledge of these tools is not assumed) Graph Theory, Representation Theory, Applied Harmonic Analysis, among others. The topics treated will include Dimension reduction, Manifold learning, Sparse recovery, Random Matrices, Approximation Algorithms, Community detection in graphs, and several others.

**Lecture notes**

**Prerequisites / notice**
The main mathematical tools used will be Probability, Linear Algebra (and real analysis), and a working knowledge of these subjects is required. In addition to these prerequisites, this class requires a certain degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: fostered
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: fostered
- Social Competencies
  - Communication: assessed
  - Cooperation and Teamwork: fostered
  - Sensitivity to Diversity: fostered
- Personal Competencies
  - Adaptability and Flexibility: fostered
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

**Credits**
8 credits

**Lecture notes**

We encourage students who are interested in mathematical data science to take both this course and "227-0434-10L Mathematics of Information" taught by Prof. H. Bölcskei. The two courses are designed to be complementary.

A. Bandeira and H. Bölcskei
### Probabilistic Methods in Combinatorics

**W 5 credits 2V+1U**  
**B. Sudakov**

**Abstract**  
This course provides a gentle introduction to the Probabilistic Method, with an emphasis on methodology. We will try to illustrate the main ideas by showing the application of probabilistic reasoning to various combinatorial problems.

**Content**  
The topics covered in the class will include (but are not limited to): linearity of expectation, the second moment method, the local lemma, correlation inequalities, martingales, large deviation inequalities, Janson and Talagrand inequalities and pseudo-randomness.

**Literature**
- Graph Coloring and the Probabilistic Method, by M. Molloy and B. Reed, Springer, 2002.

**Lecture notes**
https://moodle-app2.let.ethz.ch/course/view.php?id=15757

**Prerequisites / notice**
Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

### Algebraic Methods in Combinatorics

**W 5 credits 2V+1U**  
**Does not take place this semester.**

**Abstract**  
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

**Objective**  
The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

**Content**  
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

**Prerequisites / notice**
Students are expected to have a mathematical background and should be able to write rigorous proofs.

### Time Series Analysis

**W 4 credits 2G**  
**F. Balabdaoui**

**Abstract**  
The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Models, ARIMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

**Objective**  
The goal of the course is to have a good overview of the different types of time series and the approaches used in their statistical analysis.

**Content**  
This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exhibited by time series is the dependence between successive observations.

The key topics which will be covered as:

- Stationarity
- Autocorrelation
- Trend estimation
- Elimination of seasonality
- Spectral analysis, spectral densities
- Forecasting
- ARIMA, ARIMA Introduction to GARCH models

**Literature**
The main reference for this course is the book “Introduction to Time Series and Forecasting”, by P. J. Brockwell and R. A. Davis

**Prerequisites / notice**
Basic knowledge in probability and statistics

### Causality

**W 5 credits 3G**  
**J. Peters**

**Abstract**  
In statistics, we are used to search for the best predictors of some random variable. In many situations, however, we are interested in predicting a system's behavior under manipulations. For such an analysis, we require knowledge about the underlying causal structure of the system. In this course, we study concepts and theory behind causal inference.
Objective

After this course, you should be able to:

- understand the language and concepts of causal inference
- know the assumptions under which one can infer causal relations from observational and/or interventional data
- describe and apply different methods for causal structure learning
- given data and a causal structure, derive causal effects and predictions of interventional experiments

Content

The material covered in this course has a significant overlap with the material that has been covered in 401-3620-22L Student Seminar in Statistics: Causality FS2023.

Literature

Parts of this course will be based on the book “Elements of Causal Inference” (MIT Press, open access). More details will follow.

Prerequisites / notice

Prerequisites: basic knowledge of probability theory and regression

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

402-0448-01L Quantum Information Processing I: Concepts
This theory part QIP I together with the experimental part 402-0448-02L QIP II (both offered in the autumn semester) combine to the core course in experimental physics "Quantum Information Processing" (totally 10 ECTS credits). This applies to the Master's degree programme in Physics.

Abstract

The course covers the key concepts and formalism of quantum information processing. Topics include quantum algorithms, quantum error correction, quantum cryptography, and quantum metrology, with an emphasis on the power of quantum information processing beyond that of classical information processing. The formalism of quantum states, measurements, and channels is developed in detail.

Objective

By the end of the course students are able to explain the basic mathematical formalism of quantum mechanics and apply it to quantum information processing problems. They are able to adapt and apply these concepts and methods to analyze and discuss quantum algorithms and other quantum information-processing protocols.

Content

The topics covered in the course will include quantum circuits, gate decomposition and universal sets of gates, efficiency of quantum circuits, quantum algorithms (Shor, Grover, Deutsch-Josza,...), stabilizer-based quantum error correction, fault-tolerant designs, the BB84 quantum key distribution protocol, and simple methods of quantum metrology.

Lecture notes

Will be provided.

Literature

Quantum Computation and Quantum Information
Michael Nielsen and Isaac Chuang
Cambridge University Press

Prerequisites / notice

A good understanding of finite dimensional linear algebra is recommended.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making fostered
Problem-solving fostered

Personal Competencies

Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered

Data Science Lab

Interdisciplinary Electives

Number Title Type ECTS Hours Lecturers

263-3300-00L Data Science Lab O 14 credits 9P A. Illc, V. Boeva, R. Cotterell, J. Vogt, F. Yang

Abstract

In this class, we bring together data science applications provided by ETH researchers outside computer science and teams of computer science master's students. Two to three students will form a team working on data science/machine learning-related research topics provided by scientists in a diverse range of domains such as astronomy, biology, social sciences etc.

Objective

The goal of this class if for students to gain experience of dealing with data science and machine learning applications "in the wild". Students are expected to go through the full process starting from data cleaning, modeling, execution, debugging, error analysis, and quality/performance refinement.

Prerequisites / notice

Prerequisites: At least 8 KP must have been obtained under Data Analysis and at least 8 KP must have been obtained under Data Management and Processing.

Seminar

Number Title Type ECTS Hours Lecturers

252-5051-00L Advanced Topics in Machine Learning W 2 credits 2S R. Cotterell, M. El-Assady, N. He, F. Yang

Abstract

In this seminar, recent papers of the pattern recognition and machine learning literature are presented and discussed. Possible topics cover statistical models in computer vision, graphical models and machine learning.
Objective
The seminar "Advanced Topics in Human-Centric Computer Vision" familiarizes students with recent developments in pattern recognition and machine learning. Students will learn how to structure a scientific presentation in English which covers the key ideas of a scientific paper. An important goal of the seminar is to summarize the essential ideas of the paper in sufficient detail while omitting details which are not essential for the understanding of the work. The presentation style will play an important role and should reach the level of professional scientific presentations.

Content
The seminar will cover a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from computer vision or bioinformatics - two fields, which relies more and more on machine learning methodology and statistical models.

Literature
The papers will be presented in the first session of the seminar.

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<th>Title</th>
<th>Credits</th>
<th>Type</th>
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<td>263-3504-00L</td>
<td>Hardware Acceleration for Data Processing</td>
<td>2</td>
<td>W</td>
<td>M. J. Giardino, M. Korenberg Friedman</td>
</tr>
<tr>
<td>263-3713-00L</td>
<td>Advanced Topics in Human-Centric Computer Vision</td>
<td>2</td>
<td>W</td>
<td>J. Song</td>
</tr>
<tr>
<td>263-5100-00L</td>
<td>Topics in Medical Machine Learning</td>
<td>2</td>
<td>W</td>
<td>G. Rättsch, J. Vogt</td>
</tr>
</tbody>
</table>

Abstract

263-3504-00L
The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

Objective
The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

Content
The general application areas are big data and machine learning. The systems covered will include systems from computer architecture, high performance computing, data appliances, and data centers.

Prerequisites / notice
Students taking this seminar should have the necessary background in systems and low level programming.

263-3713-00L
In this seminar we will discuss state-of-the-art literature on human-centric computer vision topics including but not limited to human pose estimation, hand and eye-gaze estimation as well as generative modeling of detailed human activities.

Objective
The learning objective is to analyze selected research papers published at top computer vision and machine learning venues. A key focus will be placed on identifying and discussing open problems and novel solutions in this space. The seminar will achieve this via several components: reading papers, technical presentations, writing analysis and critique summaries, class discussions, and exploration of potential research topics.

Content
The goal of the seminar is not only to familiarize students with exciting new research topics, but also to teach basic scientific writing and oral presentation skills. The seminar will have a different structure from regular seminars to encourage more discussion and a deeper learning experience.

We will treat papers as case studies and discuss them in-depth in the seminar. Once per semester, every student will have to take one of the following roles:

Presenter: Give a presentation about the paper that you read in depth.
Reviewer: Perform a critical review of the paper.

Prerequisites / notice
All other students: read the paper and submit questions they have about the paper before the presentation. Participation will be limited subject to available topics. Furthermore, students will have to submit a motivation paragraph. Participants will be selected based on this paragraph.

Competencies
Method-specific Competencies: Analytical Competencies
Social Competencies: Communication
Personal Competencies: Critical Thinking

263-5100-00L
This seminar discusses recent relevant contributions to the fields of medical machine learning and related areas. Each participant will hold a presentation and lead the subsequent discussion.

Objective
Preparing and holding a scientific presentation in front of peers is a central part of working in the scientific domain. In this seminar, the participants will learn how to efficiently summarize the relevant parts of a scientific publication, critically reflect its contents, and summarize it for presentation to an audience. The necessary skills to successfully present the key points of existing research work are the same as those needed to communicate own research ideas. In addition to holding a presentation, each student will both contribute to as well as lead a discussion section on the topics presented in the class.

Content
The topics covered in the seminar are related to recent computational challenges that arise in the medical field, including but not limited to clinical data analysis, interpretable machine learning, privacy considerations, statistical frameworks, etc. Both recently published works contributing novel ideas to the areas mentioned above as well as seminal contributions from the past are on the list of selected papers.

Prerequisites / notice
Knowledge of machine learning and interest in applications in medicine. ML4H is beneficial as a prior course.

401-3620-74L
The Autumn Semester 2024 registration for this course has ended.

 Objective
Number of participants limited to 24.
Mainly for students from the Mathematics Bachelor and Master Programmes who, in addition to the introductory course unit 401-2604-00L Probability and Statistics, have heard at least one core or elective course in statistics. Also offered in the Master Programmes Statistics resp. Data Science.

401-5680-00L
This Autumn Semester 2024 registration has ended.

 Objective
Research colloquium

Science in Perspective
The minimal prerequisites for the Master's thesis registration are:

- Completed Bachelor's program
- All additional requirements completed (additional requirements, if any, are listed in the admission decree)
- Minimum degree requirements fulfilled of the course categories Data Analysis and Data Management and overall 50 credits obtained in the course category Core Courses
- Data Science Lab (14 credits) completed

Abstract
The Master's thesis concludes the study program and demonstrates the students' ability to use the knowledge and skills acquired during Master's studies to solve a complex data science problem.

Objective
To work independently and to produce a scientifically structured work.

Data Science Master - Key for Type

| Dr | Suitable for doctorate | W | Eligible for credits |
| E- | Recommended, not eligible for credits | W+ | Eligible for credits and recommended |
| O | Compulsory | Z | Courses outside the curriculum |

Key for Hours

- V: lecture
- G: lecture with exercise
- U: exercise
- S: seminar
- K: colloquium
- P: practical/laboratory course
- A: independent project
- D: diploma thesis
- R: revision course / private study

ECTS
European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
<table>
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<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0015-00L</td>
<td>Transdisciplinary Research: Challenges of Interdisciplinaryity and Stakeholder Engagement</td>
<td>W</td>
<td>2 credits</td>
<td>1S</td>
<td>B. Vienni Baptista, C. E. Pohl, M. Stauffacher</td>
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</table>

**Abstract**

This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants’ research projects more societally relevant.

**Objective**

Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, or how to secure broader impact of research. They learn to critically reflect their own research project in its societal context and on their role as scientists.

**Content**

The seminar covers the following topics:

1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants’ research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.

**Literature**

Literature will be made available to the participants.


Further, this collection of tools will be used:

https://naturalsciences.ch/topics/co-producing_knowledge
https://www.shapeidtoolkit.eu

**101-0139-00L Scientific Machine and Deep Learning for Design and Construction**

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<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>W+</td>
<td>3</td>
<td>4G</td>
<td>B. Bickel, A. Müller, M. Piovarci</td>
</tr>
</tbody>
</table>

**Abstract**

This course will present methods of scientific machine and deep learning (ML / DL) for applications in design and construction. After providing proper background on ML and the scientific ML (SciML) track, several applications of SciML together with their computational implementation during the design and construction process of the built environment are examined.

**Objective**

This course aims to provide a graduate-level introduction to machine learning, with a particular focus on scientific machine learning for applications in the design and construction phases of projects from architecture and civil engineering.

Upon completion of the course, the students will be able to:

1. Understand main ML background theory and methods.
2. Assess a problem and apply ML and DL in a computational framework accordingly.
3. Incorporate scientific domain knowledge in the SciML process.
4. Define, plan, conduct and present a SciML project.

**Content**

The course will include theory and algorithms for SciML, programming assignments, as well as a final project assessment.

The topics to be covered are:

2. Incorporation of Domain Knowledge into ML and DL.
4. ML training, validation and testing pipelines for academic and research projects.

A comprehensive series of computer/lab exercises and in-class demonstrations will take place, providing a “hands-on” feel for the course topics.

**Literature**

Suggested Reading:

Marc Peter Deisenroth, A Aldo Faisal, and Cheng Soon Ong Mathematics for Machine Learning
O. Martin: Bayesian analysis with python. Packt Publishing Ltd, 2016

**Prerequisites / notice**

Familiarity with Python is advised.
Discovering Management (Pitch) 351-0778-01L

**Does not take place this semester.**

**Abstract**
This course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

**Objective**
The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

**Content**
The exercise consists of delivering and submitting a "pitch" with a clear recommendation for one of the selected cases amongst those seen in Discovering Management, using your insights from Discovering Management, and an extra session on pitching.

**Literature**
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. Students following this course should also be enrolled for course 351-0778-00L, "Discovering Management".

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**Discovering Management 351-0778-00L**

*Does not take place this semester.*

**Entry level course in management for BSc, MSc and PHD students at all levels not belonging to D-MTEC. This course can be complemented with Discovering Management (Exercises) 351-0778-01.**

**Abstract**
Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

**Objective**
The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
1. broaden understanding of management principles and frameworks
2. advance insights into the sources of corporate and entrepreneurial success
3. develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

**Content**
The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a “lecture-style” approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. The theory sessions will be assessed via a multiple choice exam.

**Lecture notes**
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

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**Competencies**

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<th>Competencies</th>
<th>Concepts and Theories</th>
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<td>Personal Competencies</td>
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### Advanced Topics in History and Theory of Architecture

**W 1 credit 1K**

**T. Avermaete, M. Delbeke, L. Stalder, P. Ursprung**

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<th>Competencies</th>
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<td>Media and Digital Technologies</td>
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<td>Communication</td>
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<td>Personal Competencies</td>
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<td>Critical Thinking</td>
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<td>Self-direction and Self-management</td>
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**Abstract**
The seminar will consist of a series of collective readings of selected texts.

**Objective**
Knowledge of relevant texts in contemporary theory.
Capacity to critically discuss methods and discourses.

**Lecture notes**
Scans of selected texts for discussion and exercises will be provided at the beginning of the semester on the course website:

https://doctoral-program.gta.arch.ethz.ch/courses

**Prerequisites / notice**
The seminar addresses the fellows of the Doctoral Program in History and Theory of Architecture. All other doctoral students of the Faculty of Architecture are welcome.

### PhD Colloquium Theory of Information Technology for Architects

**W 2 credits 2K**

**L. Hovestadt**

<table>
<thead>
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<th>Competencies</th>
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<td>Negotiation</td>
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### Research Methods in the History and Theory of Architecture

**W 2 credits 2S**

**C. Rachele**

<table>
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### Prerequisites / notice
To benefit from this course, you should have a practical affinity to technics, as well as an abstract interest in information technology in its comprehensive cultural context.

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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 700 of 2653
The methodology of humanistic research grows more complex with every academic generation: it presents a thicket of epistemological frameworks rather than a straightforward array of tools. In the omnivorous field of architectural history and theory, the scholar faces yet further possibilities. This course considers the variety of available strategies for the creation of architectural histor(ies) and theor(ies) as an intellectual opportunity distinctive to our discipline. Through close study of a range of historically significant or innovative texts, we will deepen our understanding of how other scholars have structured their work and refine our own research methodologies.

The course, held over two semesters, combines a traditional doctoral theory seminar with a practical writing workshop. We will alternate reading-based discussions with working sessions directed towards the development of the doctoral plan to be submitted at the end of the first year.

The course schedule will be available at the beginning of the semester on the course moodle page.

Please note gta doctoral program courses begin the third week of the semester (the first week of October).

Lecture notes
PDfs of texts for discussion will be provided on the course moodle page (registered students only).

Prerequisites / notice
Required for first-year gta doctoral students; gta MAS and external doctoral students accepted by application, space permitting. Due to the intensive nature of the course, auditors and passive participants are not allowed. Please contact instructor for more information.

Competencies

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A 200 CHF deposit will be charged for the VR Headset. It will be refunded upon the return of the headset on the last day of the course.

Max. number of participants 15 students.

The course “360 – Reality to Virtuality” is interconnected with “3D Scanning and Freeform Modeling”.

You must register for both courses: “360 – Reality to Virtuality” and “3D-Modeling” (2x 2 ETCS).

Classroom teaching + 4h block + self-teaching and research at home.

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If you already have an Oculus Quest 2, you do not need to pay any deposit and can work on your own device.

Please note gta doctoral program courses begin the third week of the semester (the first week of October).

W 2 credits 2U A. Kiryk

Enrolment in agreement with the lecturer only
kiryk@arch.ethz.ch

This course explores the concept of “Hybrid Reality,” blending digital and physical spaces using VR technologies. Students will learn to digitize spaces, create immersive environments, and design interactive exhibitions.

The goal is to digitize an existing space and use it in virtual reality as a context for further design. During the course, AI tools will be utilized to enhance the photogrammetry 3D scanning process. In the first part of the course, we learn the tools; then we work on architectural VR projects, either in groups or individually. Throughout the course, we will examine VR workflows to create immersive and interactive architectural spaces. At the end of the course, we will present the works in a VR exhibition. Each student receives an Oculus Quest VR headset to work with at home throughout the semester.

Fusions of digital-analog relationships have accompanied us since the very beginning of the digitalization era. The rapidly growing impact of digital technologies on our life necessitates constant adaptation. The course introduces the term “Hybrid Reality,” which represents the coexistence of physical and digital spaces. Using state-of-the-art VR technologies, the methodology focuses on immersive, real-time, 1:1 scale space creation, exploring corporeal design, and reinventing conventional methods. Students will learn to digitize physical spaces, create hybrid reality environments, and design interactive exhibitions.

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Please send a short application email (max 150 words) to Adam Kiryk: kiryk@arch.ethz.ch.

**Transferable Skills**

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Integration into Scientific Community

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<td>900-0154-DRL</td>
<td>Summer School II (1-3 days, with Poster or Talk)</td>
<td>W</td>
<td>2 credits</td>
<td>4K</td>
<td>Lecturers</td>
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Objective
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

900-0155-DRL Summer School III (1-3 days, with Poster or Talk) W 2 credits 4K Lecturers

Abstract
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Objective
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

900-0156-DRL Summer School I (1 week) W 2 credits 4K Lecturers

Abstract
Participation in summer or winter schools with a minimum duration of 1 week.

Objective
Participation in summer or winter schools with a minimum duration of 1 week.

900-0157-DRL Summer School II (1 week) W 2 credits 4K Lecturers

Abstract
Participation in summer or winter schools with a minimum duration of 1 week.

Objective
Participation in summer or winter schools with a minimum duration of 1 week.

900-0158-DRL Summer School III (1 week) W 2 credits 4K Lecturers

Abstract
Participation in summer or winter schools with a minimum duration of 1 week.

Objective
Participation in summer or winter schools with a minimum duration of 1 week.

900-0159-DRL Summer School I (1 week, with Poster or Talk) W 3 credits 6K Lecturers

Abstract
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

900-0160-DRL Summer School II (1 week, with Poster or Talk) W 3 credits 6K Lecturers

Abstract
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

900-0161-DRL Summer School III (1 week, with Poster or Talk) W 3 credits 6K Lecturers

Abstract
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

900-0162-DRL External Conference I (incl. Poster or Talk) W 1 credit 2K Lecturers

Abstract
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

900-0163-DRL External Conference II (incl. Poster or Talk) W 1 credit 2K Lecturers

Abstract
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.
and prove your participation with the appropriate certificate.

Abstract
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

<table>
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<td>2K</td>
<td>Lecturers</td>
</tr>
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</table>

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

Doctorate Architecture - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>E-                  Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z                  Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr                  Suitable for doctorate</td>
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</table>

Key for Hours

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td>P                  practical/laboratory course</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A                  independent project</td>
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<tr>
<td>U</td>
<td>exercise</td>
<td>D                  diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R                  revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</tbody>
</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Doctorate Civil, Environmental and Geomatic Engineering


Subject Specialisation
In addition to the courses listed below, D-BAUG doctoral students are free to choose from the entire range of subject-specific courses offered by ETHZ and the University of Zurich, provided that it is an offering specifically designed for doctoral students or a course of the regular Master’s program or of the third year Bachelor’s program.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0191-00L</td>
<td>Seismic and Vibration Isolation</td>
<td>W</td>
<td>2</td>
<td>1G</td>
<td>M. Vassiliou</td>
</tr>
</tbody>
</table>

Abstract
This course will cover the analysis and design of isolation systems to mitigate earthquakes and other forms of vibrations. The course will cover:

1. Conceptual basis of seismic isolation, seismic isolation types, mechanical characteristics of isolators.
3. Design approaches and code requirements

Objective
After successfully completing this course the students will be able to:

1. Understand the mechanics of and design isolator bearings.
2. Understand the dynamics of and design an isolated structure.

Content
1. Introduction: Overview of seismic isolation; review of structural dynamics and earthquake engineering principles. Viscoelastic behavior.
2. Linear theory of seismic isolation
3. Types of seismic isolation devices - Modelling of seismic isolation devices – Nonlinear response analysis of seismically isolated structures in Matlab
4. Behavior of rubber isolators under shear and compression
5. Behavior of rubber isolators under bending
6. Buckling and stability of rubber isolators
7. Code provisions for seismically isolated buildings

Lecture notes
The electronic copies of the learning material will be uploaded to ILIAS and available through myStudies. The learning material includes:
- Reading material, and (optional) exercise problems and solutions.

Literature
- Dynamics of Structures, Theory and Applications to Earthquake Engineering, 4th edition, Anil Chopra, Prentice Hall, 2017
- Design of seismic isolated structures: from theory to practice, Farzad Naeim and James M. Kelly, John Wiley & Sons, 1999

Prerequisites / notice
- Mechanics of rubber bearings for seismic and vibration isolation, James M. Kelly and Dimitrios Konstantinidis, John Wiley & Sons, 2011

101-0522-10L Doctoral Seminar Data Science and Machine Learning in Civil, Env. and Geospatial Engineering  ● Does not take place this semester.

Abstract
Current research in machine learning and data science within the research fields of the department. The goal is to learn about current research projects at our department, to strengthen our expertise and collaboration with respect to data-driven models and methods, to provide a platform where research challenges can be discussed, and also to practice scientific presentations.

Objective
- learn about discipline-specific methods and applications of data science in neighbouring fields
- network people and methodological expertise across disciplines
- establish links and discuss connections, common challenges and discipline-specific differences
- practice presentation and discussion of technical content to a broader, less specialised scientific audience

Content
Current research at D-BAUG will be presented and discussed.

Prerequisites / notice
This doctoral seminar is intended for doctoral students affiliated with the Department of Civil, Environmental and Geomatic Engineering. Other students who work on related topics need approval by at least one of the organisers to register for the seminar.

Participants are expected to possess elementary skills in statistics, data science and machine learning, including both theory and practical modelling and implementation. The seminar targets students who are actively working on related research projects.

101-0139-00L Scientific Machine and Deep Learning for Design and Construction

Abstract
This course will present methods of scientific machine and deep learning (ML / DL) for applications in design and construction. After providing proper background on ML and the scientific ML (SciML) track, several applications of SciML together with their computational implementation during the design and construction process of the built environment are examined.

Objective
This course aims to provide a graduate-level introduction to machine learning, with a particular focus on scientific machine learning for applications in the design and construction phases of projects from architecture and civil engineering.

Upon completion of the course, the students will be able to:

1. Understand main ML background theory and methods.
2. Assess a problem and apply ML and DL in a computational framework accordingly.
3. Incorporate scientific domain knowledge in the SciML process.
4. Define, plan, conduct and present a SciML project.

Content
The course will include theory and algorithms for SciML, programming assignments, as well as a final project assessment.

The topics to be covered are:
2. Incorporation of Domain Knowledge into ML and DL.
4. ML training, validation and testing pipelines for academic and research projects.

A comprehensive series of computer/laboratory exercises and in-class demonstrations will take place, providing a "hands-on" feel for the course topics.

Lecture notes
The course script is composed by lecture slides, which are available online and will be continuously updated throughout the duration of the course.
**Literature**

Suggested Reading:

**Prerequisites / notice**

Familiarity with Python is advised.

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: fostered
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: assessed

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered

**Personal Competencies**
- Creative Thinking: fostered
- Critical Thinking: fostered
- Self-direction and Self-management: fostered

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**701-0015-00L**

**Transdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement**

*The lecture takes place if a minimum of 12 students register for it.*

**Abstract**

This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants’ research projects more societally relevant.

**Objective**

Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, or how to secure broader impact of research. They learn to critically reflect their own research project in its societal context and on their role as scientists.

**Content**

The seminar covers the following topics:
1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants’ research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.

**Literature**

Literature will be made available to the participants.

The following open access article builds a core element of the course:


available at (open access): http://www.ingentaconnect.com/content/one/oekom/gaia/2017/00000026/00000001/art00011

Further, this collection of tools will be used:
- https://naturalsciences.ch/topics/co-producing_knowledge
- https://www.shapeidtoolkit.eu

**Prerequisites / notice**

Participation in the course requires participants to be working on their own research project.

Dates (Wednesdays, 8h15-12h00)

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: fostered
- Analytical Competencies: fostered
- Problem-solving: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Sensitivity to Diversity: fostered

**Personal Competencies**
- Critical Thinking: fostered
- Self-awareness and Self-reflection: fostered

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**101-0523-15L**

**Frontiers in Machine Learning Applied to Civil, Env. and Geospatial Engineering**

*Does not take place this semester.*

**Abstract**

This doctoral seminar organised by the D-BAUG platform on data science and machine learning aims at discussing recent research papers in the field of machine learning and analyzing the transferability/ adaptability of the proposed approaches to applications in the field of civil and environmental engineering (if possible and applicable, also implementing the adapted algorithms).

**Objective**

Students will
- Critically read scientific papers on the recent developments in machine learning
- Put the research in context
- Present the contributions
- Discuss the validity of the scientific approach
- Evaluate the underlying assumptions
- Evaluate the transferability/ adaptability of the proposed approaches to own research
- (Optionally) implement the proposed approaches.

**Literature**

The following open access article builds a core element of the course:


available at (open access): http://www.ingentaconnect.com/content/one/oekom/gaia/2017/00000026/00000001/art00011

Further, this collection of tools will be used:
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**Personal Competencies**
- Critical Thinking: fostered
- Self-awareness and Self-reflection: fostered

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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 708 of 2653
Content

With the increasing amount of data collected in various domains, the importance of data science in many disciplines, such as infrastructure monitoring and management, transportation, spatial planning, structural and environmental engineering, has been increasing. The field is constantly developing further with numerous advances, extensions and modifications. The course aims at discussing recent research papers in the field of machine learning and analyzing the transferability/adaptability of the proposed approaches to applications in the field of civil and environmental engineering (if possible and applicable, also implementing the adapted algorithms).

Each student will select a paper that is relevant for his/her research and present its content in the seminar, putting it into context, analyzing the assumptions, the transferability and generalizability of the proposed approaches. The students will also link the research content of the selected paper to the own research, evaluating the potential of transferring or adapting it. If possible and applicable, the students will also implement the adapted algorithms. The students will work in groups of three students, where each of the three students will be reading each other’s selected papers and providing feedback to each other.

Notice

This doctoral seminar is intended for doctoral students affiliated with the Department of Civil, Environmental, and Geomatic Engineering. Other students who work on related topics need approval by at least one of the organizers to register for the seminar.

Participants are expected to possess elementary skills in statistics, data science and machine learning, including both theory and practical modelling and implementation. The seminar targets students who are actively working on related research projects.

### Transferable Skills

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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>900-0101-DRL</td>
<td>Transferable Skills Course I (1-3 days) Only for doctoral students.</td>
<td>W</td>
<td>1</td>
<td>2S</td>
<td>Lecturers</td>
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<td>Objective</td>
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<td>4S</td>
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<td>1 week</td>
<td>3 credits</td>
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<td>Lecturers</td>
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<td>900-0109-DRL</td>
<td>Transferable Skills Course II (1 week, with Poster or Talk)</td>
<td>1 week</td>
<td>3 credits</td>
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<tr>
<td>900-0110-DRL</td>
<td>Transferable Skills Course III (1 week, with Poster or Talk)</td>
<td>1 week</td>
<td>3 credits</td>
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<tr>
<td>900-0111-DRL</td>
<td>Transferable Skills Course I (min 1 year)</td>
<td>1 year</td>
<td>1 credit</td>
<td>W</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

Objective: Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a minimum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

Abstract: Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Only for doctoral students.
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

Objective
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>900-0113-DRL</td>
<td>Participation in Commission II (min 1 year)</td>
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<td>101-5000-00L</td>
<td>Ethics and Scientific Integrity for Doctoral Students of D-BAUG</td>
<td>W</td>
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<td>C. Sailer</td>
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<td>2K</td>
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Abstract
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

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</table>

Doctorate Civil, Environmental and Geomatic Engineering - Key for Type

| O          | Compulsory  | Z       | Courses outside the curriculum |
| W          | Eligible for credits | Dr     | Suitable for doctorate         |
| E-         | Recommended, not eligible for credits | W+     | Eligible for credits and recommended |

Key for Hours

| V       | lecture    | P       | practical/laboratory course |
| G       | lecture with exercise | A       | independent project         |
| U       | exercise   | D       | diploma thesis              |
| S       | seminar    | R       | revision course / private study |
| K       | colloquium |         |                               |

ECTS European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.

Autumn Semester 2024
# Subject Specialisation

<table>
<thead>
<tr>
<th>Number</th>
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<td>376-1791-00L</td>
<td>Introductory Course in Neuroscience I (University of Zurich)</td>
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<td>2V</td>
<td>W. Knecht, University lecturers</td>
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<td><em>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html">https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html</a></em></td>
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<td><strong>Abstract</strong></td>
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<td></td>
<td>The course gives an introduction to human and comparative neuroanatomy, molecular, cellular and systems neuroscience.</td>
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<td></td>
<td>The course gives an introduction to the development and anatomical structure of nervous systems. Furthermore, it discusses the basics of cellular neurophysiology and neuropharmacology. Finally, the nervous system is described on a system level.</td>
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<tr>
<td>1) Human Neuroanatomy I&amp;II</td>
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<td>2) Comparative Neuroanatomy</td>
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<td>3) Building a central nervous system I,II</td>
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<td>4) Synapses I,II</td>
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<td>5) Glia and more</td>
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<td>6) Excitability</td>
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<td>7) Circuits underlying Emotion</td>
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<td>8) Visual System</td>
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<td>9) Auditory &amp; Vestibular System</td>
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<td>10) Somatosensory and Motor Systems</td>
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<td>11) Learning in artificial and biological neural networks</td>
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<td><strong>Prerequisites / notice</strong></td>
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<td><strong>Abstract</strong></td>
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<td></td>
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<td><strong>Content</strong></td>
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<tr>
<td>The class covers separation techniques that are central in the purification and downstream processing of chemicals and bio-pharmaceuticals. Examples from both areas illustrate the utility of the methods:</td>
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<td>1) Adsorption and chromatography; 2) Membrane processes; 3) Crystallization and precipitation.</td>
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<td>Techniques and Technologies</td>
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<tr>
<th>Number</th>
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<tr>
<td>401-0649-00L</td>
<td>W 5 credits</td>
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<td>M. Dettling</td>
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<td><strong>Abstract</strong></td>
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<td>This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning &quot;good practice&quot; that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.</td>
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<td><strong>Objective</strong></td>
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<td>The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.</td>
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<td>The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.</td>
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<td><strong>Lecture notes</strong></td>
<td>A script will be available.</td>
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The course introduces you to recent developments in the fields of cellular and molecular neurobiology. It also supports you to develop your skills in critically reading the scientific literature. You should be able to grasp what the authors wanted to learn i.e. their goals, why the authors chose the experimental approach they used, the strengths and weaknesses of the experiments and the data presented, and how the work fits into the wider literature in the field. You will present one paper yourself, which provides you with practice in public speaking.

You are expected to take part in the discussion and to ask questions. To prepare for this you should read all the papers beforehand (they are available online, so you can show original figures with a beamer). Finish with a summary of the main points and a discussion of their significance.

**Prerequisites / notice**

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L “Applied Statistical Regression” and 401-3622-00L “Statistical Modelling” are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

**Competencies**

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<tr>
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<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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**Note**

This is not a course, but a consulting service. There are no exams nor credits. We highly recommend to contact the consulting service when planning a project, not only towards the end of analyzing the resulting data!
This course covers aspects of RNA biology related to gene expression at the posttranscriptional level. These include RNA transcription, which is important for understanding how genes are turned on and off. The students should obtain an understanding of these processes, which are at work during gene expression.

Concepts and Theories
- Micro RNAs; computational approaches to miRNAs; micro RNA function in metabolism; viruses and viral RNAs; nucleic acid-based drugs; miRNA-based interactions between the participating research groups.

Analytical Competencies
- Communication assessed
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Critical Thinking fostered
- Self-awareness and Self-reflection fostered

Presentation and discussion of current research projects carried out by various immunology-oriented research groups in Zurich.

You must attend at least 80% of the journal clubs, and give a presentation of your own. At the end of the semester there will be a 30 minute oral exam on the material presented during the semester. The grade will be based on the exam (45%), your presentation (45%), and a contribution based on your active participation in discussion of other presentations (10%).

This monthly meeting is a platform for Zurich-based immunology research groups to present and discuss their ongoing research projects. At each meeting three PhD students or Postdocs from the participating research groups present an ongoing research project in a 30 min seminar followed by a plenary discussion. The aim of this monthly meeting is to provide further education for master and doctoral students as well as Postdocs in diverse topics of immunology and to give an insight in the related research. Furthermore, this platform fosters the establishment of science- and technology-based interactions between the participating research groups.

The students will actively participate in the course which is held in the form of a seminar. Individual students will prepare particular topics of the course based on literature references and present the material in form of a seminar to their fellow students. In short, the students learn to actively participate in discussions and to prepare a presentation of a scientific topic which was mostly unknown to them before.
In the last decade, a novel type of cell compartments called biomolecular condensates have been discovered. This discovery is radically changing our understanding of the cell, its organization, and dynamics. The emerging picture is that the cytoplasm and nucleoplasm are highly complex fluids that can (meta)stably segregate into membrane-less compartments, similarly to emulsions.

This interdisciplinary course encompasses milestone works and cutting-edge research questions in the young field of biomolecular condensates, including their properties, functions, and applications. The course begins with a lecture series that introduces the topic of condensates to an interdisciplinary audience and provides a theoretical foundation for understanding current research questions in the field. The lectures provide a base for student presentations of recent publications in the field, and for research seminars given by course lecturers, who are all active researchers with diverse expertise. Through this exciting interdisciplinary understanding of biomolecular condensates, bridging biology, chemistry, biophysics, and soft matter. Students will not only learn how to critically read and evaluate scientific literature but will also gain valuable experience in giving scientific presentations to an interdisciplinary audience. Each presentation will require an introduction, critical analysis of the results, and a discussion of their significance, allowing student to substantiate their statements with a critical mindset that considers the pros and cons of chosen approaches and methods, as well as any limitations or possible follow-up experiments. This process will enable student to ask relevant questions and actively participate in class discussions, further enhancing their scientific skills.

In preparing the presentations, the students will have the unique opportunity to interact closely with each other and with the lecturers, who are all internationally well-established experts, and receive guidance in selecting a topic for the final presentation and supporting literature.
The topic of biomolecular condensates goes beyond the boundaries of traditional disciplines and requires a multi-disciplinary approach that leverages and cross-fertilizes biology, physical chemistry, biophysics, and soft matter. This course will explore the properties, functions and potential applications of biomolecular condensates, including their role in neurodegenerative diseases such as Alzheimer’s and Parkinson’s, as well as their use as smart biomimetic materials.

This course is divided into two parts. The first part will introduce the basic concepts essential to the study of biomolecular condensates and phase separation. Topics include: fundamental units and scales in soft matter, phase transitions in biology, biopolymers and molecular self-assembly, introduction to active matter. This will establish a foundation for the second part, which will explore milestone works and current research in the field of biomolecular condensates. Each lecture of this second part will consist of:

1) a short literature seminar, where student groups will present and discuss a milestone paper assigned in advance and
2) a research seminar, where one of the course lecturers will present their own state-of-the-art research in the field, building upon the milestone literature.

At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate this, students must confirm their registration by the beginning of the 3rd week of semester.

Lecture notes
Lecture slides and some scripts will be provided.

Literature
No compulsory textbooks. Literature will be provided during the course

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Transferable Skills

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<td>900-0100-DRL</td>
<td>Transferable Skills Course I (1-3 days)</td>
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<td>2S</td>
<td>Lecturers</td>
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<td>Only for doctoral students.</td>
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<td>Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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| 900-0101-DRL| Transferable Skills Course II (1-3 days)       | W    | 1    | 2S    | Lecturers |
|             | Only for doctoral students.                   |      |      |       |           |
|             | Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate. |      |      |       |           |
| Abstract    | Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. |      |      |       |           |
| Objective   | Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. |      |      |       |           |

| 900-0102-DRL| Transferable Skills Course III (1-3 days)      | W    | 1    | 2S    | Lecturers |
|             | Only for doctoral students.                   |      |      |       |           |
|             | Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate. |      |      |       |           |
| Abstract    | Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. |      |      |       |           |
| Objective   | Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. |      |      |       |           |

Educational Science for Teaching Diploma and TC

Language Courses ETH/UZH: see Science in Perspective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

**900-0104-DRL** Transferrable Skills Course II (1-3 days, with Poster or Talk)  
*Only for doctoral students.*

*Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.*

**Abstract**

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

**900-0105-DRL** Transferrable Skills Course III (1-3 days, with Poster or Talk)  
*Only for doctoral students.*

*Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.*

**Abstract**

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

**900-0106-DRL** Transferrable Skills Course I (1 week)  
*Only for doctoral students.*

*Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.*

**Abstract**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

**900-0107-DRL** Transferrable Skills Course II (1 week)  
*Only for doctoral students.*

*Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.*

**Abstract**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

**900-0108-DRL** Transferrable Skills Course III (1 week)  
*Only for doctoral students.*

*Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.*

**Abstract**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

**900-0109-DRL** Transferrable Skills Course I (1 week, with Poster or Talk)  
*Only for doctoral students.*

*Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.*

**Abstract**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**900-0110-DRL** Transferrable Skills Course II (1 week, with Poster or Talk)  
*Only for doctoral students.*

*Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.*

**Abstract**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**900-0111-DRL** Transferrable Skills Course III (1 week, with Poster or Talk)  
*Only for doctoral students.*

*Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.*

**Abstract**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.
Only for doctoral students.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

### 900-0112-DRL Participation in Commission I (min 1 year)

**W** 1 credit 2P Lecturers

Only for doctoral students.

Abstract
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

Objective
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

### 900-0113-DRL Participation in Commission II (min 1 year)

**W** 1 credit 2P Lecturers

Only for doctoral students.

Abstract
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

Objective
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

### 900-0114-DRL Member of Executive Board (min 1 year)

**W** 2 credits 4P Lecturers

Only for doctoral students.

Abstract
Active participation in the presidium or executive board of a university group for at least 1 year.

Objective
Active participation in the presidium or executive board of a university group for at least 1 year.

### 701-0703-00L Environmental Ethics (University of Zurich)

**W** 3 credits 2V University lecturers

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: 07SMEEE266

Please register at: https://www.uzh.ch/cmsssl/de/studies/application/chmobilit yin.html

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

Abstract
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.

Objective
On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

### 851-0745-00L Ethics Workshop: The Impact of Digital Life on Society

**W** 2 credits 2S E. Vayena, A. Blasimme, J. Sleigh, to be announced

Open to all Master level / PhD students.

Abstract
This workshop focuses on understanding and managing the ethical and social issues arising from the integration of new technologies in various aspects of daily life.

Objective
- Explain relevant concepts in ethics.
- Evaluate the ethical dimensions of new technology uses.
- Identify impacted stakeholders and who is ethically responsible.
- Engage constructively in the public discourse relating to new technology impacts.
- Review tools and resources currently available that facilitate resolutions and ethical practice.
- Work in a more ethically reflective way.
The workshop offers students an experience that trains their ability for critical analysis and develops awareness of responsibilities as a researcher, consumer and citizen. Learning will occur in the context of three intensive workshop days, which are highly interactive and focus on the development and application of reasoning skills.

The workshop will begin with some fundamentals: the nature of ethics, of consent and big data, of AI ethics, public trust and health ethics. Students will then be introduced to key ethical concepts such as fairness, autonomy, trust, accountability, justice, as well different ways of reasoning about the ethics of digital technologies.

A range of practical problems and issues in the domains of education, media, society, digital health and justice will be then considered. These domains are represented respectively by unique and interesting case studies. Each case study has been selected not only for its timely and engaging nature, but also for its relevance. Through the analysis of these case studies key ethical questions (such as fairness, accountability, explainability, access etc.) will be highlighted and questions of responsibility and tools for ethical practice will be explored. Throughout, the emphasis will be on learning to make sound arguments about the ethical aspects of policy, practice and research.

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<td>fostered</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
</tr>
</tbody>
</table>

#### 376-1651-00L Ethics of Life Sciences and Biotechnology

**Abstract**

This semester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their technological application. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences.

**Objective**

This course is tailored to students who want to become familiar with the analysis of ethical issues in all the different domains of life sciences and biotechnology. The course aims at equipping students with the necessary knowledge and analytic skills to understand, discuss and address the ethical aspects of science and technology in the domain of human health. The specific learning objectives of this course are:

A. Identify ethical issues in in life sciences and biotechnology.
B. Analyze and critically discuss ethical issues in life sciences and biotechnology.
C. Become aware of relevant legal and public policy frameworks.
D. Distinguish different ethical approaches and argumentative strategies in applied ethics.
E. Recognize how ethical issues relate to different accounts of technology and innovation.
F. Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
G. Autonomously anticipate ethical issues.
H. Propose and communicate solutions to ethical challenges and dilemmas.

**Content**

The course starts off with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain of applied ethics. The students will also be introduced to current theoretical accounts of technology and will start to appreciate the relevance of ethics especially with respect to new and emerging technologies. Usable analytic tools will also be provided, thus enabling the students to engage with the discipline in a practical way from the very onset of the semester.

The course will continue with thematic sessions covering a broad variety of topics all of which are relevant to the different study tracks offered by the department. In particular, the course will cover the following domains: digital health technologies and medical AI; food, nutrition and healthy longevity; biomedical engineering; genetics; neuroscience and Neurotechnologies; medical robotics; disability and rehabilitation; environmental ethics. The course will also include sessions on cross-cutting ethically relevant aspects of health sciences and technologies, namely: access to innovation, translational research, and the relation between science and public policy.

All the topics of the course will be illustrated and interactively discussed through many case studies, offering the students the opportunity to prepare and present them, and to use them in individual as well as group exercises. Throughout the course, the students will have multiple opportunities to experiment with ethical argumentation and to practice their evolving skills.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>fostered</td>
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<td></td>
<td>Analytical Competencies</td>
<td>assesssed</td>
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<td>Decision-making</td>
<td>assesssed</td>
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<td>Media and Digital Technologies</td>
<td>assesssed</td>
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<td>Problem-solving</td>
<td>assesssed</td>
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<td>Communication</td>
<td>assesssed</td>
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<td></td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Adapability and Flexibility</td>
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<td>Creative Thinking</td>
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</table>

#### 851-0178-00L Ethics and Scientific Integrity for Doctoral Students

**Abstract**

This course is interdisciplinary. If your department offers this course, please register there if possible.

**Objective**

This course sensitises doctoral students to ethical issues that may occur during their doctorate. After an introduction to ethics and good scientific practice, students are familiarised with resources that can assist them with ethical decision-making. Students get the chance to apply and deepen their knowledge in an interactive face-to-face workshop.

**Competencies**

Doctoral students learn how to identify, analyse and address ethical issues in their own scientific research. In addition, they will reflect on their professional role as scientific researchers.
Content

Part I on Moodle
The self-paced e-learning course on Moodle consists of 5 modules:

Module 1: Ethics
- Introduction to moral theory (with emphasis on practical guidance regarding decision making)

Module 2: Ethics in scientific research
- Introduction to ethical issues that occur within scientific research (i.e. regarding authorship, cooperation, data use and sharing, and other aspects that are subject to scientific integrity and good scientific practice).

Module 3: Collecting resources
- A variety of tools and resources that help identify ethical issues are presented and explained

Module 4: Setting up a strategy
- Example examination of a case regarding its ethical scope (students develop their own strategy to examine situations for their ethical implications).

Module 5: Making decisions
- Different ways of addressing ethical issues are presented and explained (i.e. how to make hard choices, or solve ethical dilemmas. But also where to seek advice if needed).

Part II
The second, face-to-face part (group sessions) of this course provides an interactive learning environment (workshop). Students get to apply their knowledge, and they are encouraged to reflect on ethical problems and to critically discuss them with fellow doctoral students.

Prerequisites / notice
For doctoral students only.

The first part on Moodle (part I) must be successfully completed before the face-to-face workshop (part II).

Hence, when you choose a group make sure you have enough time to finish the first part on Moodle before the workshop starts (appr. 20 hours).

Competencies

Subject-specific Competencies
- Concepts and Theories assessed

Method-specific Competencies
- Decision-making assessed
- Problem-solving assessed

Personal Competencies
- Critical Thinking assessed
- Integrity and Work Ethics assessed

Integration into Scientific Community

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
900-0150-DRL | Summer School I (1-3 days) | W | 1 credit | 2K | Lecturers
- Only for doctoral students.

Abstract
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Objective
Participation in summer or winter schools with a maximum duration of 3 days.

900-0151-DRL | Summer School II (1-3 days) | W | 1 credit | 2K | Lecturers
- Only for doctoral students.

Abstract
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Objective
Participation in summer or winter schools with a maximum duration of 3 days.

900-0152-DRL | Summer School III (1-3 days) | W | 1 credit | 2K | Lecturers
- Only for doctoral students.

Abstract
Participation in summer or winter schools with a maximum duration of 3 days.
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>900-0153-DRL</td>
<td>Summer School I (1-3 days, with Poster or Talk)</td>
<td>W 2</td>
<td>4K Lecturers</td>
</tr>
<tr>
<td>900-0154-DRL</td>
<td>Summer School II (1-3 days, with Poster or Talk)</td>
<td>W 2</td>
<td>4K Lecturers</td>
</tr>
<tr>
<td>900-0155-DRL</td>
<td>Summer School III (1-3 days, with Poster or Talk)</td>
<td>W 2</td>
<td>4K Lecturers</td>
</tr>
<tr>
<td>900-0156-DRL</td>
<td>Summer School I (1 week)</td>
<td>W 2</td>
<td>4K Lecturers</td>
</tr>
<tr>
<td>900-0157-DRL</td>
<td>Summer School II (1 week)</td>
<td>W 2</td>
<td>4K Lecturers</td>
</tr>
<tr>
<td>900-0158-DRL</td>
<td>Summer School III (1 week)</td>
<td>W 2</td>
<td>4K Lecturers</td>
</tr>
<tr>
<td>900-0159-DRL</td>
<td>Summer School I (1 week, with Poster or Talk)</td>
<td>W 3</td>
<td>6K Lecturers</td>
</tr>
<tr>
<td>900-0160-DRL</td>
<td>Summer School II (1 week, with Poster or Talk)</td>
<td>W 3</td>
<td>6K Lecturers</td>
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</table>

Abstract Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

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Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

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Autumn Semester 2024
<table>
<thead>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>900-0161-DRL</td>
<td>Summer School III (1 week, with Poster or Talk)</td>
<td>Only for doctoral students.</td>
<td>3 credits</td>
<td>Lecturers</td>
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<tr>
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<td>Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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<td></td>
<td>Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.</td>
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<tr>
<td>900-0162-DRL</td>
<td>External Conference I (incl. Poster or Talk)</td>
<td>Only for doctoral students.</td>
<td>1 credit</td>
<td>Lecturers</td>
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<td>Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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<td>Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.</td>
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<tr>
<td>900-0163-DRL</td>
<td>External Conference II (incl. Poster or Talk)</td>
<td>Only for doctoral students.</td>
<td>1 credit</td>
<td>Lecturers</td>
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**Doctorate Biology - Key for Type**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
</tbody>
</table>

**Key for Hours**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
This course focuses on modeling spatio-temporal problems in biology, in particular on the cell and tissue level. The main focus is on mathematical modeling of evolution, including deterministic and stochastic models, with an emphasis on tumor evolution.

The goal of this course is to understand and to appreciate mathematical models and computational methods that provide insight into the evolutionary process in general and tumor evolution in particular. Students should analyze and evaluate models and their application critically and be able to design new models.

Evolution is the one theory that encompasses all of biology. It provides a single, unifying concept to understand the living systems that we observe today. We will introduce several types of mathematical models of evolution to describe gene frequency changes over time in the context of different biological systems, focusing on asexual populations. Viruses and cancer cells provide the most prominent examples of such systems and they are at the same time of great biomedical interest. The course will cover some classical mathematical population genetics and population dynamics, and also introduce several new approaches. This is reflected in a diverse set of mathematical concepts which make their appearance throughout the course, all of which are introduced from scratch. Topics covered include the quasispecies equation, evolution of HIV, evolutionary game theory, evolutionary stability, evolutionary graph theory, tumor evolution, stochastic tunneling, genetic progression of cancer, diffusion theory, fitness landscapes, branching processes, and evolutionary escape.

Students will learn basic and advanced biophysical methods applied to problems in molecular biotechnology. The course provides an introduction to key concepts in developmental biology.

The module is composed of 3 SWS (3 hours/week): 2-hour lecture, 1-hour seminar. For the seminar, students will prepare oral presentations on specific in-depth subjects with/under the guidance of the teacher.

The biophysical methods to be taught will include:

- Light microscopy: Resolution limit of light microscopy, fluorescence, GFP, fluorescence microscopy, DIC, phase contrast, difference between wide-field and confocal microscopy
- Super resolution optical microscopy: STED, PALM, STORM, other variations
- Electron microscopy: Scanning electron microscopy, transmission electron microscopy, electron tomography, cryo-electron microscopy, single particle analysis and averaging, tomography, sectioning, negative stain
- X-ray, electron and neutron diffraction
- MRI imaging
- Scanning tunneling microscopy and atomic force microscopy
- Patch clamp technologies: Principles of patch clamp analysis and application. Various patchclamp approaches used in research and industry
- Surface plasmon resonance-based biosensors
- Molecular pore-based sensors and sequencing devices
- Mechanical molecular and cellular assembly devices
- Optical and magnetic tweezers
- CD spectroscopy
- Optogenetics
- Molecular dynamics simulations

The students will be imparted knowledge in basic and advanced biophysical methods applied to problems in molecular biotechnology. The course is fundamental to applying the methods in their daily and advanced research routines. The students will learn the physical basis of the methods as well as their limitations and possibilities to address existing and future topics in molecular biotechnology.

Gain of interdisciplinary competence in experimental and theoretical research, which qualifies for academic scientific work (master's or doctoral thesis) as well as research in biotechnology or a pharmaceutical company. The module is of general use in courses focused on modern biomolecular technologies, systems biology and systems engineering.

The students will learn basic and advanced knowledge in applying biophysical methods to address problems and overcome challenges in biotechnology, cell biology and life sciences in general. The biological and physical possibilities and limitations of the methods will be discussed and critically evaluated. By the end of the course the students will have assimilated knowledge on a portfolio of biophysical tools widening their research capabilities and aptitude.
Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides an introduction to dynamical system, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

1. Introduction to Modelling in Biology
2. Bioimage Analysis
3. Morphogen Gradients
4. Precision & Robustness of Patterning
5. Mathematical Description of Growing Biological Systems
6. Travelling Waves & Wave Pinning
7. Turing Patterns
8. Chemotaxis
9. Epithelial Organisation
10. Tissue Simulation Frameworks
11. Tissue Mechanics & Fluid Dynamics
12. Growth Control
13. Image-Based Modelling
14. Summary

The course is self-contained. The course assumes no background in biology but a good foundation regarding mathematical and computational techniques.

<table>
<thead>
<tr>
<th>636-0117-00L</th>
<th>Mathematical Modelling for Bioengineering and Systems Biology</th>
<th>4 credits</th>
<th>3G</th>
<th>D. Iber</th>
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</thead>
</table>

**Abstract**
Basic concepts and mathematical tools to explore biochemical reaction kinetics and biological network dynamics.

**Objective**
The course enables students to formulate, analyse, and simulate mathematical models of biochemical networks. To this end, the course covers basic mathematical concepts necessary to build mathematical models of biochemical reaction dynamics as well as basic concepts from dynamical systems theory. The exercises serve to deepen the understanding of the presented concepts and the mathematical methods, and to train students to numerically solve and simulate mathematical models.

**Content**
Biochemical Reaction Modelling

- Basic Concepts from Linear Algebra & Differential Equations
- Mathematical Methods: Linear Stability Analysis, Phase Plane Analysis, Bifurcation Analysis
- Dynamical Systems: Switches, Oscillators, Adaptation Signal Propagation in Signalling Networks
- Parameter Estimation

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies

- Method-specific Competencies
  - Analytical Competencies
  - Problem-solving

- Personal Competencies
  - Creative Thinking
  - Critical Thinking

**Prerequisites / notice**
The course is self-contained. The course assumes no background in biology but a good foundation regarding mathematical and computational techniques.

<table>
<thead>
<tr>
<th>636-0103-00L</th>
<th>Microtechnology</th>
<th>W</th>
<th>4 credits</th>
<th>3G</th>
<th>A. Hierlemann</th>
</tr>
</thead>
</table>

**Abstract**
Students are introduced to the basics of microtechnology, cleanroom, semiconductor and silicon process technologies. They will get to know the fabrication of mostly silicon-based microdevices and -systems and all related microfabrication processes.

**Objective**
Students are introduced to the basics of microtechnology, cleanroom, semiconductor and silicon process technologies. They will get to know the different fabrication methods for various microdevices and systems.

**Content**
Introduction to microtechnology, semiconductors, and micro electro mechanical systems (MEMS)

- Fundamentals of semiconductors and band model
- Fundamentals of devices: transistor and diode.
- Silicon processing and fabrication steps
- Silicon crystal structure and manufacturing
- Thermal oxidation
- Doping via diffusion and ion implantation
- Photolithography
- Thin film deposition: dielectrics and metals
- Wet etching & bulk micromachining
- Dry etching & surface micromachining
- Microelectronic processing and fabrication sequence
- Optical: Packaging

**Lecture notes**
Handouts in English

**Literature**

**Prerequisites / notice**
Fundamentals in physics and physicochemistry (orbital models etc.) are required, a repetitiorium of fundamental physics and quantum theory at the semester beginning can be offered.

The information on the web can be updated until the beginning of the semester.
Biotechnology of Enzymes

Abstract
This course covers the role of enzymes in biotechnology, from discovery via engineering to applications in a variety of fields from food to the pharmaceutical industry.

Objective
Students will learn to identify opportunities for utilizing enzymes in biotechnology and develop basic and advanced enzyme engineering skills, informed by the latest research and techniques.

Content
This course offers an in-depth exploration of the use and engineering of enzymes in biotechnology, spanning fundamental enzymology, enzyme engineering, and applied biocatalysis. Topics will include (1) thermodynamic, kinetic, and mechanistic principles of enzyme catalysis, (2) the generation and engineering of enzymes through technologies such as protein design and directed evolution, (3) industrially applied biocatalysis, and (4) future challenges for biocatalysis.

Literature
The course will use selected parts of textbooks, original scientific publications, and reviews, which will be shared during the lecture.

Biological Engineering and Biotechnology

Abstract
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content

Method-specific Competencies
Concepts and Theories
Techniques and Technologies
Analytical Competencies
Communication
Cooperation and Teamwork
Self-direction and Self-management

Stem Cells: Biology and Therapeutic Manipulation

Abstract
Stem cells are central in tissue regeneration and repair, and hold great potential for therapy. We will discuss the role of stem cells in health and disease, and possibilities to manipulate their behavior for therapeutic application. Basic molecular and cell biology, engineering and novel technologies relevant for stem cell research and therapy will be discussed.

Objective
Understanding of current knowledge, and lack thereof, in stem cell biology, regenerative medicine and required technologies. Theoretical preparation for practical laboratory experimentation with stem cells.
We will use different diseases to discuss how to potentially model, diagnose or heal them by stem cell based therapies. This will be used as a guiding framework to discuss relevant concepts and technologies in cell and molecular biology, engineering, imaging, bioinformatics, tissue engineering, that are required to manipulate stem cells for therapeutic application.

Topics will include:
- Embryonic and adult stem cells and their niches
- Induced stem cells by directed reprogramming
- Relevant basic cell biology and developmental biology
- Relevant molecular biology
- Cell culture systems
- Cell fates and their molecular control by transcription factors and signalling pathways
- Cell reprogramming
- Disease modelling
- Tissue engineering
- Bioimaging, Bioinformatics
- Single cell technologies

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Conceptual and Theoretical</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Techniques and Technologies</td>
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<td>Analytical Competencies</td>
<td>Media and Digital Technologies</td>
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<td>Integrity and Work Ethics</td>
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636-0118-00L Introduction to Dynamical Systems with Applications to Biology

W 4 credits 3G+2A M. H. Khammash

Abstract
Many physical systems are dynamic and are characterized by internal variables that change with time. Describing the quantitative and qualitative features of this change is the topic of dynamical systems theory. Dynamical systems arise naturally in virtually all scientific disciplines including physics, biology, chemistry and engineering. This course is a broad introduction to the topic dynamical systems.

Objective
The goal of this course is to introduce the student to dynamical systems and to develop a solid understanding of their fundamental properties. The theory will be developed systematically, focusing on analytical methods for low dimensional systems, geometric intuition, and application examples from biology. Computer simulations using mat lab will be used to demonstrate various concepts.

Content
A dynamical view of the world; the importance of nonlinearity; solutions of differential equations; solving equations on the computer; the phase plane; fixed points and stability; linear stability analysis; classifications of linear systems; Liapunov functions and nonlinear stability; cycles and oscillations; bifurcations and bifurcation diagrams. Many biological examples will be used through the course to demonstrate the concepts.

Lecture notes
Will be provided as needed.

Literature


Prerequisites / notice
Prerequisites: Calculus; a first course in differential equations; basic linear algebra (eigenvectors and eigenvalues). Matlab programming.

636-0119-00L Introduction to Statistics and R

W 6 credits 3G+2A J. Kuipers

Abstract
This course offers a practical introduction to the fundamentals of data analysis and R.

Objective
To acquire the statistical understanding to design an appropriate analysis and the practical skills to implement the analysis in R and present the results.

Content
Data analysis is fundamental for arriving at scientific conclusions and testing different hypotheses. This course offers a hands-on introduction to statistical analyses including: exploratory data analysis, testing differences in populations, p-values, power calculations, multiple testing, confounding, linear regression, maximum likelihood, model selection, and logistic regression; along with the fundamentals of R programming including markdown and data handling with the tidyverse.

Lecture notes
Lecture slides will be available.

Prerequisites / notice
Access to Rstudio with some markdown and tidyverse packages installed.

636-0017-00L Computational Biology

W 6 credits 3G+2A T. Vaughan, C. Magnus, T. Stadler

Abstract
The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Objective
Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:
- stochastic models in molecular evolution
- phylogenetic & phylodynamics inference
- maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:
- epidemiology
- pathogen evolution
- macroevolution of species

Content
The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes
Lecture slides will be available on moodle.
This course is an introduction to the wide field of Genomics. It addresses how fundamental questions in biological systems are studied.

Objectives

- To introduce students to the fundamental concepts of systems biology.
- To provide an overview of the methodologies used in systems biology.
- To develop skills in applying computational methods to analyze biological data.
- To understand the importance of computational tools in exploring and interpreting biological systems.

Competencies

- Analytical Competencies: Evaluate and interpret data from computational analysis.
- Creative Thinking: Apply creative solutions to complex biological problems.
- Problem-solving: Identify and solve problems related to biological systems.

Prerequisites

- Basic knowledge in linear algebra, analysis, and statistics will be helpful.
- Programming in R for project work.

Literature

- Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.

Software

- R for data analysis.
- BEAST for phylogenetic analysis.

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

- Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.

The course is organized jointly by D-BSSE and LYO-X, a Quantitative Systems Pharmacology consulting company situated in Basel.

The technical components of this course are to be evaluated weekly.

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory
- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature

Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

263-3210-00L Deep Learning W 8 credits 3V+2U+2A T. Hofmann

Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:
  - Advanced Machine Learning
    https://ml2.inf.ethz.ch/courses/aml/
  - Computational Intelligence Lab
    http://da.inf.ethz.ch/teaching/2019/CIL/
  - Introduction to Machine Learning
    https://las.inf.ethz.ch/teaching/introml-s19
  - Statistical Learning Theory
    http://ml2.inf.ethz.ch/courses/slt/
  - Computational Statistics
    https://stat.ethz.ch/lectures/ss19/comp-stats.php
  - Probabilistic Artificial Intelligence
    https://las.inf.ethz.ch/teaching/pai-f18

263-5053-00L Technology Investing W 2 credits 3S A. Ilac, C. Jurzyk

Abstract
Venture Capital is important to fund big transformational ideas and is often misunderstood by tech or research entrepreneurs. This lecture immerses participants in the role of a Venture Capitalist (VC) to learn from experienced entrepreneurs and investors. In small teams, you work on a case of a real start-up and defend the case in a simulated investment committee consisting of experienced VCs.
Objective
After attending this course, students will be able to:
- Explain the differences between VC and founder thinking
- Evaluate if a start-up is suited for venture capital ("VC readiness")
- Evaluate founder friendliness of term sheets
- Determine funding needs & strategy for a start-up from research to first round
- Write and evaluate an investment memo

Content
The course is practically oriented and features guest speakers from leading venture capital firms and start-ups. The course embraces a unique perspective combining technology and investor thinking. The seminar is structured around five days with the following themes.

The detailed program is listed here: https://bit.ly/techinvesting23

The macro picture. Why does venture capital exist? What are major tech breakthrough areas and their disruptive potential? We also review the differences in the US and European perspective as well as developments towards more impact and diversity conscious funds.

A peek into the mind of a VC. How to build a successful VC? Learn what key factors & processes required to build a successful venture capital company. This includes strategic decisions for investment thesis, structure of a fund, portfolio economics, valuation & ownership targets, cap table. In addition, we introduce the fundamentals of the investment process (including due diligence, term sheets, and deal memo) as well as portfolio management.

The founder’s perspective. Why should you raise venture capital and how? Learn to evaluate the founder friendliness of terms, company approach, strategic decisions, negotiation and valuation.

Fundraising types. Learn about different types of funding and their implications. This includes an overview of the Swiss ecosystem and a discussion of the different types (grants, equity, loans, SAFE, crowd, …). We also include a practical session on crypto technology for modern fund-raising using launchpads and tokenized shares.

Tying it all together. The last day is focused on simulating an investment committee meeting where the groups present their deal memos and discuss with the audience.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management

Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Abstract
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice
The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management

Social Competencies
Communication
Cooperation and Teamwork

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

263-5210-00L Probabilistic Artificial Intelligence W 8 credits 3V+2U+2A A. Krause


Only for Biotechnologie Master, Programme Regulations 2021 or doctoral students of D-BSSE.
Abstract: This course provides an overview of modern concepts of bioengineering across different levels of complexity, from single molecules to systems, microscaled reactors to production environments, and across different fields of applications.

Objective: Students will be able to recognize major developments in bioengineering across different organisms and levels of complexity and be able to relate it to major technological and conceptual advances in the underlying sciences.

Content: Molecular and cellular engineering; Synthetic biology; Engineering strategies in biology; from single molecules to systems; downscaling bioengineering; Bioengineering in chemistry, pharmaceutical sciences, and diagnostics, personalized medicine.

Lecture notes: Handouts during class

Literature: Will be announced during the course

Competencies: Subject-specific Competencies

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Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract: Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective: Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Language Courses ETH/UZH: see Science in Perspective

Educational Science for Teaching Diploma and TC

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 732 of 2653
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Objective: Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

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Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.
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**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

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<td>900-0114-DRL</td>
<td>Member of Executive Board (min 1 year)</td>
<td>W</td>
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**851-0178-00L** Ethics and Scientific Integrity for Doctoral Students

This course is interdisciplinary. If your department offers this course, please register there if possible.

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<td>1 credit</td>
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**Abstract**

Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

**Objective**

Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

**[Part I on Moodle](#)**

The self-paced e-learning course on Moodle consists of 5 modules:

1. **Module 1: Ethics**
   - Introduction to moral theory (with emphasis on practical guidance regarding decision making)

2. **Module 2: Ethics in scientific research**
   - Introduction to ethical issues that occur within scientific research (i.e. regarding authorship, cooperation, data use and sharing, and other aspects that are subject to scientific integrity and good scientific practice).

3. **Module 3: Collecting resources**
   - A variety of tools and resources that help identify ethical issues are presented and explained

4. **Module 4: Setting up a strategy**
   - Example examination of a case regarding its ethical scope (students develop their own strategy to examine situations for their ethical implications).

5. **Module 5: Making decisions**
   - Different ways of addressing ethical issues are presented and explained (i.e. how to make hard choices, or solve ethical dilemmas. But also where to seek advice if needed).

**Part II**

The second, face-to-face part (group sessions) of this course provides an interactive learning environment (workshop). Students get to apply their knowledge, and they are encouraged to reflect on ethical problems and to critically discuss them with fellow doctoral students.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
- **Method-specific Competencies**
  - Decision-making: assessed
- **Personal Competencies**
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed

**Data:** 15.06.2024 12:39  |  **Autumn Semester 2024**  |  **Page 734 of 2653**
Abstract
This course (e-learning module followed by workshop) equips doctoral students with knowledge and tools to recognize, discuss and address ethical issues of their research.

Objective
Doctoral students learn how to identify, analyze and address ethical issues in their own research. They will also reflect on their professional role as scientists.

Content
This course introduces doctoral students to ethical issues that may occur during their research activities. After an introduction to ethics and good scientific practice, participants are familiarised with resources that can assist them with ethical decision-making (e-learning module on Moodle). In the second, face-to-face part, participants will have the opportunity to critically discuss their knowledge and share their experiences with fellow doctoral students in a discipline specific context.

Integration into Scientific Community

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<tr>
<th>Number</th>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 735 of 2653
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**Doctorate Biosystems Science and Engineering - Key for Type**

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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 736 of 2653
### Key for Hours

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<td>exercise</td>
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<td>K</td>
<td>colloquium</td>
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<td>practical/laboratory course</td>
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<td>A</td>
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<td>R</td>
<td>revision course / private study</td>
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**ECTS**  
European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Inorganic Chemistry

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<td>Group seminar on elemental analysis and isotope ratio determinations using various plasma sources</td>
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<tr>
<td>Content</td>
<td>Developments in plasma mass spectrometry and alternative plasma sources</td>
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<td>529-0199-00L</td>
<td>Inorganic and Organometallic Chemistry</td>
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<td>C. Copéret, M. Bezděk, D. Günther, M. Kovalenko, T. Lippert, V. Mougel, P. Steinegger</td>
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<td>2V</td>
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<td>Introduction to the fundamentals of lasers and their applications with an emphasis on micro- and nano-structuring. Several applications which are still in the research state, will be discussed together with industrial applications, such as micro lithography and laser welding. Other aspects are the materials that are applied in these applications, e.g. photoresists, and their functioning.</td>
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<td>Introduction to the fundamentals of lasers and their applications with an emphasis on micro- and nano structuring. Several applications which are still in the research state, e.g. non-optical lithographies, will be discussed together with industrial applications, such as micro lithography and laser welding. Other aspects are the materials that are applied in these applications, e.g. photoresists, and their functioning.</td>
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<td>Content</td>
<td>Introduction to lasers, overview of micro- and nanotechnology, micro lithography, photoresists: classical types and new developments, laser cutting and welding, laser cleaning, laser ablation, polymer ablation: designed polymers, lasers and surfaces, laser spectroscopy, laser chemical vapor deposition, pulsed laser deposition (PLD), special materials by PLD, alternative structuring methods.</td>
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<td>FSRM, CD-ROM: An Introduction to the World of Microsystems, Neuchatel.</td>
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Organic Chemistry

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<td>J. W. Bode, E. M. Carreira, P. Chen, K. Lang, B. Morandi, H. Wernemers, R. Zenobi</td>
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Subject Specialisation

Doctorate Chemistry and Applied Biosciences

Further information at: https://www.ethz.ch/en/doctorate.html
In the last decade, a novel type of cell compartments called biomolecular condensates have been discovered. This discovery is radically changing our understanding of the cell, its organization, and dynamics. The emerging picture is that the cytoplasm and nucleoplasm are highly complex fluids that can (meta)stably segregate into membrane-less compartments, similar to emulsions.

This interdisciplinary course encompasses milestone works and cutting-edge research questions in the young field of biomolecular condensates, including their properties, functions, and applications. The course begins with a lecture series that introduces the topic of condensates to an interdisciplinary audience and provides a theoretical foundation for understanding current research questions in the field. The lectures provide a base for student presentations of recent publications in the field, and for research seminars given by course lecturers, who are all active researchers with diverse expertise. Through this exciting interdisciplinary understanding of biomolecular condensates, bridging biology, chemistry, biophysics, and soft matter.

Students will not only learn how to critically read and evaluate scientific literature but will also gain valuable experience in giving scientific presentations to an interdisciplinary audience. Each presentation will require an introduction, critical analysis of the results, and a discussion of their significance, allowing student to substantiate their statements with a critical mindset that considers the pros and cons of chosen approaches and methods, as well as any limitations or possible follow-up experiments. This process will enable student to ask relevant questions and actively participate in class discussions, further enhancing their scientific skills.

In preparing the presentations, the students will have the unique opportunity to interact closely with each other and with the lecturers, who are all internationally well-established experts, and receive guidance in select a topic for the final presentation and supporting literature.

The topic of biomolecular condensates goes beyond the boundaries of traditional disciplines and requires a multi-disciplinary approach that leverages and cross-fertilizes biology, physical chemistry, biophysics, and soft matter. This course will explore the properties, functions and potential applications of biomolecular condensates, including their role in neurodegenerative diseases such as Alzheimer's and Parkinson's, as well as their use as smart biomimetic materials.

This course is divided into two parts. The fist part will introduce the basic concepts essential to the study of biomolecular condensates and phase separation. Topics include: fundamental units and scales in soft matter, phase transitions in biology, biopolymers and molecular self-assembly, introduction to active matter. This will establish a foundation for the second part, which will explore milestone works and current research in the field of biomolecular condensates. Each lecture of this second part will consist of:

1) a short literature seminar, where student groups will present and discuss a milestone paper assigned in advance and
2) a research seminar, where one of the course lecturers will present their own state-of-the-art research in the field, building upon the milestone literature.

At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate this, students must confirm their registration by the beginning of the 3rd week of semester.

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Physical Chemistry

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**Objective**


**Lecture notes**

Unterlagen in der ersten Stunde verteilt.

**Prerequisites / notice**

Zugang mit Bewilligung des Dozenten

**Literature**

Varriert nach aktuellem Stand der Forschung

**Objective**

The students will understand how to use the tools needed to analyze simple highly resolved spectra. They will become familiar with experimental techniques in high resolution molecular spectroscopy and will understand how molecular spectroscopy can be applied to solve problems with respect to atmospheric pollutants and the detection of molecules in interstellar space.

**Content**

The students will learn how to record rotationally and rovibrationally resolved spectra in the THz and IR frequency range. For that purpose state-of-the-art sources like synchrotrons, FELs and other THz sources will be discussed. In this context, the basics of Fourier transform infrared spectroscopy will also be reviewed. The analysis of such spectra with interactive programs will then be explained. Finally, applications of high resolution molecular spectroscopy in the field of atmospheric and interstellar chemistry will be discussed. The identification and the quantitative determination of atmospheric pollutants will be discussed in detail. In addition, the identification of interstellar molecules in the context of the origin of life will be reviewed. The question of the identification of the interstellar unidentified infrared bands and of the interstellar diffuse bands will also be addressed. Finally, high resolution molecular spectroscopy of chiral molecules in the context of molecular parity violation will be discussed.

**Abstract**

Institut-Seminar covering current research topics in Physical Chemistry.
The topic of biomolecular condensates goes beyond the boundaries of traditional disciplines and requires a multi-disciplinary approach that leverages and cross-fertilizes biology, physical chemistry, biophysics, and soft matter. This course will explore the properties, functions and potential applications of biomolecular condensates, including their role in neurodegenerative diseases such as Alzheimer's and Parkinson's, as well as their use as smart biomimetic materials.

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2) a research seminar, where one of the course lecturers will present their own state-of-the-art research in the field, building upon the milestone literature.

At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate this, students must confirm their registration by the beginning of the 3rd week of semester.

Lecture notes Lecture slides and some scripts will be provided.

Literature No compulsory textbooks. Literature will be provided during the course

Competencies

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Lecture notes

529-0060-00L MPS Colloquium 0 credits 3K G. Jeschke, A. Barnes, M. Ernst, P. H. Hünenberger, M. Reiher, J. Richardson, R. Riek, S. Riniker, T. Schmidt

Abstract Seminar series covering current developments in Molecular Physical Science

Objective Discussing current developments in Molecular Physical Science

Competencies

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<td>Project Management</td>
<td>Sensitivity to Diversity</td>
<td>Self-awareness and Self-reflection</td>
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<td>Negotiation</td>
<td>Self-direction and Self-management</td>
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551-0357-00L Cellular Matters: Properties, Functions and Applications of Biomolecular Condensates

The number of participants is limited to 30 and will only take place with a minimum of 6 participants.

At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate...
This Master level course delves into the emerging field of biomolecular condensates - membrane-less organelles in cells. Using interdisciplinary concepts from biology, chemistry, biophysics, and soft matter, we will explore the biological properties of these condensates, their functions in health and disease, and their potential as new biomimetic materials for various applications.

In the last decade, a novel type of cell compartments called biomolecular condensates have been discovered. This discovery is radically changing our understanding of the cell, its organization, and dynamics. The emerging picture is that the cytoplasm and nucleoplasm are highly complex fluids that can (meta)stably segregate into membrane-less compartments, similar to emulsions.

Students will not only learn how to critically read and evaluate scientific literature but will also gain valuable experience in giving scientific presentations to an interdisciplinary audience. Each presentation will require an introduction, critical analysis of the results, and a discussion of their significance, allowing student to substantiate their statements with a critical mindset that considers the pros and cons of chosen approaches and methods, as well as any limitations or possible follow-up experiments. This process will enable student to ask relevant querions and actively participate in class discussions, further enhancing their scientific skills.

In preparing the presentations, the students will have the unique opportunity to interact closely with each other and with the lecturers, who are all internationally well-established experts, and receive guidance in selectin a topic for the final presentation and supporting literature.

This course is divided into two parts. The fist part will introduce the basic concepts essential to the study of biomolecular condensates and phase separation. Topics include: fundamental units and scales in soft matter, phase transitions in biology, biopolymers and molecular self-assembly, introduction to active matter. This will establish a foundation for the second part, which will explore milestone works and current research in the field of biomolecular condensates. Each lecture of this second part will consist of:

1) a short literature seminar, where student groups will present and discuss a milestone paper assigned in advance and
2) a research seminar, where one of the course lecturers will present their own state-of-the art research in the field, building upon the milestone literature.

At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate this, students must confirm their registration by the beginning of the 3rd week of semester.

This interdisciplinary course encompasses milestone works and cutting-edge research questions in the young field of biomolecular condensates, including their properties, functions, and applications. The course begins with a lecture series that introduces the topic of condensates to an interdisciplinary audience and provides a theoretical foundation for understanding current research questions in the field. The lecturers provide a base for student presentations of recent publications in the field, and for research seminars given by course lecturers, who are all active researchers with diverse expertise. Through this exciting interdisciplinary understanding of biomolecular condensates, bridging biology, chemistry, biophysics, and soft matter.

Seminar for Group Members
In the weekly group seminar, in which members of the research team present and discuss the results of their projects and selected reports from the current scientific literature.

Lecture notes
Lecture slides and some scripts will be provided.

Literature
No compulsory textbooks. Literature will be provided during the course.

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<td>Personal Competencies</td>
<td>Adaptable and Flexibility</td>
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### Polymer Science

#### Pharmaceutical Sciences

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<tr>
<td>535-2000-00L</td>
<td>Seminar for Group Members</td>
<td>W</td>
<td>0</td>
<td>2S</td>
<td>G. Schneider</td>
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<tr>
<td>Abstract</td>
<td>Weekly group seminar, in which members of the research team present and discuss the results of their projects and selected reports from the current scientific literature.</td>
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<tr>
<td>Objective</td>
<td>Participants learn to present scientific studies and discuss own results in greater context.</td>
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<tr>
<td>535-0900-00L</td>
<td>Seminars on Drug Discovery and Development</td>
<td>E-</td>
<td>1</td>
<td>1K</td>
<td>R. Schibli, C. Halin Winter, J. Hall, J.-C. Leroux, U. Quitterer, G. Schneider, H. U. Zeilhofer</td>
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<tr>
<td>Abstract</td>
<td>State-of-the-art information on drug discovery and development by experts from academia and industry.</td>
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<tr>
<td>Objective</td>
<td>State-of-the-art information on drug discovery and development.</td>
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<tr>
<td>Content</td>
<td>Seminar series of the Institute of Pharmaceutical Sciences. Experts from academia and industry report on relevant topics.</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 742 of 2653
The lecture series takes place at the ETH Hönggerberg and covers a variety of major activities involved in drug discovery: selecting drug targets, technologies used in drug discovery, small, medium and large drugs, objectives of the medicinal chemist, assessing drug safety, principles of personalized medicine, designing clinical trials, how intellectual property is protected, as well as others.

The objective of the course is to gain a global understanding of most of the important phases in the discovery and development of modern synthetic and biological drugs, from the first activities to clinical trials. The lecture is intended for students that have an interest in the area and/or may consider a career working in drug discovery. This lecture course complements knowledge and experience gained in the research project performed by the Ph.D. student.

Thirteen two hour lectures for life-science PhD students and students of the Pharmaceutical Sciences Master, given by experts from the ETH, UZH, USZ and the pharmaceutical industry.

Introduction to the modern drug discovery process - Principles of drug pharmacokinetics and drug metabolism - Computer sciences in drug discovery - Drug targets - In vitro methods in drug discovery - Natural products in drug discovery - Medicinal chemistry: Chemical lead selection/optimization - Antibodies and therapeutic proteins: Targets and drugs - In vivo molecular imaging in drug discovery - Drug formulation: Key development consideration, Current new APIs challenges and FDA rising standards - Preclinical safety, adverse drug events and drug-drug interactions - Clinical development steps including trial design - Intellectual property in drug discovery and development

To be distributed during the lecture

Formally none, but a basic understanding in biochemistry, physiology and chemistry is highly desirable as it will certainly help to get the most from the lectures.

### Additional Courses

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tr>
<td>529-0195-00L</td>
<td>Scientific Information Retrieval &amp; Management in Life Sciences and Chemistry</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>O. Renn, L. Betschart, J. Dolenc</td>
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</tbody>
</table>

**Abstract**

Students learn how to effectively retrieve, critically judge, analyze, and manage published scientific information – important skill sets in chemistry and life sciences where scientists need to deal with vast amounts of information. The course, using practical examples, also covers scientific writing, visualizations, science communication and state-of-the-art technologies such as text mining.

**Objective**

Students are made aware about the wide variety of information solutions that exist today for all kinds of research processes, get an independent understanding of how they are derived and learn how to critically judge their quality. They learn how scientific communication works today and on which concepts and principles it is based. They develop the ability to select appropriate, subject-specific databases or tools for a given specific scientific question based on a sound understanding on how a tool or database has been developed and maintained, thus building the personal capacity of doing research effectively and efficiently by integrating scientific information into the research process when needed. Students learn how to evaluate information solutions, to build suitable search strategies and to integrate them in their information workflows. Also, they learn how to effectively communicate their own scientific results using various distribution channels and to measure the impact of their outreach activities. Overall, they gain the ability to perform all steps of the research cycle in a time- and cost-efficient manner, from the research strategy up to writing a first paper and their Ph.D. thesis.

**Content**

The course has been primarily designed for Ph.D. students, also for the Life Science Zurich Graduate School, but is also open to Master students. In a series of 12 units, which always include practical examples (for some lectures a notebook is required), the use of scientific information is taught not in a database-centric view but corresponding to the steps through which scientific research is conducted – including the dissemination of scientific results. This is particularly interesting for students who are about to write-up their first paper or thesis.

Students will learn about the different types of information resources and tools, get an insight into the numerous databases and tools that exists and how those are built and maintained, enabling them to critically judge the value and trustworthiness of an information resource. Additionally, they will learn how to communicate their own scientific results properly, using also additional measures that are reflected by alternative metrics.

The following topics are covered in twelve modules:

1. & 2. The world of scientific publishing: basics, publishing models
2. Searching and retrieving scientific information using search engines and literature databases
3. Searching and retrieving scientific information using subject-specific databases in chemistry and materials science
4. Searching and retrieving scientific information using subject-specific databases in life sciences
5. Tools for analyzing scientific information
6. Tools for managing scientific information and sharing knowledge, including pipelining tools
7. Patents
8. Text (literature) mining
9. Visualizing molecules for lab reports, presentations, posters, and publications
10. Scientific writing, good design & good scientific practice
11. Communicating & analyzing the impact of (your) science

**Lecture notes**

The slide deck and supplementary materials will be made available in the teaching document repository (ILIAS) after each lecture.

**Literature**

Additional literature and reference are provided in the course material.

**Competencies**

- **Method-specific Competencies**
  - Analytical Competencies
  - Media and Digital Technologies
  - Project Management
- **Social Competencies**
  - Communication
- **Personal Competencies**
  - Critical Thinking

**Transferrable Skills**

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<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
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<tr>
<td>900-0100-DRL</td>
<td>Transferable Skills Course I (1-3 days) Only for doctoral students.</td>
<td>W</td>
<td>1</td>
<td>2S</td>
<td>Lecturers</td>
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</table>

**Abstract**

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

**Content**

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Literature**

To be distributed during the lecture

**Prerequisites / notice**

For doctoral students.
<table>
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<tr>
<th>Course Code</th>
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<th>Duration</th>
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<th>Semester</th>
<th>Lecturers</th>
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<td>Transferable Skills Course III (1-3 days)</td>
<td>Only for doctoral students.</td>
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<td>1 credit</td>
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<td>900-0103-DRL</td>
<td>Transferable Skills Course I (1-3 days, with Poster or Talk)</td>
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<td>W</td>
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<td>Transferable Skills Course II (1-3 days, with Poster or Talk)</td>
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<tr>
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Transferable Skills Course I (1 week, with Poster or Talk)  
Only for doctoral students.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Transferable Skills Course II (1 week, with Poster or Talk)  
Only for doctoral students.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Transferable Skills Course III (1 week, with Poster or Talk)  
Only for doctoral students.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Participation in Commission I (min 1 year)  
Only for doctoral students.

Objective
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

Abstract
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

Participation in Commission II (min 1 year)  
Only for doctoral students.

Objective
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

Abstract
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

Member of Executive Board (min 1 year)  
Only for doctoral students.

Objective
Active participation in the presidium or executive board of a university group for at least 1 year.

Abstract
Active participation in the presidium or executive board of a university group for at least 1 year.

Ethics and Scientific Integrity for Doctoral Students in Chemistry and Related Fields  
C. Copéret, S. J. Sturla

Objective
Doctoral students learn how to identify, analyse and address ethical issues in their own scientific research. In addition, they will reflect on their professional role as scientific researchers.
Content

Part I on Moodle
The self-paced e-learning course on Moodle consists of 5 modules:

Module 1: Ethics
- Introduction to moral theory (with emphasis on practical guidance regarding decision making)

Module 2: Ethics in scientific research
- Introduction to ethical issues that occur within scientific research (i.e. regarding authorship, cooperation, data use and sharing, and other aspects that are subject to scientific integrity and good scientific practice)

Module 3: Collecting resources
- A variety of tools and resources that help identify ethical issues are presented and explained

Module 4: Setting up a Strategy
- Example examination of a case regarding its ethical scope (students develop their own strategy to examine situations for their ethical implications).

Module 5: Making decisions
- Different ways of addressing ethical issues are presented and explained (i.e. how to make hard choices, or solve ethical dilemmas. But also where to seek advice if needed).

Part II
The second, face-to-face part of this course focuses on chemistry-specific aspects. It provides an interactive learning environment. Students get to apply their knowledge, and they are encouraged to reflect on ethical problems and to critically discuss them with fellow doctoral students.

Lecture notes
Moodle

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<th>Integration into Scientific Community</th>
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Lecture notes
Moodle

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 746 of 2653
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**
Participation in summer or winter schools with a minimum duration of 1 week.

**Objective**
Participation in summer or winter schools with a minimum duration of 1 week.

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**Autumn Semester 2024**
Objective

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

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<th>Doctorate Chemistry and Applied Biosciences - Key for Type</th>
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ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Subject Specialisation

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Transferable Skills

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and prove your participation with the appropriate certificate.

**Abstract**
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**Objective**
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

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<tr>
<th>Course Code</th>
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<td><strong>Abstract</strong></td>
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<td><strong>Abstract</strong></td>
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<td>T. I. Eglinton, H. Stoll</td>
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<td><strong>Abstract</strong></td>
<td>This course sensitises doctoral students to ethical issues that may occur during their doctorate. After an introduction to ethics and good scientific practice, students are familiarised with resources that can assist them with ethical decision-making. Students get the chance to apply their knowledge in a discipline specific context.</td>
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<td><strong>Objective</strong></td>
<td>Doctoral students learn how to identify, analyse and address ethical issues in their own scientific research. In addition, they will reflect on their professional role as scientific researchers.</td>
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<td><strong>Content</strong></td>
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<td>Module 1: Ethics</td>
<td>- Introduction to moral theory (with emphasis on practical guidance regarding decision making)</td>
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<td>Module 2: Ethics in scientific research</td>
<td>- Introduction to ethical issues that occur within scientific research (i.e. regarding authorship, cooperation, data use and sharing, and other aspects that are subject to scientific integrity and good scientific practice).</td>
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<td>Module 3: Collecting resources</td>
<td>- A variety of tools and resources that help identify ethical issues are presented and explained</td>
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<td>Module 4: Setting up a strategy</td>
<td>- Example examination of a case regarding its ethical scope (students develop their own strategy to examine situations for their ethical implications).</td>
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<td></td>
<td>Module 5: Making decisons</td>
<td>- Different ways of addressing ethical issues are presented and explained (i.e. how to make hard choices, or solve ethical dilemmas. But also where to seek advice if needed).</td>
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**Integration into Scientific Community**

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<tr>
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<tr>
<td>900-0150-DRL</td>
<td>Summer School I (1-3 days)</td>
<td>W</td>
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<td></td>
<td>Only for doctoral students.</td>
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<td>Lecturers</td>
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<td>Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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</tbody>
</table>
Abstract
Participation in summer or winter schools with a maximum duration of 3 days.

Objective
Participation in summer or winter schools with a maximum duration of 3 days.

900-0151-DRL
Summer School II (1-3 days)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Participation in summer or winter schools with a maximum duration of 3 days.

Objective
Participation in summer or winter schools with a maximum duration of 3 days.

900-0152-DRL
Summer School III (1-3 days)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Participation in summer or winter schools with a maximum duration of 3 days.

Objective
Participation in summer or winter schools with a maximum duration of 3 days.

900-0153-DRL
Summer School I (1-3 days, with Poster or Talk)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

900-0154-DRL
Summer School II (1-3 days, with Poster or Talk)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

900-0155-DRL
Summer School III (1-3 days, with Poster or Talk)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

900-0156-DRL
Summer School I (1 week)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Participation in summer or winter schools with a minimum duration of 1 week.

Objective
Participation in summer or winter schools with a minimum duration of 1 week.

900-0157-DRL
Summer School II (1 week)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Participation in summer or winter schools with a minimum duration of 1 week.

Objective
Participation in summer or winter schools with a minimum duration of 1 week.

900-0158-DRL
Summer School III (1 week)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Participation in summer or winter schools with a minimum duration of 1 week.

Objective
Participation in summer or winter schools with a minimum duration of 1 week.

900-0159-DRL
Summer School I (1 week, with Poster or Talk)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Participation in summer or winter schools with a minimum duration of 1 week.

Objective
Participation in summer or winter schools with a minimum duration of 1 week.
### Abstract
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

### Objective
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

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<td>Lecturers</td>
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<tr>
<td>900-0161-DRL</td>
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<td>Only for doctoral students.</td>
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<td>Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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<td>900-0162-DRL</td>
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<td>Lecturers</td>
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<td></td>
<td>Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.</td>
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<tr>
<td>900-0163-DRL</td>
<td>External Conference II (incl. Poster or Talk)</td>
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### Doctorate Earth Sciences - Key for Type

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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<td>O</td>
<td>Compulsory</td>
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### Key for Hours

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<tr>
<td>V</td>
<td>lecture</td>
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<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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### ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
The Role of Intellectual Property in the Engineering and Technical Sector

Abstract
The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.

Literature
Bronwyn Hall / Dietmar Harhoff, Recent Research on the Economics of Patents, 2011
Bronwyn Hall / Nathan Rosenberg (eds.), Handbook of the Economics of Innovation, 2 volumes, Amsterdam 2010, pp. 1471-1570
Suzanne Scotchmer, Innovation and Incentives, 2004

Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Decision-making
- Problem-solving
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

Assessed

Subject Specialisation

<table>
<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tr>
<td>851-0587-01L</td>
<td>CIS PhD Colloquium</td>
<td>W</td>
<td>2 credits</td>
<td>2K</td>
<td>University lecturers</td>
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<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<td></td>
<td>UZH Module Code: 615G932C</td>
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<tr>
<td>Abstract</td>
<td>In this internal colloquium doctoral students present their work after about 12 months of research.</td>
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<tr>
<td>Objective</td>
<td>The aim of this colloquium is that the presenters receive feedback on their research at an important stage (a stage at which significant changes of direction, methodology, etc. may still be undertaken) in the PhD process.</td>
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<tr>
<td>Content</td>
<td>Presentation of doctoral research.</td>
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<td>Lecture notes</td>
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<tr>
<td>Literature</td>
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<td>Prerequisites / notice</td>
<td>Dates: See <a href="http://www.cis.ethz.ch/education/index">http://www.cis.ethz.ch/education/index</a></td>
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| 851-0735-10L | Startups and Law              | W    | 2 credits | 2V    | P. Peyrot |
|              | Particularly suitable for students of D-ITET, D-MAVT. |
| Abstract     | The students shall obtain a basic knowledge about the legal environment of entrepreneurs. They shall be able to recognize and evaluate legal issues connected to an entrepreneurial activity and suggest possible solutions. |
| Objective    | The students shall obtain the following competence: - They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise. - They shall be able to contribute to the legal management of the company and to discuss legal issues. - They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company. |
| Lecture notes | A comprehensive script will be made available online on the moodle platform. |
| Competencies | Subject-specific Competencies: Concepts and Theories assessed |
|              | Method-specific Competencies: Analytical Competencies assessed, Decision-making fostered, Problem-solving assessed |
|              | Social Competencies: Communication fostered, Negotiation fostered |
|              | Personal Competencies: Adaptability and Flexibility fostered, Creative Thinking assessed, Critical Thinking assessed, Integrity and Work Ethics fostered |

| 851-0735-09L | Workshop & Lecture Series on the Law & Economics of Innovation | W    | 2 credits | 2S    | S. Bechtold |
|             | This series is a joint project by ETH Zurich and the Universities of St. Gallen and Zurich. It provides an overview of interdisciplinary research on intellectual property, innovation, antitrust, privacy & technology policy. Scholars from law, economics, management and related fields present their current research. All speakers are internationally well-known experts from Europe, the U.S. & beyond. |
| Abstract    | After the workshop and lecture series, participants should be acquainted with interdisciplinary approaches towards intellectual property, innovation, antitrust, privacy and technology policy research. They should also have an overview of current topics of international research in these areas. |
| Objective   | The workshop and lecture series will present a mix of speakers who represent the wide range of current social science research methods applied to intellectual property, innovation, antitrust, privacy and technology policy issues. In particular, theoretical models, empirical and experimental research as well as legal research methods will be represented. |
| Lecture notes | Papers discussed in the workshop and lecture series are posted in advance on the course web page. |
|              | Suzanne Scotchmer, Innovation and Incentives, 2004 |
|              | Bronwyn Hall / Nathan Rosenberg (eds.), Handbook of the Economics of Innovation, 2 volumes, Amsterdam 2010 |
|              | Bronwyn Hall / Dietmar Harhoff, Recent Research on the Economics of Patents, 2011 |
| Competencies | Subject-specific Competencies: Concepts and Theories assessed |
|              | Method-specific Competencies: Analytical Competencies assessed, Problem-solving assessed |
|              | Social Competencies: Communication assessed |
|              | Personal Competencies: Creative Thinking assessed, Critical Thinking assessed |

| 851-0738-01L | The Role of Intellectual Property in the Engineering and Technical Sector | W    | 2 credits | 2V    | K. Houshang Pour Islam |
|             | Particularly suitable for students of D-BAUG, D-BIOL, D-BSSE, D-CHAB, D-ITET, D-MAVT. |
| Abstract    | The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace. |
This colloquium offers an opportunity to discuss recent and ongoing research in the behavioral sciences, both at the micro- and macro-levels of cognitive, behavioral, and social science.

The colloquium features presentations from internal and external researchers as well as presentations of doctoral students close to submitting their dissertation research plan.

The colloquium features invited presentations from internal and external researchers as well as presentations of doctoral students close to submitting their dissertation research plan.

The colloquium provides a forum for researchers and graduate students in cognitive science to present/discuss their ongoing projects as well as jointly discuss current publications in cognitive science and related fields. A subset of the sessions will include invited external visitors presenting their research. Participants of this colloquium are expected to be involved in active research group.

The colloquium offers an opportunity to discuss recent and ongoing research and scientific ideas in the behavioral sciences, both at the micro- and macro-levels of cognitive, behavioral, and social science.

The colloquium features presentations from internal and external researchers as well as presentations of doctoral students close to submitting their dissertation research plan.

The colloquium provides a forum for researchers and graduate students in cognitive science to present/discuss their ongoing projects as well as jointly discuss current publications in cognitive science and related fields. A subset of the sessions will include invited external visitors presenting their research. Participants of this colloquium are expected to be involved in active research group.
Objective
Graduate student train and improve their presentation skills based on their own project ideas, all participants stay informed on current trends in the field and have the opportunity for networking with invited scholars.

851-0585-41L Computational Social Science

W 3 credits 2S D. Helbing, C. I. Hausladen, J. C.-Y. Yang

Abstract
The seminar aims at three-fold integration: (1) bringing modeling and computer simulation of techno-socio-economic processes and phenomena together with related empirical, experimental, and data-driven work, (2) combining perspectives of different scientific disciplines (e.g. sociology, computer science, physics, complexity science, engineering), (3) bridging between fundamental and applied work.

Objective
Participants of the seminar should understand how tightly connected systems lead to networked risks, and why this can imply systems we do not understand and cannot control well, thereby causing systemic risks and extreme events.

They should also be able to explain how systemic instabilities can be understood by changing the perspective from a component-oriented to an interaction- and network-oriented view, and what fundamental implications this has for the proper design and management of complex dynamical systems.

Computational Social Science and Global Systems Science serve to better understand the emerging digital society with its close co-evolution of information and communication technology (ICT) and society. They make current theories of crises and disasters applicable to the solution of global-scale problems, taking a data-based approach that builds on a serious collaboration between the natural, engineering, and social sciences, i.e. an interdisciplinary integration of knowledge.

Literature
Ball: Why Society Is A Complex Matter
• Helbing: Social Self-Organization
• Helbing: Managing Complexity
• Colander/Kupers: Complexity and the Art of Public Policy
• Mitchell: Complexity
• Buckley: Society – A Complex Adaptive System
• Castellan/Hafferty: Sociology and Complexity Science
• Mikhailov/Calenbuhr: From Cells to Society
• Mainzer: Thinking in Complexity
• Sawyer: Social Emergence
• Books published by the Santa Fe Institute

Computational Social Science
https://science.sciencemag.org/content/sci/323/5915/721.full.pdf

Manifesto of Computational Social Science
https://link.springer.com/article/10.1140/epjst/e2012-01697-8

Social Self-Organisation

How simple rules determine pedestrian behaviour and crowd disasters
https://www.pnas.org/content/108/17/6884.short

Peer review and competition in the Art Exhibition Game
https://www.pnas.org/content/113/30/8414.short

Generalized network dismantling
https://www.pnas.org/content/116/14/6554.short

Computational Social Science: Obstacles and Opportunities
https://science.sciencemag.org/content/369/6507/1060?rss%3D1=

Bit by Bit; Social Research in the Digital Age
https://www.amazon.co.uk/Bit-Social-Research-Digital-Age-ebook/dp/B072MFPXX2/

Further literature will be recommended in the lectures.

Prerequisites / notice
Students need to present a new subject, for which they have not earned any credit points before.

Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Chatham House rules apply to this course. Materials may not be shared without previous written permission.

Competencies
Subject-specific Competencies
Concepts and Theories assessed

Method-specific Competencies
Techniques and Technologies assessed
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving fostered
Project Management fostered

Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence assessed
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

851-0609-06L Governing the Energy Transition

W 2 credits 2V T. Schmidt, L. P. Fesenfeld

Primarily suited for Master and PhD level.

Autumn Semester 2024
This course addresses the role of policy and its underlying politics in the transformation of the energy sector. It covers historical, socioeconomic, and political perspectives and applies various theoretical concepts to understand specific aspects of the governance of the energy transition.

**Objective**
- To gain an overview of the history of the transition of large technical systems
- To recognize current challenges in the energy system to understand the theoretical frameworks and concepts for studying transitions
- To gain knowledge on the role of policy and politics in energy transitions

**Content**
Climate change, access to energy and other societal challenges are directly linked to the way we use and create energy. Both the 2015 United Nations Paris climate change agreement and the UN Sustainable Development Goals make a fast and extensive transition of the energy system necessary. This lecture introduces the social and environmental challenges involved in the energy sector and discusses the implications of these challenges for the rate and direction of technical change in the energy sector. It compares the current situation with historical socio-technical transitions and derives the consequences for policy-making. It introduces theoretical frameworks and concepts for studying innovation and transitions. It then focuses on the role of policy and policy change in governing the energy transition, considering the role of political actors, institutions, and policy feedback. The grade will be determined by a final exam.

**Lecture notes**
Slides and reading material will be made available via moodle.ethz.ch (only for registered students).

**Prerequisites / notice**
This course is particularly suited for students of the following programmes: MA Comparative International Studies; MSc Energy Science & Technology; MSc Environmental Sciences; MSc Management, Technology & Economics; MSc Science, Technology & Policy; ETH & UZH PhD programmes.

**851-0252-10L**

**Project in Behavioural Finance**

- **W** 3 credits 2S
- **S. Andraszewicz, C. Hölscher, A. C. Roberts**

**Abstract**
In this seminar, students will study cognitive processes, behaviour and the underlying biological response to financial decisions. Research methods such as asset market experiments, lottery games, risk preference assessment, psychometrics, neuroimaging and psychophysiology of decision processes will be discussed. Financial bubbles and crashes will be the core interest.

**Objective**
This course has four main goals:
1. To learn about the most important topics within Behavioural Finance
2. To learn to effectively select, review and present information using modern telecommunication tools
3. To practice working on group projects in hybrid working conditions (online + in-person)
4. To solve an applied behavioral finance business case stemming from an industry partner

**Content**
The course does not contain mandatory reading. Instead, it offers suggested literature that provides guidance to the students who, prepare a presentation on core topics in behavioral finance. The point of this exercise is to critically select the most relevant information on a given topic and present to non-expert educated colleagues. At the same time, the audience learns about the key topics in behavioral finance. Every session involves a discussion moderated and supported by the lecturers.

Throughout the semester, students work on solutions to real business cases stemming from a company partner. They can receive feedback and guidance from project leaders of the industry partner and from the academic supervisors. In the final meeting of the semester, students pitch solutions to their business cases.

The course takes place entirely online. The objective is to prepare the students for the future work in online and hybrid arrangements.

**Prerequisites / notice**
Students from all domains of ETH and all levels of education are welcome in the course.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

- **Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management

- **Social Competencies**
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation

- **Personal Competencies**
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-direction and Self-management

**701-0015-00L**

**Transdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement**

- **W** 2 credits 1S
- **B. Vienni Baptista, C. E. Pohl, M. Staffacher**

**Abstract**
This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants' research projects more societally relevant.

**Objective**
Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, or how to secure broader impact of research. They learn to critically reflect their own research project in its societal context and on their role as scientists.

**Content**
The seminar covers the following topics:
1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants' research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.
Literature

Literature will be made available to the participants.
The following open access article builds a core element of the course:
available at (open access): http://www.ingentaconnect.com/contentone/oekom/gaia/2017/00000026/00000001/art00011

Further, this collection of tools will be used:
https://naturalsciences.ch/topics/co-producing_knowledge
https://www.shapeidtoolkit.eu

Prerequisites / notice

Participation in the course requires participants to be working on their own research project.

Dates (Wednesdays, 8h15-12h00)

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>fostered</td>
</tr>
<tr>
<td>Social Competencies</td>
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851-0252-13L Network Modeling

Particularly suitable for students of D-MATH, D-INFK and in the MSc Data Science

Students are required to have basic knowledge in inferential statistics, such as regression models.

Abstract

Social Network Science is a distinct domain of data science that focuses on relational systems. Various models have been proposed to describe structures and dynamics of networks, including statistical and mathematical methods. In this course, the emphasis is placed on the statistical analysis of (social) systems and their connection to social theories and data sources.

Objective

The following topics will be covered:

- Introduction to network models and their applications
  - Stylized models:
    * uniform random graph models
    * small world models
    * preferential attachment models
  - Models for testing hypotheses while controlling for the network structure:
    * Quadratic assignment procedure regression (QAP regression)
  - Models for testing hypotheses on the network structure:
    * Models for one single observation of a network: exponential random graph models (ERGMs)
    * Models for panel network data: stochastic actor-oriented models (SAOMs)
The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

Content

The following topics will be covered:

- Introduction to network models and their applications
  - Stylized models:
    * uniform random graph models
    * small world models
    * preferential attachment models
  - Models for testing hypotheses while controlling for the network structure:
    * Quadratic assignment procedure regression (QAP regression)
  - Models for testing hypotheses on the network structure:
    * Models for one single observation of a network: exponential random graph models (ERGMs)
    * Models for panel network data: stochastic actor-oriented models (SAOMs)
    * Models for relational event data: dynamic network actor models (DyNAMs)
The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

Lecture notes

Slides and lecture notes are distributed via the associated course moodle.


Prerequisites / notice

Students are required to have basic knowledge in inferential statistics and should be familiar with linear and logistic regression models.

851-0252-15L Network Analysis

Particularly suitable for students of D-INFK, D-MATH.

Abstract

Network science is a distinct domain of data science that is characterized by a specific kind of data being studied. While areas of application range from archaeology to zoology, we concern ourselves with social networks for the most part. Emphasis is placed on descriptive and analytic approaches rather than theorizing, modeling, or data collection.
**Objective**

Students will be able to identify and categorize research problems that call for network approaches while appreciating differences across application domains and contexts. They will master a suite of mathematical and computational tools, and know how to design or adapt suitable methods for analysis. In particular, they will be able to evaluate such methods in terms of appropriateness and efficiency.

**Content**

The following topics will be covered with an emphasis on structural and computational approaches and frequent reference to their suitability with respect to substantive theory:

* Empirical Research and Network Data
* Macro and Micro Structure
* Centrality
* Roles
* Cohesion
* Influence

**Lecture notes**

Slides and lecture notes are distributed via the associated course moodle.

**Literature**


**Competencies**

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**Contract Design I**

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for “Contract Design I (851-0742-00L; Fall 2023)” and enroll. The password is “ContractDesign01”.

It is NOT a legal drafting class focused on contractual language.

**Number of participants limited to 160. Max 80 ETHZ and 80 UZH Students**

**Abstract**

Contract Design I is taught by Professor Stremitzer and aims to bridge the gap between economic contract theory, contract law, and the writing of real-world contracts. In this course, we will take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction takes place and then engineer contracts that achieve the desired outcome.

**Objective**

Contracts are agreements between parties to engage in transactions. A good contract creates value by giving parties the right incentives to meet their objectives. A good contract designer scrutinizes the economic situation in which parties find themselves and tailors the contract to the challenges at hand. To help you become sophisticated contract designers, we draw from insights for which more than half a dozen Nobel Prizes were awarded in the past two decades and transfer them to the art of writing real-world contracts. In other words, Contract Design will provide you with analytical tools to design contracts that help you be better lawyers, business leaders, and startup founders.

We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting and apply the theoretical insights to real-life case studies ranging from purchases & sales of assets, oil & gas exploration, movie financing, production & distribution, construction & development, M&A deals, venture capital financing, to executive compensation and many other types of transactions.

The course follows a flipped-classroom model: You will watch learning videos specifically produced for this course ahead of class. We will use class time to discuss real-world case studies. The videos will be made available before the lecture each week and need to be watched ahead of coming to class. Computer-graded quizzes at the beginning of each class will test students’ understanding of the concepts introduced in the videos.

As the emphasis of this class is on class discussion, attendance is mandatory. Absent important reasons, you cannot miss class more than twice.

The lectures will be recorded but only made available to those who miss lectures with excused absence.

**For ETH students:** Your grade will consist of two parts:

1) You will take weekly computer-based quizzes during class time. Thus, it is important that you attend the lectures to be able to finish the quizzes and pass this course.
2) You compose short responses to take-home questions on case studies we assign and upload them ahead of class (Pass/Fail).

Note that UZH and UNISG students enrolling in this course need to earn more ECTS for completing this course than ETH students (due to curricula reasons). This is why UZH and UNISG students must complete a written assignment in addition to the weekly quizzes and take-home questions. UZH students also have to complete an additional group project. UZH and UNISG students should check out the description of the class at their respective home institutions.

**Lecture notes**

Handouts, prerecorded videos, slides, case studies, and other materials available on a dedicated webpage: contractdesign.org. Access to this webpage is free of charge for ETH students as ETH purchased a license for ETH students.
This course introduces students to scientific and technological developments that require regulation or enable legal innovation. We focus particularly on the challenges to current law posed by prominent near-future technologies.

In previous years, the course has featured esteemed speakers from various sectors, including industry leaders like Google, NGOs such as Digital Society Switzerland and The European Consumer Organization, regulatory bodies like the Swiss Competition Commission, and noted academics.

The course is open to ETH students through the Science in Perspective program of the Department of Humanities, Social and Political Sciences.

The planned course outline is below.

- Overview of Law and Technology
- Fundamental Rights
- AI & Discrimination
- Landmark Big Tech Cases
- Regulation of Digital Platforms & Content Moderation
- Online Consumer Protection
- Law and Tech Scholarship Series

A number of recent regulations will be discussed, including the EU's AI Act, the Digital Services Act (DSA), and the Digital Markets Act (DMA), as well as emerging internet phenomena, like ChatGPT.

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for "Law & Tech (851-0732-06L, HS 2024)" and enroll.

Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, DMATH, D-MTEC, D-INFK, and D-MAVT.

If you have any questions regarding the course, please write an email to the teaching assistants, Lucas Gericke (lucas.gericke@gess.ethz.ch) or Serge von Steiger (serge.vonsteiger@gess.ethz.ch).

Studies are expected to implement themselves models of techno-socio-economic processes and systems, particularly agent-based models, complex networks models, decision making, group dynamics, human crowds, or game-theoretical models. Credit points are finally earned for the implementation of a mathematical or empirical model from the complexity science literature, its presentation, and documentation by a project report.

The lecture slides will be presented on the course Moodle after each lecture.
Prerequisites / notice

The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.

Good programming skills and a good understanding of probability & statistics and calculus are expected.

Students need to present a new subject, for which they have not earned any credit points before.

Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Chatham House rules apply to this course. Materials may not be shared without previous written permission.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies

Communication assessed
Cooperation and Teamwork assessed
Customer Orientation fostered
Leadership and Responsibility assessed
Self-presentation and Social Influence assessed
Sensitivity to Diversity assessed
Project Management assessed

Negotiation fostered

Personal Competencies

Adaptability and Flexibility assessed
Critical Thinking assessed
Creative Thinking assessed
Leadership and Responsibility assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

Evidence-Based Design: Methods and Tools for Evaluating Architectural Design

W 3 credits 2S M. Gath Morad, C. Hölscher, L. Narvaez Zertuche, C. Veddeler

Abstract

Students are taught a variety of analytic techniques that can be used to evaluate architectural design. The concept of evidence-based design is introduced, and complemented with theoretical background on space syntax and spatial cognition. This is a project-oriented course, students implement a range of methods on a sample project. The course is tailored for architecture design students.

Objective

The course aims to teach students how to evaluate a design project from the perspective of the end user. The concept of evidence-based design is introduced through a series of case studies. Students are given a theoretical background in space syntax and spatial cognition, with a view to applying this knowledge during the design process. The course covers a range of methods including visibility analysis, network analysis, conducting real-world observations, and virtual reality for architectural design. Students apply these methods to a case study of their choice, which can be at building or urban scale. For students taking a B-ARCH or M-ARCH degree, this can be a completed or ongoing design studio project. The course gives students the chance to implement the methods iteratively and explore how best to address the needs of the eventual end-user during the design process.

The course is tailored for students studying for B-ARCH and M-ARCH degrees. As an alternative to obtaining D-GESS credit, architecture students can obtain course credit in "Vertiefungsfach" or "Wahlfach".

Applied Network Science: Sports Networks

W 3 credits 2S U. Brandes

Abstract

We study applications of network science methods, this semester in the domain of sports. Topics are selected for diversity in sports, research questions, and techniques with applications such as passing networks, team rankings, or career trajectories. Student teams present results from the recent literature, possibly with replication, in a conference format.

Objective

Network science as a paradigm is entering domains from engineering to the humanities but application is tricky. By examples from recent research on sports analytics, students learn to appreciate that, and how, context matters. They will be able to assess the appropriateness of approaches for substantive research problems, and especially when and why quantitative approaches are or are not suitable.
Doctoral candidates from all ETH departments, whose research is related to global sustainable development issues, are invited to give a presentation about their ongoing work and discuss their doctoral project in a seminar with a diverse group of researchers. The seminar is open to all Master level / PhD students.

### Competencies

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### Objective

- Explain relevant concepts in ethics.
- Evaluate the ethical dimensions of new technology uses.
- Identify impacted stakeholders and who is ethically responsible.
- Engage constructively in the public discourse relating to new technology impacts.
- Review tools and resources currently available that facilitate resolutions and ethical practice.
- Work in a more ethically reflective way.

### Content

The workshop offers students an experience that trains their ability for critical analysis and develops awareness of responsibilities as a researcher, consumer and citizen. Learning will occur in the context of three intensive workshop days, which are highly interactive and focus on the development and application of reasoning skills.

The workshop will begin with some fundamentals: the nature of ethics, of consent and big data, of AI ethics, public trust and health ethics. Students will then be introduced to key ethical concepts such as fairness, autonomy, trust, accountability, justice, as well different ways of reasoning about the ethics of digital technologies.

A range of practical problems and issues in the domains of education, media, society, digital health and justice will be then considered. These domains are represented respectively by unique and interesting case studies. Each case study has been selected not only for its timely and engaging nature, but also for its relevance. Through the analysis of these case studies key ethical questions (such as fairness, accountability, explainability, access etc.) will be highlighted and questions of responsibility and tools for ethical practice will be explored. Throughout, the emphasis will be on learning to make sound arguments about the ethical aspects of policy, practice and research.

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### Objective

This course explores the automation of decisions in the legal system. We delve into the machine learning tools needed to predict judge decision-making and ask whether techniques in model explanation and algorithmic fairness are sufficient to address the potential risks.

This course introduces students to the data science tools that may provide the first building blocks for a robot judge. While building a working robot judge might be far off in the future, some of the building blocks are already here, and we will put them to work.

Data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, technologies force us to think carefully about notions of fairness and justice and how they should be applied.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is a criminal defendant to commit another crime? How much additional revenue will this new tax law collect? Students will investigate and implement the relevant machine learning tools for making these types of predictions, including regression, classification, and deep neural networks models.

We then use these predictions to better understand the operation of the legal system. Under what conditions do judges tend to make errors? Against which types of defendants do parole boards exhibit bias? Which jurisdictions have the most tax loopholes? Students will be introduced to emerging applied research in this vein. In a semester paper, students (individually or in groups) will conceive and implement an applied data-science research project.

### Content

Data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, these technologies force us to think carefully about notions of fairness and justice and how they should be applied.

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The course aims at providing students with practical knowledge and skill of processing, interpreting and analyzing empirical educational data, including different lenses through which to view the nature of inquiry in the field, research design, and an overview of quantitative, qualitative and mixed methods research.

The course will be centered around exploring methodological perspectives by focusing on conceptual aspects of datasets and experiments in the Learning Sciences. Face-to-face meetings will be held every fortnight, although students will be expected to work individually on weekly tasks (e.g., discussing relevant literature, creating and justifying research designs, performing data analysis).

The course has the following components: a) Planning design-based research/research designs, b) Overview of quantitative, qualitative, mixed methods in Learning Sciences, c) Ethics of Learning Sciences research

The course makes students experience an exemplary human-centered design process. They will learn about and practically apply human-centered design and evaluation methods that will allow them to view their solution from the human perspective, e.g., the user, developer or website owner perspective. By taking part in the evaluation of other teams, they will also take the user perspective themselves.

By the end of this seminar, students will be able to identify and compare different approaches in (online) social network research. They will systematically review the relevant literature and present their arguments in a structured and coherent way.

Humans and Social Networks in the Digital Age

The digital transformation profoundly impacts humans and how they behave online and offline. Interactions in online social networks offer new opportunities (e.g., political movements, global cultural diffusion) and risks (e.g., fake news). In this seminar, we examine recent sociological and psychological research on how the digital transformation affects individuals and their social behaviors.

The digital transformation has made the “online world” increasingly important for the “offline world”. Hence, interactions in online social networks ultimately affect how people feel, think, behave and interact in offline settings. This course aims to present and structure open debates in online and offline social network research with a focus on social network processes, individual outcomes, and emergent social phenomena. By taking a social networks perspective, we view individuals and their behavior in online and offline settings, ethical challenges in conducting social networks research, the effects of the digital transformation on people’s feelings, thoughts, preferences, and behaviors (e.g., digital mental health), and how online social and cultural phenomena emerge (e.g., the diffusion of culture and the spread of social movements).

The course makes students experience an exemplary human-centered design process. They will learn about and practically apply human-centered design and evaluation methods that will allow them to view their solution from the human perspective, e.g., the user, developer or website owner perspective. By taking part in the evaluation of other teams, they will also take the user perspective themselves.
At the beginning of the course, the students will receive an introduction to usable IT security and privacy and relevant concepts. Afterwards, a selection of current research questions from that area will be presented. The students form teams and select one of the proposed research questions. This question will accompany the students throughout the semester. They will design and evaluate a human-centered solution to that question. To be able to do so, they will receive input on human-centered design and evaluation tools. Their progress and the inclusion of the human perspective will be subject to feedback in milestone presentations. The students' human-centered solution can take the form of a concept (e.g., a concept for a product or app), interface (e.g., a visual or tangible interface), or prototype (e.g., sketches, a click-dummy or a built prototype). The solution will then be subject to evaluations. The solutions will be user-tested by members of other teams that thereby take the perspective of a user themselves. In addition, the solutions will be analyzed from different stakeholders' perspectives, such as developers or website owners. Finally, the students will reflect on potential changes that results from the evaluations and their consequences.

Literature


Prerequisites / notice

This course is especially recommended after the related lecture "851-0390-00 G Human-Centered IT Security and Privacy". However, previous participation in the lecture is not a requirement and not necessary for succeeding in the course.

Competencies

Subject-specific Competencies
Concepts and Theories assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Project Management assessed

Social Competencies
Communication fostered
Cooperation and Teamwork assessed
Customer Orientation fostered
Sensitivity to Diversity fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection assessed
Self-direction and Self-management fostered

Psychodelic Science: Psychology Pharmacology
Physiology Psychotherapy Philosophy Religion Politics

Abstract
This lecture series covers psychodelic science mainly psychologically, and additionally pharmaco logically, physiologically, psychotherapeutically, philosophically, religiously, and politically. All contributions will also be reflected on from the viewpoint of the humanities and psychology.

Objective
To provide students with a multidisciplinary introduction to psychodelic science, and to also comprehensively embed this in a reflection from a humanities/psychology viewpoint.
Psychedelic science is a multidisciplinary field of study that involves scholars of the mind and scholars of the natural sciences. In this course, psychedelic science is presented mainly from the point of view of psychology, but will additionally also be considered from the viewpoints of pharmacology, physiology, psychotherapy, philosophy, religion, and politics. All contributions will also be reflected on from the viewpoint of the humanities and psychology. The psychedelic studies treated in this course that involve humans focus on controlled and ethically approved studies where these substances are administered to medically screened, prepared, and supported participants.

Private/illicit use of psychedelics is not a topic of this course.

A psychedelic experience can be characterized as a temporary nonordinary state of consciousness (NSC) that is occasioned by classic (serotonergic) psychedelics such as psilocybin, mescaline, N,N-dimethyltryptamine (DMT), and lysergic acid diethylamide (LSD). Psychologically, the psychedelic experience can mainly manifest at the perceptual, cognitive, affective, volitional, and somesthetic level. The nonordinary perceptual spectrum ranges from visions (e.g., patterns or beings) to the subjective experience of an all-encompassing oneness, which also transcends the distinction between the perceiver and the perceived. The nonordinary cognitive spectrum ranges from no longer functioning thinking to very clear thinking, the nonordinary affective spectrum, for example, from deepest sadness to highest bliss, the nonordinary volitional spectrum from the feeling of being able to somewhat influence what is happening to the feeling of having no longer a will of one’s own, and the nonordinary somesthetic spectrum, for example, from feelings of bodily heaviness/compression to feelings of bodily lightness/floating.

Heuristically, as one possibility, a psychological typology of the psychedelic experience can be characterized to fall into three main types religious-like experiences (which may be interpreted religiously/spiritually by the individuals having them, but may also be interpreted materialistically or agnostically), autobiographical experiences, and tripartite-mind (cognition/affection/conation) miscellaneous experiences. Investigating the psychedelic experience is a worthwhile endeavor as, for instance, certain aspects of this experience have been associated with increased subjective well-being both for healthy individuals as well as for patients – for example, persisting positive effects on attitudes, mood, and behavior in healthy individuals and sustained symptom reduction in individuals suffering from depression, anxiety, and addiction.

Psychedelic science is overall a large multidisciplinary effort that requires collaboration of scholars of the mind and scholars of the natural sciences to advance the scientific knowledge of it. In this spirit, this course will – besides the main lecturer (PD Dr. phil. Kurt Stocker, a psychologist) – also involve further psychedelic-science scholars giving individual lectures in their respective field of expertise psychology (PD Dr. phil. Katrin Preller, University of Zurich & Yale University), pharmacology (Dr. phil. nat. Dino Luethi, University Hospital Basel; Dr. phil. nat. Deborah Rudin, University Hospital Basel; Prof. Dr. phil. Linda Simmler, University of Basel), physiology (PD Dr. sc. nat. Felix Scholkmann, University of Zurich & University of Bern), psychiatry/psychotherapy (Prof. Dr. med. Gregor Hasler, University of Fribourg; Dr. med. dr. sc. ETH Milan Scheidegger, University of Zurich), and philosophy (Dr. Peter Sjöstedt-Hughes, University of Exeter). Overall, this course will provide an informative overview of the research foundations that have made psychedelic science what it is today, and will also provide an identification of the research frontiers that must be addressed to expand the psychedelic science of tomorrow.
The objective is to analyze human-insect interactions by identifying key historical factors (economic, scientific, political). Students will integrate current frameworks in the study of environmental history through the combination of primary sources and interdisciplinary research. They will develop skills rooted in their interest in insects and learn to translate them into feedback to peers. Scholars typically approach Nature-related histories by focusing on environmental change, the commodification of resources, and the legacy of natural history collections. Examples of this approach include studies on deforestation, dam constructions, the rubber boom, and the colonial history of European museums. In contrast to these commonly explored topics, insects are often underrepresented in historical research, both as living creatures and metaphors. Addressing this gap, the seminar explores human-insect interactions from a global historical perspective between 1650 and 2000. This exploration encompasses a critical and relational understanding of the history of the scientific study of insects (entomology) and the processes of imperial expansion and global territorialization. To achieve this, students will learn how human-insect interactions led to radical transformations in diverse environments, reflecting a particular modern conception of nature influenced by control anxieties related to economic profit and tropical diseases. Moreover, students will examine how ways of knowing about insects and the environment were influenced by broader correlated economic and imperial factors. Focusing on insect (hi)stories, the aim of this seminar is to apply new methodologies for non-human agencies and source analysis on both micro and macro scales in global and environmental histories.

Literature in general can be seen as fundamentally concerned with the forms and functions of knowledge and (sometimes scientific) understanding, but the genre of science fiction is unique in that it literalises this approach in a far-reaching fashion as the future of science and technology. We will explore knowledge, and the "science of literature" through a diverse range of science fiction texts.

This course introduces students to the various forms and functions of knowledge and science in literature, particularly within the realm of science fiction, the genre that most directly epitomises this fundamental connection within literary texts. In analysing how it shifts our understanding of ourselves and of supposedly inalterable facts about the reality we inhabit, we will examine how science fiction demonstrates that fiction is neither fundamentally in conflict with scientific knowledge, as previously supposed, nor a mere vehicle for its celebration, as still commonly presumed of science fiction. Instead, the genre, with its radical investigations into other forms of being, fearing and hoping, plays a crucial role in the social formation, order and negation of knowledge. As such, science fiction also represents a vital thought experiment regarding the "science of fiction", i.e. the development of a knowledge of literature and the many fascinating ways in which it helps us to know our own world better, in turn.

In this course, we will take a systematic and theory-based approach to a deeper understanding of science fiction, particularly concerning its historical and cultural embeddedness, unique aesthetic/narrative tools, and relationship with the critical and technocultural contexts that shape it. Employing contemporary theoretical approaches, we will discuss a variety of themes within primary texts alongside diverse critical sources, all of which ultimately relate to knowledge and knowability. Particular areas of focus may include: other worlds and alien existences; altered temporality and alternate history; utopia and dystopia; climate fiction and the Anthropocene; trans-, posthumanist and cyborg identities; robots and AI; and alternative futurisms. Moreover, the course will thereby also engage with the fundamental (and at times overlooked) role of order and presentation of knowledge, i.e. its aesthetic and narrative forms, within science and literature.

The seminar explores insects as historical actors and their diverse interactions with human societies over time and space. It offers an overview of recent approaches in environmental history and multispecies ethnography while providing an analytical framework to understand global processes of natural resource exploitation, knowledge formation, and imperialism. This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

The seminar aims to inspire a nuanced understanding of the dynamics of expertise in society. Cross-fertilizing literature from science and technology studies (STS) and from activists’ movements, it focuses on contemporary controversies around emerging technologies and climate policy, where trust in science is said to be undermined (e.g. climate skepticism or anti-vaccine movements). 1) Introduce to the role and functions of expertise in democratic societies. 2) Familiarize with assumptions about science and society embedded in contemporary controversies. 3) Inspire critical perspectives on (dis)trust in science through activists’ movements on contested environmental and technological issues. 4) Develop a creative position on the relations between science, trust and politics.
### Content

Engineers and scientists often pursue their studies and research in the hope that their knowledge can contribute to make a better world, inform democratic deliberation and help public understanding of complex issues. Yet this special status of science and technology is being increasingly contested by marginalized publics, lobbies, exposed populations, and by members of the scientific communities themselves. Climate skepticism or vaccine hesitancy are some of the most vivid examples of this confusing situation. In this seminar, students will learn to reflect on expertise as a form of scientific engagement in the messiness of democratic deliberation and public life, beyond the noble but outdated ideal of “speaking truth to power”.

The exercise of expertise is stumbling upon several conundrums. Which knowledge is relevant in which situation? How to make sure that some crucial perspectives are not left in the shadows? How to identify representative experts and make sure that they speak on behalf of a structured community? Whose voices are being silenced? On the other side of the spectrum, the public is often said to lack proper understanding of science and thus in need of being educated or disciplined. Or it is suspected of being manipulated by lobbies or foreign hostile powers, or of being too attached to its own privileges and unwilling to act in favor of the common good. Whose agency is being acknowledged in sociotechnical controversies and whose agency is being denied and why? The seminar will provide a deep understanding of these perspectives, by putting them in a broader historical and epistemological context. Students will thus learn to critically assess their strengths as well as their blind spots.

Whereas opposing technological developments (anti 5G or anti-vaccine activists) or pushing to act accordingly to science (pro climate movements such as Extinction Rebellion or Scientist Rebellion), activists movements make up for a rich field of investigation on the dynamics of expertise and of how various publics can make sense of scientific knowledge. Cross-fertilizing activist’s texts and experiences with literature in science and technology studies and anthropology, this class will be organized as a structured conversation and a collective mapping of actors and key concepts of sociotechnical controversies. Over the course of the semester, students will learn not only to navigate some of the most heated contemporary debates, but also to articulate their own position on an issue of their choice.

### Competencies

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### 851-0541-00L

**Truth and Historical Injustice: The Production of Knowledge about Past Mass Atrocities**

**W** 3 credits 2V S. M. Scheuzger

**Abstract**
The course deals with the scientific production of knowledge about past mass atrocities. It looks at the interplay of different disciplines, methods and technological means that have been involved in this production over time. Further, it poses the question of what truth can mean in this context.

**Objective**
The students a) know the main features of the discussion about the truth in the reconstruction of past events; b) have an understanding of the interplay, but also the coexistence of different scientific methods and technological means in the multidisciplinary production of knowledge about past mass crimes; c) have knowledge of important processes of dealing with past mass crimes from the second half of the 20th century onwards.

**Content**
When discussing the truthfulness of the academic study of the past, politically and ideologically motivated mass crimes are often cited as historical events in order to substantiate the necessity of a claim to truth. In doing so, moral arguments can be made or historical truth can be asserted as a basic prerequisite for living together in a democratic society under constitutional conditions. The production of knowledge about past atrocities has always been an endeavour in which various scientific disciplines have been involved. The multidisciplinary character of the production of knowledge about mass crimes has become even more accentuated since the second half of the 20th century, not least due to the emergence of new technological possibilities. The course offers a brief introduction to the discussion about the meaning of truth about past events. It looks at how different scientific approaches - from the humanities to the natural sciences - have been involved in coming to terms with mass crimes and how they have been related to each other. It deals with the question of what role certain techniques and technologies have played in the production of knowledge about past atrocities and how this has changed over time. These techniques and technologies range from the evaluation of documents and the taking of testimonies to specialised database programs, genetic analysis or imaging techniques, to digital technologies for the procurement of information on social media and the internet or for the modelling of past events.

In addressing these questions, the course looks at processes of dealing with the past from the middle of the 20th century to the 21st century in Europe, Latin America and Africa.

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### 851-0456-00L

**Research in Ethics, Technology and Society**

**W** 2 credits 2S M. Boenig-Liptsin, G. Dörthe

**Abstract**
Through thematic discussions of readings, presentation and workshoping of writing-in-progress, and discussions with invited guests, this course brings together advanced students doing research is in science, technology and society to develop their knowledge and projects in community with peers, postdoctoral fellows, and faculty.

**Objective**
The objective of the course is to provide students doing their own research on topics in science, technology and society with focused peer-feedback and tailored theoretical and methodological discussions to support the development of their projects.

**Content**
The course is focused on content from STS and moral and political theory and develops empirical, qualitative, and interpretive social science methods, such as ethnography/participant observation, historical archival research, discourse and document analysis, and semi-structured interviews. Specific thematic, reading, methodological foci are determined by the group to meet the specific needs of each participant.

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### 851-0392-00L

**Privacy Quantification and Usable Protection Mechanisms**

**W** 3 credits 2S N. Zufferer, V. Zimmermann

**Abstract**
Students will gain an overview of the main privacy metrics that are used to evaluate privacy risks related to the use of a given technology. They will also be introduced to the concepts of privacy/utility balance and usable security. Practical exercises and reading of recently published scientific articles will be used to present practical cases of the theoretical tools presented in class.
This course aims to provide the students with a global knowledge of the concepts related to privacy, and the methodology and tools to identify, analyze, and address threats while taking the user into account in the process. They will adopt a “privacy mindset”, thus enabling them to automatically take privacy into account, in a usable way, when designing or analyzing a system.

### Content
First, the course will introduce the different definitions and approaches of privacy (e.g., privacy by control, privacy by design) as well as the ethical concerns and considerations related to information security and privacy research (e.g., responsible disclosure, full disclosure).

Second, the students will be introduced to the different methods, properties, and metrics to assess and/or guarantee a certain level of privacy. They will be introduced to the properties and metrics related to anonymization (e.g., k-anonymity, l-diversity), data aggregation (e.g., randomized responses, ε-differential privacy), as well as other privacy assessment methodologies (e.g., inferential privacy).

Third, the course will address usability issues and the role of individuals (i.e., users) in privacy management (i.e., usable security and privacy) and the design of privacy-enhancing technologies. In this context, we will analyze the main concepts seen during the course and discuss their advantages and disadvantages in terms of usability, as well as their implementation for mass-market and large-scale technologies.

Across all three parts of the course, practical exercises, as well as recent research articles reading, and presentations will be used as a complement to support the concepts seen in class, as well as to provide concrete examples of methodologies related to the assessment of privacy in general.

### Literature


### Competencies

#### Subject-specific Competencies

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### 851-0527-00L Introduction to the History of Technology: Concepts, W 3 credits 2V R. Wichum and Current Debates

#### Abstract
Technology and society cannot be separated: No society functions without technology. The seminar offers a problem-oriented introduction to basic questions of the history of technology, introduces approaches to the history of technology and discusses selected, ongoing debates.

#### Objective
The course seeks to provide a critical introduction to the issues, methods, and selected areas of research in the history of technology.

#### Content
History of technology investigates technological developments that arise in specific historical contexts. These developments are perceived by social groups or entire societies as a means of social change and ultimately find use or are forgotten. The questions that history of technology poses derive from the technological and social change that are a product of contemporary orientation and thinking; current historiographical methods provide the tools for answering these questions.

### 851-0193-00L Understanding in Science and Mathematics: A W 2 credits 2S Philosophical Perspective

#### Abstract
Understanding is a central goal of science and mathematics, but what exactly is the nature of scientific and mathematical understanding? This seminar will read and discuss a number of key philosophical contributions on understanding in philosophy of science, philosophy of mathematics, and epistemology. You will also practice your skills in giving clear and engaging oral presentations.

#### Objective
The main objective of this seminar is to gain an in-depth understanding of the recent literature on understanding in the philosophy of science, the philosophy of mathematics, and epistemology. Another practical objective is to increase your skills in giving clear and engaging oral presentations.

#### Content
Understanding is a central goal of science and mathematics: scientists seek to understand various phenomena in the natural world, while mathematicians aim to increase our understanding of the mathematical world. But what exactly is the nature of understanding in science and mathematics? This issue has been largely neglected in twentieth century philosophy of science, philosophy of mathematics, and epistemology. Yet, in the past twenty years, there has been a regain of philosophical interest into the notion of understanding, leading to a flourishing literature. The aim of this seminar is to gain an in-depth understanding of these recent philosophical developments.

To this end, we will read a number of key philosophical contributions on understanding in philosophy of science, philosophy of mathematics, and epistemology. Along the way, we will address general issues on understanding such as: What is the relation between understanding and knowledge? Does understanding necessarily require explanation? How can understanding be transmitted? What exactly is the value of understanding? We will also look into specific case studies of scientific and mathematical understanding.

Each session will be decomposed into three blocks. In blocks 1 and 2, we will have a short presentation (~15 minutes) of a contribution by a discussion. Block 3 will be methodological and will be concerned with how to give good oral presentations, an essential skill in academia. We will use this block to debrief on the presentations of the day and see how they could be improved. We will also discuss resources on best practices in oral communication.

### 851-0297-00L Manipulation in Literature and Cultural History W 3 credits 2V S. S. Leuenberger

#### Abstract
This lecture focuses on the manipulation and control of individuals and the masses. The power of manipulation is based on subtle use of persuasive linguistic elements and knowledge of the desires and fears of the intended audience. In addition to a theoretical overview, the lecture concentrates on the literary and discursive texts that dispute the control of protagonists. Block 3 will be methodological and will be concerned with how to give good oral presentations, an essential skill in academia. We will use this block to debrief on the presentations of the day and see how they could be improved. We will also discuss resources on best practices in oral communication.
### Transferable Skills

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<th>Number</th>
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and prove your participation with the appropriate certificate.

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<td>W</td>
<td>1</td>
<td>2U</td>
<td>G. Achermann</td>
</tr>
<tr>
<td></td>
<td>This course is interdisciplinary. If your department offers this course, please register there if possible.</td>
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<tr>
<td>Abstract</td>
<td>This course sensitises doctoral students to ethical issues that may occur during their doctorate. After an introduction to ethics and good scientific practice, students are familiarised with resources that can assist them with ethical decision-making. Students get the chance to apply and deepen their knowledge in an interactive face-to-face workshop.</td>
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<tr>
<td>Objective</td>
<td>Doctoral students learn how to identify, analyse and address ethical issues in their own scientific research. In addition, they will reflect on their professional role as scientific researchers.</td>
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<tr>
<td>Content</td>
<td>Content:</td>
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<tr>
<td></td>
<td>Part I on Moodle</td>
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<tr>
<td></td>
<td>The self-paced e-learning course on Moodle consists of 5 modules:</td>
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<td></td>
<td>Module 1: Ethics</td>
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<td></td>
<td>- Introduction to moral theory (with emphasis on practical guidance regarding decision making)</td>
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<td></td>
<td>Module 2: Ethics in scientific research</td>
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<td></td>
<td>- Introduction to ethical issues that occur within scientific research (i.e. regarding authorship, cooperation, data use and sharing, and other aspects that are subject to scientific integrity and good scientific practice).</td>
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<td></td>
<td>Module 3: Collecting resources</td>
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<td></td>
<td>- A variety of tools and resources that help identify ethical issues are presented and explained</td>
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<td>Module 4: Setting up a strategy</td>
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<td></td>
<td>- Example examination of a case regarding its ethical scope (students develop their own strategy to examine situations for their ethical implications).</td>
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<td>Module 5: Making decisions</td>
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<td></td>
<td>- Different ways of addressing ethical issues are presented and explained (i.e. how to make hard choices, or solve ethical dilemmas. But also where to seek advice if needed).</td>
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<tr>
<td>Prerequisites / notice</td>
<td>For doctoral students only.</td>
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<td></td>
<td>The second, face-to-face part (group sessions) of this course provides an interactive learning environment (workshop). Students get to apply their knowledge, and they are encouraged to reflect on ethical problems and to critically discuss them with fellow doctoral students.</td>
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<td></td>
<td>Hence, when you choose a group make sure you have enough time to finish the first part on Moodle before the workshop starts (appr. 20 hours).</td>
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### Integration into Scientific Community

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

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<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Duration</th>
<th>Credits</th>
<th>Lecturers</th>
<th>Abstract</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>900-0150-DRL</td>
<td>Summer School I (1-3 days)</td>
<td>W</td>
<td>1</td>
<td>2K</td>
<td>Participation in summer or winter schools with a maximum duration of 3 days. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
<td>Participation in summer or winter schools with a maximum duration of 3 days. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
</tr>
<tr>
<td>900-0151-DRL</td>
<td>Summer School II (1-3 days)</td>
<td>W</td>
<td>1</td>
<td>2K</td>
<td>Participation in summer or winter schools with a maximum duration of 3 days. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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</tr>
<tr>
<td>900-0152-DRL</td>
<td>Summer School III (1-3 days)</td>
<td>W</td>
<td>1</td>
<td>2K</td>
<td>Participation in summer or winter schools with a maximum duration of 3 days. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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</tr>
<tr>
<td>900-0153-DRL</td>
<td>Summer School I (1-3 days, with Poster or Talk)</td>
<td>W</td>
<td>2</td>
<td>4K</td>
<td>Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
<td>Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.</td>
</tr>
<tr>
<td>900-0154-DRL</td>
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<td>2</td>
<td>4K</td>
<td>Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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<td>2</td>
<td>4K</td>
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<td>Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.</td>
</tr>
<tr>
<td>900-0156-DRL</td>
<td>Summer School I (1 week)</td>
<td>W</td>
<td>2</td>
<td>4K</td>
<td>Participation in summer or winter schools with a minimum duration of 1 week. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
<td>Participation in summer or winter schools with a minimum duration of 1 week. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
</tr>
<tr>
<td>900-0157-DRL</td>
<td>Summer School II (1 week)</td>
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<td>4K</td>
<td>Participation in summer or winter schools with a minimum duration of 1 week. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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</tr>
<tr>
<td>900-0158-DRL</td>
<td>Summer School III (1 week)</td>
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<td>4K</td>
<td>Participation in summer or winter schools with a minimum duration of 1 week. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
<td>Participation in summer or winter schools with a minimum duration of 1 week. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
</tr>
<tr>
<td>900-0159-DRL</td>
<td>Summer School I (1 week, with Poster or Talk)</td>
<td>W</td>
<td>3</td>
<td>6K</td>
<td>Participation in summer or winter schools with a minimum duration of 1 week. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
<td>Participation in summer or winter schools with a minimum duration of 1 week. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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</tbody>
</table>

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 772 of 2653
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**Objective**
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

<table>
<thead>
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<th>Summer School II (1 week, with Poster or Talk)</th>
<th>W</th>
<th>3 credits</th>
<th>6K</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.</td>
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<table>
<thead>
<tr>
<th>900-0161-DRL</th>
<th>Summer School III (1 week, with Poster or Talk)</th>
<th>W</th>
<th>3 credits</th>
<th>6K</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.</td>
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<table>
<thead>
<tr>
<th>900-0162-DRL</th>
<th>External Conference I (incl. Poster or Talk)</th>
<th>W</th>
<th>1 credit</th>
<th>2K</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.</td>
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<tr>
<th>900-0163-DRL</th>
<th>External Conference II (incl. Poster or Talk)</th>
<th>W</th>
<th>1 credit</th>
<th>2K</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.</td>
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<tr>
<th>900-0164-DRL</th>
<th>External Conference III (incl. Poster or Talk)</th>
<th>W</th>
<th>1 credit</th>
<th>2K</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.</td>
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**Doctorate Humanities, Social and Political Sciences - Key for Type**

<table>
<thead>
<tr>
<th>W+</th>
<th>Eligible for credits and recommended</th>
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<tbody>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
</tbody>
</table>

- **Z**: Courses outside the curriculum
- **Dr**: Suitable for doctorate
- **O**: Compulsory

**Key for Hours**

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
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<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

**ECTS**: European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Module 1: Current topics in translational medicine presented by speakers from academia and industry. The basic course in "Good Clinical Practice" (GCP) contains two full-time training days (Module 1 and Module 2) and addresses:

- Timely and concise presentations of postgraduate students, post-docs, senior scientists, professors, as well as external guests from both ETHeart Joint Scientific Colloquium (Autumn Semester) and ETHeart projects, followed by lectures on chosen topics of cardiovascular medicine and research given by leading international academics and industry.

The course consists of two modules.

Module 1: Movement.
- Acquire knowledge about the latest technological advancements in wearable and unobtrusive technologies for sports and health.
- Objective 2: Acquire skills to design novel non-invasive technologies for sport and health.
- The course consists of two modules.

Module 2: Cardiac.
- This module focuses on the latest technologies for monitoring the cardiac cycle and blood pressure. The module starts by succinctly providing background information on cardiac physiology and then briefly introduces conventional technologies used in daily practice. This module subsequently focuses on the latest technologies and the latest data analysis techniques to monitor the cardiac cycle for assisting individuals in sport activities or monitoring their health conditions.

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### Subject Specialisation

#### Health Sciences and Technology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0302-01L</td>
<td>GCP Basic Course (Modules 1 and 2)</td>
<td>W</td>
<td>1</td>
<td>1G</td>
<td>G. Senti, C. Fila, R. Grossmann</td>
</tr>
<tr>
<td>Abstract</td>
<td>The basic course in &quot;Good Clinical Practice&quot; (GCP) contains two full-time training days (Module 1 and Module 2) and addresses elementary aspects for the appropriate conduct of clinical trials and non-clinical research projects involving human beings. Successful participation will be confirmed by a certificate that is recognized by the Swiss authorities. Students will get familiar with: - Key Ethics documents - (Inter)national Guidelines and Laws (e.g., ICH-GCP, DIN EN ISO 14155, TPA, HRA) - Sequence of research projects and project-involved parties - Planning of research projects (statistics, resources, study design, set-up of the study protocol) - Approval of research projects by Authorities (SwissEthics, Swissmedic, FOPH) - Roles and responsibilities of project-involved parties Students will learn how to: - Classify research projects according the risk-based approach of the HRA - Write a study protocol - Inform participating patients/study subjects - Obtain consent by participating patients/study subjects - Classify, document and report Adverse Events - Handle projects with biological material from humans and/or health-related personal data</td>
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<tr>
<td>Objective</td>
<td>Module 1: Research and Research Ethics, Guidelines, (inter)national Legislation, Development of therapeutic products, Methodology (Study Design), Study documents (Study protocol, Investigator's Brochure, Patient Information Leaflet, Informed Consent Form) Module 2: Roles and Responsibilities, Approval procedures, Notification and Reporting, Study documentation, Research with biological material and health-related data, data protection, data retention</td>
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<tr>
<td>Content</td>
<td>Does not take place this semester.</td>
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<tr>
<td>376-0303-00L</td>
<td>Colloquium in Translational Science (Autumn Semester) Does not take place this semester.</td>
<td>W</td>
<td>1</td>
<td>1K</td>
<td>A. Alimonti, V. Falk, J. Goldhahn, K. Maniura, R. M. Rossi, S. Schürle-Finke, G. Shivashankar, E. Vayena, V. Vogel</td>
</tr>
<tr>
<td>Abstract</td>
<td>Current topics in translational medicine presented by speakers from academia and industry.</td>
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<tr>
<td>Objective</td>
<td>Getting insight into actual areas and problems of translational medicine.</td>
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<tr>
<td>Content</td>
<td>Timely and concise presentations of postgraduate students, post-docs, senior scientists, professors, as well as external guests from both academcis and industry will present topics of their interest related to translational medicine.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>No compulsory prerequisites, but student should have basic knowledge about biomedical research.</td>
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<tr>
<td>376-0305-00L</td>
<td>ETHEart Joint Scientific Colloquium (Autumn Semester) Does not take place this semester.</td>
<td>W</td>
<td>1</td>
<td>1K</td>
<td>V. Falk</td>
</tr>
<tr>
<td>Abstract</td>
<td>Lectures, presentations and discussions on chosen topics in biologics, (bio-) materials, devices, sensors, robotics and data science and their relevance for cardiovascular medicine.</td>
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<tr>
<td>Objective</td>
<td>Deeper, mutual understanding of current medical challenges and technical solutions in cardiovascular medicine.</td>
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<tr>
<td>Content</td>
<td>Timely and didactically structured presentations of postgraduate students, post-docs, senior scientists and professorson topics from Zurich Heart / ETHEart projects, followed by lectures on chosen topics of cardiovascular medicine and research given by leading international clinical scientists in the field.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>No compulsory prerequisites, but students should have basic knowledge about cardiovascular system, physiology and biomedical research.</td>
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<tr>
<td>376-1176-00L</td>
<td>Wearable and Mobile Technologies of the Future - Focus on Sports and Health Does not take place this semester.</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>C. Menon, C. Ahmadizadeh, C. Otesteau</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course focuses on the progress in the field of wearable and unobtrusive technologies for sports and health. Topics as monitoring heart health and blood pressure, biofeedback and improvement of motor skills and performance are covered. The focus lies on learning about the principles and design of the new generation of non-invasive technologies in fitness-, athletic and medical applications.</td>
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<tr>
<td>Objective</td>
<td>Objective 1: Acquire knowledge about the latest technological advancements in wearable and unobtrusive technologies for sports and health. Objective 2: Acquire skills to design novel non-invasive technologies for sport and health.</td>
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<tr>
<td>Content</td>
<td>The module consists of two modules.</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 774 of 2653
Artificial Intelligence in Rehabilitation and Healthcare

**Abstract**
Students will delve into AI fundamentals (e.g., regression, classification, and deep neural networks) and their role in patient monitoring & personalized rehab. Collaborative projects offered by MedTech companies provide hands-on experience in developing and evaluating AI-driven solutions. This course will emphasise AI's explainability and ethical dimensions fostering its critical analysis.

**Objective**
1. Evaluate the effectiveness of AI tools and algorithms in the context of rehabilitation and healthcare, and suggest modifications or improvements as needed.
2. Understand the ethical and legal considerations surrounding the use of AI in rehabilitation and healthcare and apply this knowledge to ensure patient privacy and data security.
3. Identify potential limitations and risks of using AI in rehabilitation and healthcare and propose strategies to mitigate these challenges.
4. Collaborate effectively with other students on group projects that involve developing and im-plementing AI-based rehabilitation and healthcare solutions.

**Content**
In the class ‘Artificial Intelligence (AI) in Rehabilitation and Healthcare’, we will explore the integration of advanced technology in the field of rehabilitation. The class consists of both theoretical and practical components. In the theoretical part, students are introduced to the fundamental concepts of artificial intelligence, including regressions and classification in machine learning, deep neural networks, and large language models. They will explore the applications of AI in rehabilitation and healthcare, including patient monitoring, personalized treatment plans, and predictive analytics.

- In the practical component, each student will work with one of the clinics or technology companies to identify real-world problems and gain hands-on experience in developing AI in rehabilitation and healthcare. The practical work will be done in the course room with student assistants and experts from the companies. They will use Python as main language on their own laptops with ready-to-use Jupiter notebooks that could have access to our lab's server if needed for computational resources. They will directly start using programming languages and tools to build models, analyze data, and create algorithms that can be used to improve patient outcomes.
- Throughout the class, students are encouraged to think critically about the ethical implications of using AI in rehabilitation. They examine the potential benefits and risks of using advanced technology in patient care and explore ways to mitigate potential negative outcomes.

**Prerequisites / notice**
- Required classes:
  - 401-0643-00L Statistik I
  - 401-0643-13L Statistik II
  - 376-1983-00L Foundations of Data Science
- Recommended courses:
  - 252-0842-00L Programmieren und Problemlösen

---

**Introductory Course in Neuroscience I (University of Zurich)**

**Abstract**
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

**UZH Module Code:** SPV0Y005

**Mind the enrolment deadlines at UZH:**
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

**Objective**
The course gives an introduction to human and comparative neuroanatomy, molecular, cellular and systems neuroscience.

**Content**
1. Human Neuroanatomy I &II
2. Comparative Neuroanatomy
3. Building a central nervous system I &II
4. Synapses I &II
5. Glia and more
6. Excitability
7. Circuits underlying Emotion
8. Visual System
9. Auditory & Vestibular System
10. Somatosensory and Motor Systems
11. Learning in artificial and biological neural networks

**Prerequisites / notice**
For doctoral students of the Neuroscience Center Zurich (ZNZ).

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**Colloquium in Biomechanics**

**Abstract**
Current topics in biomechanics presented by speakers from academia and industry.

**Objective**
Getting insight into actual areas and problems of biomechanics.

---

**Transdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement**

**Abstract**
The lecture takes place if a minimum of 12 students register for it.

**Objective**
For doctoral students of the Neuroscience Center Zurich (ZNZ), or
- 376-0022-00L (Imaging and Computing in Medicine) or 376-1983-00L (Foundations of Data Science)

**Prerequisites / notice**
- Course prerequisites:
  - For D-MAVT Master’s: none
  - For D-MAVT Master’s: none
  - For D-MAVT Master’s and PhD students:
    - • If BSc in electrical/mechanical engineering or computer science: none
    - • If any other BSc program: 376-0022-00L (Imaging and Computing in Medicine) or 376-1983-00L (Foundations of Data Science)

---

**Notice**
For D-HEST Master’s and PhD students:
- None

For ITET Master’s:
- None

For Biomedical Engineering Master’s:
- None

For ITET Master’s:
- None

For Biomedical Engineering Master’s and PhD students:
- None
Abstract
This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants’ research projects more societally relevant.

Objective
Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, or how to secure broader impact of research. They learn to critically reflect their own research project in its societal context and on their role as scientists.

Content
The seminar covers the following topics:
1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants’ research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.

Literature
Literature will be made available to the participants.

The following open access article builds a core element of the course:
available at (open access): http://www.ingentaconnect.com/content/one/oekom/gaia/2017/00000026/00000001/art00011

Further, this collection of tools will be used:
https://naturalsciences.ch/topics/co-producing_knowledge
https://www.shapeidtoolkit.eu

Prerequisites / notice
Participation in the course requires participants to be working on their own research project.

Dates (Wednesdays, 8h15-12h00)

Competencies
<table>
<thead>
<tr>
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<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Critical Thinking</td>
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Food Science

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<th>Lecturers</th>
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<td>W</td>
<td>1</td>
<td>2K</td>
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Transferable Skills

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<table>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
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<td>W</td>
<td>3</td>
<td>2V</td>
<td>A. Blasimme, E. Vayena, to be announced</td>
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</tbody>
</table>

Content
- Principles of biomedical ethics and how they relate to pharmaceutical innovation
- Introduction to drug development, with a focus on the Swiss regulatory ecosystem
- Current trends and impediments to effective drug development, including the use of AI in drug discovery
- Translational medicine and its ethical implications
- Ethical Aspects of pre-clinical research, including animal replacement technologies like organoids and organ chips
- Ethical aspects of clinical research
- Special regulatory pathways: expanded access / compassionate use
- Special regulatory pathways: accelerated approval
- Drug development and public health. emergency use of new drugs
- Drug pricing: introduction to its regulatory and ethical aspects

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Health Sciences and Technology

Only for doctoral students D-HEST.

Abstract
This course allows D-HEST PhD students to fulfill the requirements of the mandatory training in ethics. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences.

Objective
The course aims at equipping students with the necessary knowledge and analytic skills to understand, discuss and address the ethical aspects of science and technology in relation to human health. The specific learning objectives of this course are:

- Identify ethical issues in in life sciences and biotechnology.
- Analyze and critically discuss ethical issues in life sciences and biotechnology.
- Become aware of relevant legal and public policy frameworks.
- Distinguish different ethical approaches and argumentative strategies in applied ethics.
- Recognize how ethical issues relate to different accounts of technology and innovation.
- Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
- Autonomously anticipate ethical issues.
- Propose and communicate solutions to ethical challenges and dilemmas.

Content
This course allows the students to autonomously decide among a broad list of topics specifically designed to be aligned with the scientific interests of D-HEST doctoral programs.

Competition

Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Decision-making
- Problem-solving
- Communication
- Sensitivity to Diversity
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication
- Sensitivity to Diversity

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

Ethics Workshop: The Impact of Digital Life on Society

Open to all Master level / PhD students.

Abstract
This workshop focuses on understanding and managing the ethical and social issues arising from the integration of new technologies in various aspects of daily life.

Objective
- Explain relevant concepts in ethics.
- Evaluate the ethical dimensions of new technology uses.
- Identify impacted stakeholders and who is ethically responsible.
- Engage constructively in the public discourse relating to new technology impacts.
- Review tools and resources currently available that facilitate resolutions and ethical practice.
- Work in a more ethically reflective way.

Content
The workshop offers students an experience that trains their ability for critical analysis and develops awareness of responsibilities as a researcher, consumer and citizen. Learning will occur in the context of three intensive workshop days, which are highly interactive and focus on the development and application of reasoning skills.

The workshop will begin with some fundamentals: the nature of ethics, of consent and big data, of AI ethics, public trust and health ethics. Students will then be introduced to key ethical concepts such as fairness, autonomy, trust, accountability, justice, as well different ways of reasoning about the ethics of digital technologies.

A range of practical problems and issues in the domains of education, media, society, digital health and justice will be then considered. These domains are represented respectively by unique and interesting case studies. Each case study has been selected not only for its timely and engaging nature, but also for its relevance. Through the analysis of these case studies key ethical questions (such as fairness, accountability, explainability, access etc.) will be highlighted and questions of responsibility and tools for ethical practice will be explored. Throughout, the emphasis will be on learning to make sound arguments about the ethical aspects of policy, practice and research.

Competition

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

Ethics and Scientific Integrity for Doctoral Students

This course is interdisciplinary. If your department offers this course, please register there if possible.

Abstract
This course sensitises doctoral students to ethical issues that may occur during their doctorate. After an introduction to ethics and good scientific practice, students are familiarised with resources that can assist them with ethical decision-making. Students get the chance to apply and deepen their knowledge in an interactive face-to-face workshop.

Objective
Doctoral students learn how to identify, analyse and address ethical issues in their own scientific research. In addition, they will reflect on their professional role as scientific researchers.

Competition

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

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Content

Part I on Moodle
The self-paced e-learning course on Moodle consists of 5 modules:

Module 1: Ethics
- Introduction to moral theory (with emphasis on practical guidance regarding decision making)

Module 2: Ethics in scientific research
- Introduction to ethical issues that occur within scientific research (i.e. regarding authorship, cooperation, data use and sharing, and other aspects that are subject to scientific integrity and good scientific practice).

Module 3: Collecting resources
- A variety of tools and resources that help identify ethical issues are presented and explained

Module 4: Setting up a strategy
- Example examination of a case regarding its ethical scope (students develop their own strategy to examine situations for their ethical implications).

Module 5: Making decisions
- Different ways of addressing ethical issues are presented and explained (i.e. how to make hard choices, or solve ethical dilemmas. But also where to seek advice if needed).

Part II
The second, face-to-face part (group sessions) of this course provides an interactive learning environment (workshop). Students get to apply their knowledge, and they are encouraged to reflect on ethical problems and to critically discuss them with fellow doctoral students.

For doctoral students only.

The first part on Moodle (part I) must be successfully completed before the face-to-face workshop (part II).

Hence, when you choose a group make sure you have enough time to finish the first part on Moodle before the workshop starts (appr. 20 hours).

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
Method-specific Competencies
- Decision-making assessed
- Problem-solving assessed
Personal Competencies
- Critical Thinking assessed
- Integrity and Work Ethics assessed

900-0100-DRL Transferable Skills Course I (1-3 days) W 1 credit 2S Lecturers

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

900-0101-DRL Transferable Skills Course II (1-3 days) W 1 credit 2S Lecturers

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

900-0102-DRL Transferable Skills Course III (1-3 days) W 1 credit 2S Lecturers

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

900-0103-DRL Transferable Skills Course I (1-3 days, with Poster or Talk) W 2 credits 4S Lecturers

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

900-0104-DRL Transferable Skills Course II (1-3 days, with Poster or Talk) W 2 credits 4S Lecturers

Only for doctoral students.
<table>
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<tr>
<th>Course ID</th>
<th>Course Title</th>
<th>Credits</th>
<th>Week(s)</th>
<th>Type</th>
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<td>2 credits</td>
<td>900-1111-DRL</td>
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<td>4S</td>
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<td>4S</td>
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<td>6S</td>
<td>Lecturers</td>
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<td>6S</td>
<td>Lecturers</td>
<td>1 week.</td>
<td>Participants need to present either a poster or a talk at this occasion.</td>
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</table>
### Participation in Commission I (min 1 year)
Only for doctoral students.

**Abstract**
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

**Objective**
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

**900-0112-DRL**
Participation in Commission I (min 1 year)  
W 1 credit 2P Lecturers

**Integration into Scientific Community**

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<th>Number</th>
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<td>Lecturers</td>
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**Abstract**
Participation in summer or winter schools with a maximum duration of 3 days.

**Objective**
Participation in summer or winter schools with a maximum duration of 3 days.

| 900-0151-DRL | Summer School II (1-3 days) Only for doctoral students. | W    | 1 credit | 2K     | Lecturers |

**Abstract**
Participation in summer or winter schools with a maximum duration of 3 days.

**Objective**
Participation in summer or winter schools with a maximum duration of 3 days.

| 900-0152-DRL | Summer School III (1-3 days) Only for doctoral students. | W    | 1 credit | 2K     | Lecturers |

**Abstract**
Participation in summer or winter schools with a maximum duration of 3 days.

**Objective**
Participation in summer or winter schools with a maximum duration of 3 days.

| 900-0153-DRL | Summer School I (1-3 days, with Poster or Talk) Only for doctoral students. | W    | 2 credits | 4K     | Lecturers |

**Abstract**
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

**Objective**
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

| 900-0154-DRL | Summer School II (1-3 days, with Poster or Talk) Only for doctoral students. | W    | 2 credits | 4K     | Lecturers |

**Abstract**
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

**Objective**
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

| 900-0155-DRL | Summer School III (1-3 days, with Poster or Talk) Only for doctoral students. | W    | 2 credits | 4K     | Lecturers |
Abstract: Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

Objective: Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

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<td>1 credit</td>
<td>2K Lecturers</td>
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900-0164-DRL  External Conference III (incl. Poster or Talk)  W  1 credit  2K  Lecturers

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

Doctorate Health Sciences and Technology - Key for Type

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<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<td>Dr</td>
<td>Suitable for doctorate</td>
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<td>O</td>
<td>Compulsory</td>
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Key for Hours

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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

ECTS  European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Subject Specialisation

### Creative Thinking Seminar

**Number** 227-0811-00L  
**Title** Creative Thinking Seminar  
**Type** W  
**ECTS** 2 credits  
**Hours** 2S  
**Lecturers** A. C. Notz

**Abstract**  
This seminar aims to understand better what creativity and creative thinking is by looking at the history of the creativity dispositive we are embedded in. We will look, learn and apply creative artistic practices to find innovative solutions. And we will also look beyond the artistic practices, into the creative potential of today’s technologies, especially Generative AI.

**Objective**  
The students will gain insights into the concept and mechanics of Creative Thinking. They will trace the historical roots of creativity and its contemporary significance, explore how Creative Thinking intersects with modern innovations and technologies. The students will develop a comprehensive understanding of Creative Thinking and its practical application, start to cultivate the ability to generate innovative solutions through creative practices and will analyze the broader implications of creativity in various contexts.

**Content**  
In the business world Creative Thinking is considered to be one of the “top ten skills” or “most In-Demand skill” in 2024. With Creative Thinking innovative solutions to problems are developed and not only a large number of ideas but also a variety and range of them are brainstormed. It seems that in today’s dynamic world, creativity isn’t just an asset – but actually necessity. But what exactly is Creative Thinking? In the above mentioned business context it is assumed everybody knows. And what is creativity? And how can we use it. Or not. Originally, connected to artistic practice, creativity is nowadays a skill and practice that can be found in all work areas, especially innovation and maybe even in technological applications themselves. Today, not only because of creative economy, creative cities or innovation, but also because of generative AI creativity has gained new and broad attention. In the seminar we go back in history to the invention of the genius and look at different social subsystems like art, psychology, economy as well as field as fashion, advertisement and arts and crafts, how our understanding of creativity has emerged till today.

### Seminar in Theoretical Computer Science

**Number** 252-4202-00L  
**Title** Seminar in Theoretical Computer Science  
**Type** W  
**ECTS** 2 credits  
**Hours** 2S  
**Lecturers** A. Steger, B. Gärtner, M. Hoffmann, J. Lengler, D. Steurer

**Abstract**  
Presentation of recent publications in theoretical computer science, including results by diploma, masters and doctoral candidates.

**Objective**  
The goal is to introduce students to current research, and to enable them to read, understand, and present scientific papers.

**Prerequisites / notice**  
This seminar takes place as part of the joint research seminar of several theory groups. Intended participation is for students with excellent performance only. Formal restriction is: prior successful participation in a master level seminar in theoretical computer science.

### Big Data

**Number** 263-3010-00L  
**Title** Big Data  
**Type** W  
**ECTS** 10 credits  
**Hours** 3V+2U+4A  
**Lecturers** G. Fourny

**Abstract**  
The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations.

**Objective**  
Do you want to be able to query your own data productively and efficiently in your future semester projects, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This course teaches you how to do so as well as the dos and don'ts. "Big Data" refers to the case when the amount of data is very large (100 GB and more), or when the data is not completely structured (or messy). The Big Data revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it are needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today’s technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each one of your projects efficiently and consistently.
This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage (S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Large scale analytics and machine learning are outside of the scope of this course.

Literature

Course textbook: https://ghislainfourny.github.io/big-data-textbook/

Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

Prerequisites / notice

The lecture is hybrid, meaning you can attend with us in the lecture hall, or on Zoom, or watch the recordings on YouTube later. Exercise sessions are in presence.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departmentes interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2023

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
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<td>Method-specific Competencies</td>
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<td></td>
<td>Social Competencies</td>
<td>Communication</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>fostered</td>
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</tbody>
</table>

Abstract

Venture Capital is important to fund big transformational ideas and is often misunderstood by tech or research entrepreneurs. This lecture immerses participants in the role of a Venture Capitalist (VC) to learn from experienced entrepreneurs and investors. In small teams, you work on a case of a real start-up and defend the case in a simulated investment committee consisting of experienced VCs.

Objective

After attending this course, students will be able to:
- Explain the differences between VC and founder thinking
- Evaluate if a start-up is suited for venture capital ("VC readiness")
- Evaluate founder friendliness of term sheets
- Determine funding needs & strategy for a start-up from research to first round
- Write and evaluate an investment memo

263-5053-00L  Technology Investing  W  2 credits  3S  A. Ilic, C. Jurytiko

Autumn Semester 2024
The course is practically oriented and features guest speakers from leading venture capital firms and start-ups. The course embraces a unique perspective combining technology and investor thinking. The seminar is structured around five days with the following themes.

The detailed program is listed here: https://bit.ly/techinvesting23

The macro picture. Why does venture capital exist? What are major tech break-through areas and their disruptive potential? We also review the differences in the US and European perspective as well as developments towards more impact and diversity conscious funds.

A peek into the mind of a VC. How to build a successful VC? Learn what key factors & processes required to build a successful venture capital company. This includes strategic decisions for investment thesis, structure of a fund, portfolio economics, valuation & ownership targets, cap table. In addition, we introduce the fundamentals of the investment process (including due diligence, term sheets, and deal memo) as well as portfolio management.

The founder’s perspective. Why should you raise venture capital and how? Learn to evaluate the founder friendliness of terms, company approach, strategic decisions, negotiation and valuation.

Fundraising types. Learn about different types of funding and their implications. This includes an overview of the Swiss ecosystem and a discussion of the different types (grants, equity, loans, SAFE, crowd, …). We also include a practical session on crypto technology for modern fund-raising using launchpads and tokenized shares.

Tying it all together. The last day is focused on simulating an investment committee meeting where the groups present their deal memos and discuss with the audience.

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<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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<tr>
<td></td>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
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<td>Analytical Competencies</td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
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<td>Media and Digital Technologies</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Problem-solving</td>
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<td>Self-presentation and Social Influence</td>
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<td>Project Management</td>
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<td>Sensitivity to Diversity</td>
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<td>Communication</td>
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263-5054-00L Patenting Digital Innovations

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<th>Objective</th>
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<td>After attending this course, students will be able to:</td>
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<tr>
<td>- Understand the basics of patenting in the digital space relevant for a global market</td>
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<td>- Evaluate patenting opportunities with a more differentiated view on the topic</td>
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<td>- Effectively use patents as a cost-effective part of a technology startup’s business plan</td>
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<td>- Conduct patent searches, freedom-to-operate analysis and infringement analyses</td>
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<tr>
<td>- Write their first software/AI-related invention disclosure suitable for patenting</td>
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</table>

Content

The course is focused on patenting digital innovations. It is designed for students with entrepreneurial interests that like to get a hands-on perspective on the topic of intellectual property strategies and patents.

The seminar includes presentations and practical group exercises to apply the acquired knowledge in practice. Entrepreneurs and leading IP experts are joining the seminar as guest speakers for discussion of real-life examples.

Topics that will be covered include:
- Best practices that any AI/software startups should know about IP and patents
- How investors evaluate a strong IP situation of a start-up
- How to efficiently monitor competitor patent activity and obtain “FTO”
- How to create an effective patent filing strategy that grows with the business
- How to efficiently create AI patents while not getting distracted from the founder’s core business

The course also contains a group work of a “FTO battle” where two teams compete in a freedom-to-operate analysis and individual work to write their first invention disclosure related to an AI or software topic.

263-5057-00L From Publication to the Doctor’s Office

<table>
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<tr>
<th>Abstract</th>
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<tbody>
<tr>
<td>This seminar course is designed to provide students with an opportunity to review and critically evaluate recent publications in medical field focusing on examples when CS method or bioinformatics/statistical technique has lead to an instrumentation, technique or drug approved for clinical practice use.</td>
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</table>

Objective

Throughout the course, students will read and analyze recent publications that demonstrate successful applications and sometimes failures in medicine. Promising research applications will also be discussed. The publications will cover a wide range of topics, including drug discovery, image analysis, prognostic models, and learning healthcare.
The course will be structured as half lecture content and half seminar content. Lectures will review state of the medical practice prior to the discovery, obstacles in moving the field forward, and the need for improvement. Lecture will be followed by the seminar part where students will take turns presenting the assigned publications and leading the discussions. Students’ presentations will focus on the main findings, and specific steps taken to translate the finding into clinical practice.

Publications will include examples of:
- specific CS/bioinformatics/statistics applications that has been brought to “bedside” – has been approved by European Medicines Agency / Food and Drug Administration (USA) for clinical use or are widely used in medical research;
- examples of failures of how a discovery did not translate into an endproduct and why;
- current active research areas.

Covered topics will include some of the following:
- Drug discovery: Computer-aided drug discovery has become an integral part of the drug development process, enabling researchers to design and screen large libraries of molecules in silico (i.e., using computer simulations) before synthesizing and testing them in the lab. This has led to the discovery of new drug candidates for a wide range of diseases, including cancer, Alzheimer’s disease, and HIV/AIDS.
- Genomics: Advances in computational genomics have enabled researchers to analyze and interpret large-scale genomic data, including DNA sequencing data, to identify disease-causing mutations, genetic risk factors, and drug targets. Examples of the development of personalized medicine, where treatments are tailored to an individual’s genetic makeup. Examples when drug target identified by genetics has led to approved treatment.
- Imaging: Computer vision and image processing techniques have revolutionized medical imaging, enabling researchers to extract quantitative information from medical images that were previously inaccessible. This has led to the development of new diagnostic and prognostic tools for a wide range of diseases, including cancer, cardiovascular disease, and neurological disorders.
- Real-world data applications: emulation of clinical trials using electronic health records data.
- Large language models: Generating clinical trial protocols using large language models. Natural Language Processing for information extraction and interpretation.
- Learning healthcare systems: Advances in data analytics and information technology have enabled the development of learning healthcare systems, which use real-time data from electronic health records, medical devices, and other sources to improve patient outcomes and reduce healthcare costs. This has the potential to transform the way healthcare is delivered, making it more personalized, efficient, and effective.

In addition to the presentations, students will also be required to write critical reviews of the assigned publications throughout the course. The reviews will be evaluated based on the students’ ability to identify the strengths and weaknesses of the publications and to provide insightful and constructive feedback.

**Competencies**

- Subject-specific Competencies: fostered
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies: fostered
  - Analytical Competencies
  - Communication
- Social Competencies: assessed
  - Cooperation and Teamwork
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
- Personal Competencies: fostered
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics

**Prerequisites / notice**

The course is intended for advanced undergraduate and graduate students with a background in computer science, bioinformatics, or a related field and interest in applying their skills to medical research.

This course assumes a working knowledge of R/Python and intermediate statistical analysis, including linear, logistic, survival regressions or ability and interest to learn them outside of the class.

**Abstract**

This course provides theoretical and practical insights into technology entrepreneurship. It focusses on the process of building new ventures from the idea to successfully scaling its business operations.

**Objective**

Students will develop internationally scalable and technology-based ventures using the Startup Navigator and ScaleUp Navigator Framework. They will learn how to structure and communicate these ideas to business angel and venture capital investors.

**Content**

This course provides theoretical and practical insights into technology entrepreneurship. It focusses on the process of building new ventures from the idea to successfully scaling its business operations. All tasks will lead students to give a complete pitch presentation in front of business experts and investors at the end of the seminar. The course structure will broadly follow the four dimensions of the St.Galler Startup NavigatorTM.

- Profiling (Problem-Solution-Fit): Here, students will learn to answer questions such as (1) what is your motivation to start a business? (2) What is the real customer problem? (2) What solution can be identified? (3) Who are the customers? (4) What is the job they need done? etc.
- Prototyping (Product-Market-Fit): After this section, students will be able to answer questions such as (1) What is the product or service that solves a customer need? (2) What is the value proposition? (3) What is the unique selling proposition? (4) What is the go-to market strategy? (5) Who are the competitors? etc.
- Sourcing (Execution-Fit): Here, students will learn to address questions such as (1) What are important team roles? (2) How to leverage network and partners? (3) What are the requirements to execute the business? (4) Are there any IP-related challenges? (5) How may we co-create with others? etc.
- Scaling (Performance-Fit): In this section, students will reflect their concept in terms of scalability. They will learn to answer questions such as (1) How do we create purpose-driven culture for growth? (2) How do we scale-up revenues? (3) How do we optimize our startup’s valuation in Series-X funding? (4) What kind of exit options are there?

As a result, students develop internationally scalable and technology-driven businesses in teams. The special focus lies on the ability to successfully pitch these ventures to business angels or venture capital investors.

**Literature**

- Course slides and case-based literature provided by the instructor.
- Additional material pointed out by the instructor prior to and during the course.
Abstract
In this doctoral seminar, current research at the Institute for Visual Computing will be presented and discussed. The goal is to learn about current research projects at our institute, to strengthen our expertise in the field, to provide a platform where research challenges can be discussed, and also to practice scientific presentations.

Objective
This course is designed to help junior researchers in Computer Science develop the skills needed to write their first research articles and/or their Doctoral Plan. Participants will be expected to produce several short texts as homework assignments, so ideally they will already be working on writing about their research in English when they take the course. Assignment submissions can include sections of the Doctoral Plan as well as sections of research articles and conference papers. Participants will receive individual feedback on these texts during the course, both from the instructor and from their peers.

Content
Participants will be expected to produce several short texts as homework assignments, so ideally they will already be working on writing about their research in English when they take the course. Assignment submissions can include sections of the Doctoral Plan as well as sections of research articles and conference papers. Participants will receive individual feedback on these texts during the course, both from the instructor and from their peers.

Part 1: Part 1 will provide an introduction to the course, and will then focus on using model texts, improving vocabulary and phrasing, and constructing reader-friendly sentences.

Part 2: We will discuss structural decisions about research articles in different journals, review the basics of paragraph structure and organization, and examine how to create better flow in a text.

Part 3: We will work on creating successful introductions, integrating the literature, and writing abstracts.

Part 4: Part 4 will address the main content and grammar concerns of writing about methods and results, and review key grammar concepts for writing complex sentences.

Part 5: We will look at how to construct discussion and conclusion sections and how to strike the right tone of caution/confidence. We will then discuss the editing process, preparing articles for submission, and responding to reviewers' comments.

All sessions will involve group work and peer review of participants' writing.

Content
Current research at the IVC will be presented and discussed.

Prerequisites / notice
This course requires solid knowledge in the area of Computer Graphics and Computer Vision as well as state-of-the-art research.

264-5812-00L
Doctoral and Research Writing in Computer Science A Z

Abstract
This course is designed to help junior researchers in Computer Science develop the skills needed to write their first research articles and/or their Doctoral Plan.

Objective
This short course (5 x 4-lesson workshops) is designed to help doctoral students develop the skills needed to write their first research articles, conference submissions and proposals. The course will help participants to:
- understand the needs of different target readerships,
- manage the writing process efficiently,
- structure texts effectively,
- produce logical flow in sentences and paragraphs,
- edit texts before submission, and
- revise texts in response to colleagues' feedback and reviewers' comments.

Content
Participants will be expected to produce several short texts as homework assignments, so ideally they will already be working on writing about their research in English when they take the course. Assignment submissions can include sections of the Doctoral Plan as well as sections of research articles and conference papers. Participants will receive individual feedback on these texts during the course, both from the instructor and from their peers.

Part 1: Part 1 will provide an introduction to the course, and will then focus on using model texts, improving vocabulary and phrasing, and constructing reader-friendly sentences.

Part 2: We will discuss structural decisions about research articles in different journals, review the basics of paragraph structure and organization, and examine how to create better flow in a text.

Part 3: We will work on creating successful introductions, integrating the literature, and writing abstracts.

Part 4: Part 4 will address the main content and grammar concerns of writing about methods and results, and review key grammar concepts for writing complex sentences.

Part 5: We will look at how to construct discussion and conclusion sections and how to strike the right tone of caution/confidence. We will then discuss the editing process, preparing articles for submission, and responding to reviewers' comments.

All sessions will involve group work and peer review of participants' writing.

264-5813-00L
Doctoral and Research Writing in Computer Science B Z

Abstract
This course is designed to help junior researchers in Computer Science develop the skills needed to write their first research articles and/or their Doctoral Plan.

Objective
This short course (5 x 4-lesson workshops) is designed to help doctoral students develop the skills needed to write their first research articles, conference submissions and proposals. The course will help participants to:
- understand the needs of different target readerships,
- manage the writing process efficiently,
- structure texts effectively,
- produce logical flow in sentences and paragraphs,
- edit texts before submission, and
- revise texts in response to colleagues' feedback and reviewers' comments.

Content
Participants will be expected to produce several short texts as homework assignments, so ideally they will already be working on writing about their research in English when they take the course. Assignment submissions can include sections of the Doctoral Plan as well as sections of research articles and conference papers. Participants will receive individual feedback on these texts during the course, both from the instructor and from their peers.

Part 1: Part 1 will provide an introduction to the course, and will then focus on using model texts, improving vocabulary and phrasing, and constructing reader-friendly sentences.

Part 2: We will discuss structural decisions about research articles in different journals, review the basics of paragraph structure and organization, and examine how to create better flow in a text.

Part 3: We will work on creating successful introductions, integrating the literature, and writing abstracts.

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Part 5: We will look at how to construct discussion and conclusion sections and how to strike the right tone of caution/confidence. We will then discuss the editing process, preparing articles for submission, and responding to reviewers' comments.

All sessions will involve group work and peer review of participants' writing.

263-5907-00L
Geometry for Computational Design and Fabrication

Abstract
The main intention of the course is to present geometric concepts that turned out to simplify the solution of problems in computational design and fabrication and hold promise to provide useful methodology for future research in this area.
We will meet for the mandatory kick-off meeting online in October. You will get detailed information together with the invitation email in the

### Ethics and Scientific Integrity for Doctoral Students

**Number**: 851-0178-00L  
**Title**: Ethics and Scientific Integrity for Doctoral Students  
**Type**: W  
**ECTS**: 1  
**Hours**: 2U  
**Lecturers**: G. Achermann

#### Abstract
This course sensitises doctoral students to ethical issues that may occur during their doctorate. After an introduction to ethics and good scientific practice, students are familiarised with resources that can assist them with ethical decision-making. Students get the chance to apply and deepen their knowledge in an interactive face-to-face workshop.

#### Objective
Doctoral students learn how to identify, analyse and address ethical issues in their own scientific research. In addition, they will reflect on their professional role as scientific researchers.

#### Content

- **Part I on Moodle**
  - The self-paced e-learning course on Moodle consists of 5 modules:
    - Module 1: Ethics  
      - Introduction to moral theory (with emphasis on practical guidance regarding decision making)
    - Module 2: Ethics in scientific research  
      - Introduction to ethical issues that occur within scientific research (i.e. regarding authorship, cooperation, data use and sharing, and other aspects that are subject to scientific integrity and good scientific practice).
    - Module 3: Collecting resources  
      - A variety of tools and resources that help identify ethical issues are presented and explained
    - Module 4: Setting up a strategy  
      - Example examination of a case regarding its ethical scope (students develop their own strategy to examine situations for their ethical implications).
    - Module 5: Making decisions  
      - Different ways of addressing ethical issues are presented and explained (i.e. how to make hard choices, or solve ethical dilemmas. But also where to seek advice if needed).

- **Part II**
  - The second, face-to-face part (group sessions) of this course provides an interactive learning environment (workshop). Students get to apply their knowledge, and they are encouraged to reflect on ethical problems and to critically discuss them with fellow doctoral students.

#### Prerequisites / notice
For doctoral students only.

- The first part on Moodle (part I) must be successfully completed before the face-to-face workshop (part II).
- Hence, when you choose a group make sure you have enough time to finish the first part on Moodle before the workshop starts (appr. 20 hours).

#### Competencies

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<thead>
<tr>
<th>Subject-specific Competencies</th>
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<th>Personal Competencies</th>
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<tr>
<td>Concepts and Theories</td>
<td>Decision-making</td>
<td>Critical Thinking</td>
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<td>assessed</td>
<td>assessed</td>
<td>Integrity and Work Ethics</td>
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### Learning to Teach

**Number**: 851-0373-00L  
**Title**: Learning to Teach  
**Type**: W  
**ECTS**: 2  
**Hours**: 2U  
**Lecturers**: M. Lehner, B. Volk

#### Abstract
This programme is designed for ETH Doctoral Teaching Assistants with current teaching responsibilities.

#### Objective
In this course Doctoral Teaching Assistants will...

- discuss learning science and teaching techniques with peers.
- design the introduction of their course/lecture/exercise class.
- develop learning activities according to learning objectives.
- practice classroom assessment techniques in order to measure student learning.
- engage in peer feedback in order to improve own teaching.

#### Content
We will meet for the mandatory kick-off meeting online in October. You will get detailed information together with the invitation email in the first week of the semester. The online phase, where you work through 6 modules in the Moodle course page will end in November. We will meet also face-to-face for the Consolidation workshop. You will find more information on the course page in Moodle.

#### Prerequisites / notice
This programme is designed for ETH Doctoral Teaching Assistants with current teaching responsibilities (exercises, excursions, supervision of practicals, lectures, etc.) or those who will assume teaching tasks in the semester following the programme. No previous teacher training is required.
Competencies

Subject-specific Competencies
- Concepts and Theories: fostered
- Media and Digital Technologies: fostered

Method-specific Competencies
- Communication: fostered
- Cooperation and Teamwork: assessed
- Adaptable and Flexible: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered
- Negotiation: assessed

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered

Competencies

851-0745-00L Ethics Workshop: The Impact of Digital Life on Society

Open to all Master level / PhD students.

Abstract
This workshop focuses on understanding and managing the ethical and social issues arising from the integration of new technologies in various aspects of daily life.

Objective
- Explain relevant concepts in ethics.
- Evaluate the ethical dimensions of new technology uses.
- Identify impacted stakeholders and who is ethically responsible.
- Engage constructively in the public discourse relating to new technology impacts.
- Work in a more ethically reflective way.

Content
The workshop offers students an experience that trains their ability for critical analysis and develops awareness of responsibilities as a researcher, consumer and citizen. Learning will occur in the context of three intensive workshop days, which are highly interactive and focus on the development and application of reasoning skills.

The workshop will begin with some fundamentals: the nature of ethics, of consent and big data, of AI ethics, public trust and health ethics. Students will then be introduced to key ethical concepts such as fairness, autonomy, trust, accountability, justice, as well different ways of reasoning about the ethics of digital technologies.

A range of practical problems and issues in the domains of education, media, society, digital health and justice will be then considered. These domains are represented respectively by unique and interesting case studies. Each case study has been selected not only for its timely and engaging nature, but also for its relevance. Through the analysis of these case studies key ethical questions (such as fairness, accountability, explainability, access etc.) will be highlighted and questions of responsibility and tools for ethical practice will be explored. Throughout, the emphasis will be on learning to make sound arguments about the ethical aspects of policy, practice and research.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Media and Digital Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered
- Negotiation: assessed

Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered

Course units in Humanities, Social and Political Sciences
Educational Science for Teaching Diploma and TC
Language Courses ETH/UZH: see Science in Perspective
Course units in Management, Technology and Economics

900-0100-DRL Transferable Skills Course I (1-3 days)

Only for doctoral students.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

900-0101-DRL Transferable Skills Course II (1-3 days)

Only for doctoral students.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

900-0102-DRL Transferable Skills Course III (1-3 days)

Only for doctoral students.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.
Abstract: Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective: Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Description</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>900-0103-DRL</td>
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<td></td>
<td>Only for doctoral students.</td>
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<tr>
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<td>900-0104-DRL</td>
<td>Transferable Skills Course II (1-3 days, with Poster or Talk)</td>
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<tr>
<td>900-0109-DRL</td>
<td>Transferable Skills Course I (1 week, with Poster or Talk)</td>
<td>3</td>
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<tr>
<td>900-0110-DRL</td>
<td>Transferable Skills Course II (1 week, with Poster or Talk)</td>
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Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**900-0111-DRL** Transferrable Skills Course III (1 week, with Poster or Talk)

| Only for doctoral students. |

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**Objective**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**900-0112-DRL** Participation in Commission I (min 1 year)

| W | 1 credit | 2P |

Lecturers

**Abstract**

Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

**Objective**

Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

**900-0113-DRL** Participation in Commission II (min 1 year)

| W | 1 credit | 2P |

Lecturers

**Abstract**

Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

**Objective**

Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

**900-0114-DRL** Member of Executive Board (min 1 year)

| W | 2 credits | 4P |

Lecturers

**Abstract**

Active participation in the presidium or executive board of a university group for at least 1 year.

**Objective**

Active participation in the presidium or executive board of a university group for at least 1 year.

**Integration into Scientific Community**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<td>900-0150-DRL</td>
<td>Summer School I (1-3 days)</td>
<td>W</td>
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<td>2K</td>
<td>Lecturers</td>
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</table>

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**

Participation in summer or winter schools with a maximum duration of 3 days.

**Objective**

Participation in summer or winter schools with a maximum duration of 3 days.

**900-0151-DRL** Summer School II (1-3 days)

| W | 1 credit | 2K |

Lecturers

**Abstract**

Participation in summer or winter schools with a maximum duration of 3 days.

**Objective**

Participation in summer or winter schools with a maximum duration of 3 days.

**900-0152-DRL** Summer School III (1-3 days)

| W | 1 credit | 2K |

Lecturers

**Abstract**

Participation in summer or winter schools with a maximum duration of 3 days.

**Objective**

Participation in summer or winter schools with a maximum duration of 3 days.

**900-0153-DRL** Summer School I (1-3 days, with Poster or Talk)

| W | 2 credits | 4K |

Lecturers

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate. 

**Abstract**

Participation in summer or winter schools with a maximum duration of 3 days.

**Objective**

Participation in summer or winter schools with a maximum duration of 3 days.
### Abstract
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

### Objective
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

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<td>900-0155-DRL</td>
<td>Summer School III (1-3 days, with Poster or Talk)</td>
<td>W 2 credits 4K</td>
<td>Lecturers</td>
</tr>
<tr>
<td>900-0156-DRL</td>
<td>Summer School I (1 week)</td>
<td>W 2 credits 4K</td>
<td>Lecturers</td>
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<tr>
<td>900-0157-DRL</td>
<td>Summer School II (1 week)</td>
<td>W 2 credits 4K</td>
<td>Lecturers</td>
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<tr>
<td>900-0158-DRL</td>
<td>Summer School III (1 week)</td>
<td>W 2 credits 4K</td>
<td>Lecturers</td>
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<tr>
<td>900-0159-DRL</td>
<td>Summer School I (1 week, with Poster or Talk)</td>
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<td>Lecturers</td>
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<tr>
<td>900-0160-DRL</td>
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<td>W 3 credits 6K</td>
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<tr>
<td>900-0161-DRL</td>
<td>Summer School III (1 week, with Poster or Talk)</td>
<td>W 3 credits 6K</td>
<td>Lecturers</td>
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</table>

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

### Notes
- Autumn Semester 2024
- Only for doctoral students.
- Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.
- Participants need to present either a poster or a talk at this occasion.
### External Conference I (incl. Poster or Talk)

<table>
<thead>
<tr>
<th>Code</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>900-0162-DRL</td>
<td>External Conference I (incl. Poster or Talk)</td>
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<td>1</td>
<td>2K</td>
<td>Lecturers</td>
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</table>

Only for doctoral students.

**Abstract**
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

**Objective**
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

### External Conference II (incl. Poster or Talk)

<table>
<thead>
<tr>
<th>Code</th>
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<td>900-0163-DRL</td>
<td>External Conference II (incl. Poster or Talk)</td>
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### External Conference III (incl. Poster or Talk)

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**Objective**
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**Doctorate Computer Science - Key for Type**

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<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<td>O</td>
<td>Compulsory</td>
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**Key for Hours**

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<tr>
<td>V</td>
<td>lecture</td>
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<td>G</td>
<td>lecture with exercise</td>
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<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
<table>
<thead>
<tr>
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<tr>
<td>151-0371-00L</td>
<td>Advanced Model Predictive Control</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>M. Zeilinger, A. Carron, L. Hewing, J. Köhler</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
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<td></td>
<td>Model predictive control (MPC) has established itself as a powerful control technique for complex systems under state and input constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
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<td></td>
<td>Design, implement and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.</td>
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<tr>
<td></td>
<td>Content</td>
<td></td>
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<td></td>
<td>Topics include: - Nominal MPC for uncertain systems (nominal robustness) - Robust MPC - Stochastic MPC - Review of regression methods - Set-membership Identification and robust data-driven MPC - Bayesian regression and stochastic data-driven MPC - MPC as safety filter for reinforcement learning</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
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<td>Lecture notes will be provided.</td>
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<td>Prerequisites / notice</td>
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<td>Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control in Spring Semester) strongly recommended. Background in linear algebra and stochastic systems recommended.</td>
</tr>
<tr>
<td>227-0105-00L</td>
<td>Introduction to Estimation and Machine Learning</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
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<td>Mathematical basics of estimation and machine learning, with a view towards applications in signal processing.</td>
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<td>Objective</td>
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<td>Students master the basic mathematical concepts and algorithms of estimation and machine learning.</td>
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<td>Content</td>
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<td>Review of probability theory; basics of statistical estimation; least squares and linear learning; Hilbert spaces; singular-value decomposition; kernel methods, neural networks, and more</td>
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<td></td>
<td>Lecture notes</td>
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<td>Lecture notes will be handed out as the course progresses.</td>
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<td></td>
<td>Prerequisites / notice</td>
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<td>solid basics in linear algebra and probability theory</td>
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<tr>
<td>227-0146-00L</td>
<td>Data Conversion System Design</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>T. Burger, G. Cervelli, R. Reutemann</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
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<td>This course provides a thorough treatment of integrated data conversion systems from system level specifications and trade-offs, over architecture choice down to circuit implementation.</td>
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<td>Objective</td>
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<td>Data conversion systems are substantial sub-parts of many electronic systems, e.g. the audio conversion system of a home-cinema systems or the base-band front-end of a wireless modem. Data conversion systems usually determine the performance of the overall system in terms of dynamic range and linearity. Students will learn the underlying principles of data conversion and be introduced to the different methods and circuit architectures to implement such a conversion. The conversion methods such as successive approximation or algorithmic conversion are explained based on their operation principle accompanied with the appropriate mathematical calculations, including effects of non-idealities in some cases. After successful completion of the course students should understand the concept of an ideal ADC, know all major converter architectures, their principle of operation and what governs their performance.</td>
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<td>Content</td>
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<td>- Introduction: examples of data conversion architectures; information representation; abstraction, categorization and symbolic representation; basic conversion algorithms; data converter application; tradeoffs among key parameters; ADC taxonomy. - Dual-slope &amp; successive approximation register (SAR) converters: dual slope principle &amp; converter; SAR ADC operating principle; SAR implementation with a capacitive array; range extension with segmented array. - Algorithmic &amp; pipelined A/D converters: algorithmic conversion principle; sample &amp; hold stage; pipe-lined converter; multiplying DAC; flash sub-ADC and n-bit MDAC; redundancy for correction of non-idealities, error correction. - Performance metrics and non-linearity: ideal ADC; offset, gain error, differential and integral non-linearities; capacitor mismatch; impact of capacitor mismatch on SAR ADC's performance. - Flash, folding an interpolating analog-to-digital converters: flash ADC principle, thermometer to binary coding, sparkline correction; limitations of flash converters; the folding principle, residue extraction; folding amplifiers; cascaded folding; interpolation for folding converters; cascaded folding and interpolation. - Noise in analog-to-digital converters: types of noise; noise calculation in electronic circuit, kT/C-noise, sampled noise; noise analysis in switched-capacitor circuits; aperture time uncertainty and sampling jitter. - Delta-sigma A/D-converters: linearity and resolution; from delta-modulation to delta-sigma modulation; first-order delta-sigma modulation, circuit level implementation; clock-jitter &amp; SNR in delta-sigma modulators; second-order delta-sigma modulation, higher-order modulation, design procedure for a single-loop modulator. - Digital-to-analog converters: introduction; current scaling D/A converter, current steering DAC, calibration for improved performance, delta-sigma D/A-converters.</td>
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<td>Lecture notes</td>
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<td>Slides are available online under <a href="https://lis-students.ee.ethz.ch/lectures/analog-to-digital-converters/">https://lis-students.ee.ethz.ch/lectures/analog-to-digital-converters/</a></td>
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<td>Prerequisites / notice</td>
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<td>It is highly recommended to attend the course &quot;Analog Integrated Circuits&quot; of Prof. T. Jang as a preparation for this course.</td>
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<td>Competencies</td>
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<td>Subject-specific Competencies</td>
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<td>Techniques and Technologies</td>
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<td>Analytical Competencies</td>
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Data: 15.06.2024 12:39 | Autumn Semester 2024 | Page 794 of 2653
The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.

Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

This course explores the exciting realm of carbon-based nanoelectronics, where the remarkable quantum properties of materials like graphene, carbon nanotubes, graphene nanoribbons, and single molecules are used for building electronic devices.

Subject-specific Competencies
- Concepts and Theories
- Technics and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

Sufficient mathematical maturity, in particular in linear algebra, analysis.

Available on the course Moodle platform.


A comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.

The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.

- Provide an understanding of the physics of failure and reliability. Introduce the degradation and failure mechanisms, basics of failure analysis, methods and tools of reliability testing.

Summary of reliability and failure analysis terminology; physics of failure: materials properties, physical processes and failure mechanisms; failure analysis: basics and properties of instruments; quality assurance of technical systems (introduction); introduction to stochastic processes; reliability analysis; component selection and qualification; maintainability analysis (introduction); design rules for reliability, maintainability, reliability tests (introduction).

Comprehensive copy of transparencies


Understanding the physics of failures and failure mechanisms enables reliability analysis and serves as a practical guide for electronic devices design, integration, systems development and manufacturing. The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.

The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.

By the end of the course, the students will be familiar with the state of the art in commodity computer hardware attacks and defenses. More specifically, the students will learn about:

- security problems of commodity hardware that we use everyday and how you can defend against them.
- relevant computer architecture and operating system aspects of these issues.
- hands-on techniques for performing hardware attacks.

This is the course where you get credit points by building some of the most advanced exploits on the planet! The luckiest team will collect a Best Demo Award at the end of the course.

Experience with Linux, low-level systems programming and computer architecture.


This course covers the security of commodity computer hardware (e.g., CPU, DRAM, etc.) with a special focus on cutting-edge hands-on research. The aim of the course is familiarizing the students with hardware security and more specifically microarchitectural and circuit-level attacks and defenses through lectures and implementing some of these advanced attacks.

By the end of the course, the students will be familiar with the state of the art in commodity computer hardware attacks and defenses. More specifically, the students will learn about:

- security problems of commodity hardware that we use everyday and how you can defend against them.
- relevant computer architecture and operating system aspects of these issues.
- hands-on techniques for performing hardware attacks.

This is the course where you get credit points by building some of the most advanced exploits on the planet! The luckiest team will collect a Best Demo Award at the end of the course.

Experience with Linux, low-level systems programming and computer architecture.


This course explores the exciting realm of carbon-based nanoelectronics, where the remarkable quantum properties of materials like graphene, carbon nanotubes, graphene nanoribbons, and single molecules are used for building electronic devices.

Carbon-based Nanoelectronics

This course explores the exciting realm of carbon-based nanoelectronics, where the remarkable quantum properties of materials like graphene, carbon nanotubes, graphene nanoribbons, and single molecules are used for building electronic devices.
Objective
The objective of this course is to understand how the electronic properties of carbon-based materials can be exploited for fabricating quantum devices. We will delve into both the theoretical and experimental aspects, discussing how these materials' unique properties can be translated into device functionality.

On the theoretical side, we'll cover how the chemical structure of the material and its dimensionality, ranging from 0D to 2D, affects the electronic properties. We'll also discuss how charge carriers flow through the devices and what charge transport mechanisms are at play.

On the experimental side, we'll cover how such devices are fabricated, including how the materials are synthesized. We'll also discuss how to characterize the devices and assess their performance.

Content
The course will cover the following carbon-based materials:
- Single-molecule
- Graphene (single layer, bilayer, twisted bilayer)
- Graphene nanoribbons
- Carbon nanotubes

For each material, we will discuss:
- Electronic structure and charge transport properties
- Material synthesis and characterization
- Device integration and characterization

The course also includes a presentation by each student on a related scientific publication. This presentation is compulsory and accounts for 50% of the grade.

Lecture notes
Lecture slides are distributed every week. In addition, relevant scientific articles and book chapters will be provided for self-study.

In addition to the slides, the following supplementary books can be recommended:

Prerequisites / notice
A basic knowledge of solid-state physics and quantum mechanics is required. The course is taught in English.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>assessed</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
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<td></td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<td></td>
<td>Self-direction and Self-management</td>
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</table>

227-0671-00L Nanodevices and Circuits for the Beyond-Moore Era

Abstract
Big Data, AI and the Internet of Things demand new hardware which overcomes the limitations of von Neumann architectures. The lecture gives an insight how the fundamental physics and the resulting complex functionalities of nanodevices and circuits offer viable alternatives. Their increased computational power and energy efficiency are demonstrated through neuromorphic computing applications.

Objective
The students will gain a firm understanding in the theory and pioneering experiments of electronic and heat transport at atomic-to-nanometer length-scales. Advanced device functionalities enabled by recently discovered material systems will be covered. The students will learn how to exploit such phenomena for designing nanodevices and circuits to energy-efficiently implement neuromorphic algorithms for a sustainable future of information technologies.

Lecture notes
The presentation slides and further material will be provided every week.

Prerequisites / notice
Basic knowledge of solid state physics and semiconductors.

Competencies

| Subject-specific Competencies          | Concepts and Theories | assessed |
|                                       | Techniques and Technologies | assessed |
| Method-specific Competencies          | Analytical Competencies | fostered |
|                                       | Media and Digital Technologies | fostered |
|                                       | Problem-solving        | fostered |
| Social Competencies                   | Communication          | fostered |
| Personal Competencies                 | Critical Thinking      | fostered |

227-0689-00L System Identification

Abstract
Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.

Objective
To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.

Content
Introduction to modeling: Black-box and grey-box models; Parametric and non-parametric models; ARX, ARMAX (etc.) models.

Optimal experimental design, Cramer-Rao bounds, input signal design.

Parametric identification methods. On-line and batch approaches.

Literature
Closed-loop identification strategies. Trade-off between controller performance and information available for identification.


Additional papers will be available via the course Moodle.

Prerequisites / notice
Control systems (227-0216-00L) or equivalent.

227-0955-00L Seminar in Electromagnetics, Photonics and Terahertz

Abstract
Selected topics of the current research activities at the IEF and closely related institutions are discussed.
Objective

Have an overview on the research activities of the IEF institute.

Abstract

Advanced Machine Learning

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

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Objective

In this course students will obtain an overarching view on thin film deposition techniques with a focus on epitaxial deposition processes. The main learning objectives are:

- Identification of most relevant deposition technique for a given application.
- Understanding of growth mechanism and growth modes.
- Understanding strategies for engineering the functionalities of the films using the deposition process.
- Selection of the most appropriate characterization technique.
- Understanding device concepts and fundamental limits in the technology relevant ultra-thin limit.
- Assessing the relevance of scientific literature dealing with complex oxide thin films.
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has fostered the development of a variety of applications and devices. This course provides an introduction to THz science, technology and applications. The goal of this course is to enable students to determine whether a THz solution can be applied to a particular scientific or technological problem. Armed with the fundamentals of THz science and of current THz technologies, covered in this introductory course, students will be able to weigh the capabilities, advantages and limitations of THz tools to address topics ranging from phonons in solid state systems and molecular vibrations in solutions to medical imaging and wireless communications.

401-3055-64L Algebraic Methods in Combinatorics

Abstract
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

The course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments
- Spaces of polynomials and tensor product methods
- Eigenvalues of graphs and their application
- The Combinatorial Nullstellensatz and the Chevalley-Warning theorem
- Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

401-5680-00L Foundations of Data Science Seminar

Abstract
Research colloquium

The Terahertz (THz) range (0.1 – 10 THz), lies between the infrared and microwave spectral regions and has become accessible in the past few years. This new capability has had great impact in scientific research, and has led to technological advances and to the development of a variety of applications and devices. This course provides an introduction to THz science, technology and applications. The goal of this course is to enable students to determine whether a THz solution can be applied to a particular scientific or technological problem. Armed with the fundamentals of THz science and of current THz technologies, covered in this introductory course, students will be able to weigh the capabilities, advantages and limitations of THz tools to address topics ranging from phonons in solid state systems and molecular vibrations in solutions to medical imaging and wireless communications.
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Problem-solving assessed
Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Leadership and Responsibility fostered
Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Transferable Skills
During the doctoral studies, at least 1 CP ECTS must be acquired in the field of ethics / good scientific practice. See also https://www.ethicsrp.ethz.ch/courses.

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
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<tr>
<td>227-0809-00L</td>
<td>Ethics in Technology</td>
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<tr>
<td>Objective</td>
<td>Should we use this technology or not? What are the ethical opportunities and risks of this technological application? Should we always pursue all that is technically possible? What is ethics? How do ethics and technologies relate to each other? Does ethics hinder technological progress? How can ethics foster innovation? Which ethical theory should we apply in a global research-context? The course in times of fast technological progress and rapid technology-based innovation, being able to distinguish on ethical grounds what is technically feasible from all that is technically possible proves to be essential for a humane and sustainable future for humanity and for the planet. The aim of this introductory course is to introduce the ethics of technology by discovering different ethical theories and models while applying them to concrete technological innovations.</td>
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<tr>
<td>Content</td>
<td>This course considers the correlation between ethics and technologies. The relationship of ethics and technologies will be explored as reciprocal, with each contributing to the other. Applications of groundbreaking technologies often reshape the ethical environment by creating new solutions to societal challenges and new value. At the same time, scientists and technologists all perform their work within an ethically informed context. Meanwhile, ethics contributes to technology by stimulating technological innovation, by recognizing technological inventions, and by providing ethical guidance. Ethics bears on technology even by setting the parameters in which research, discussions, and studies can be conducted. No one should delude themselves that freedom of research cannot be infringed. New ideas and discoveries have always faced suppression on ethical grounds, because they represent challenges to putative “absolute truths” or undermine the enforcement of economic or political power structures. Even in today’s world, the danger of members of the technology community not being able to conduct their research freely and independently still exists. At the same time, ethics can limit technology as well. For example, health and safety guidelines, patents, intellectual property rights, competition policy, consumer protection, and ethical codes of conduct belong to this category. This impact of ethics can be perceived as blocking and hindering technological innovation. In reality, ethics is only informing the innovation process that not everything that is doable is ethically good and should be done. At this point, different ethical theories and models need to be considered in order to gain ethical guidance.</td>
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Literature

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<tr>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>851-0178-00L</td>
<td>Ethics and Scientific Integrity for Doctoral Students</td>
<td>W</td>
<td>1</td>
<td>2U</td>
<td>G. Achermann</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course sensitises doctoral students to ethical issues that may occur during their doctorate. After an introduction to ethics and good scientific practice, students are familiarised with resources that can assist them with ethical decision-making. Students get the chance to apply and deepen their knowledge in an interactive face-to-face workshop.</td>
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<td>Objective</td>
<td>Doctoral students learn how to identify, analyse and address ethical issues in their own scientific research. In addition, they will reflect on their professional role as scientific researchers.</td>
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</table>
The students will gain insights into the concept and mechanics of Creative Thinking. They will trace the historical roots of creativity and its contemporary significance, explore how Creative Thinking interacts with modern innovations and technologies. Originally, connected to artistic practice, creativity is nowadays a skill and practice that can be found in all work areas, especially in innovation and maybe even in technological applications themselves. Today, not only because of creative economy, creative cities or innovation, but also because of generative AI creativity has gained new and broad attention. In the seminar we go back in history to the invention of the genius and look at different social subsystems like art, psychology, economy as well as field as fashion, advertisement and inventors will be brainstormed. It seems that in today's dynamic world, creativity isn't just an asset – but actually necessity. But what exactly is Creative Thinking? In the above mentioned business context it is assumed everybody knows. And what is creativity? And how can we use it. Or not.

Part I

The self-paced e-learning course on Moodle consists of 5 modules:

Module 1: Ethics
- Introduction to moral theory (with emphasis on practical guidance regarding decision making)

Module 2: Ethics in scientific research
- Introduction to ethical issues that occur within scientific research (i.e. regarding authorship, cooperation, data use and sharing, and other aspects that are subject to scientific integrity and good scientific practice).

Module 3: Collecting resources
- A variety of tools and resources that help identify ethical issues are presented and explained

Module 4: Setting up a strategy
- Example examination of a case regarding its ethical scope (students develop their own strategy to examine situations for their ethical implications).

Module 5: Making decisions
- Different ways of addressing ethical issues are presented and explained (i.e. how to make hard choices, or solve ethical dilemmas. But also where to seek advice if needed).

Part II

The second, face-to-face part (group sessions) of this course provides an interactive learning environment (workshop). Students get to apply their knowledge, and they are encouraged to reflect on ethical problems and to critically discuss them with fellow doctoral students.

Prerequisites / notice

For doctoral students only.

The first part on Moodle (part I) must be successfully completed before the face-to-face workshop (part II).

Hence, when you choose a group make sure you have enough time to finish the first part on Moodle before the workshop starts (appr. 20 hours).

Competencies

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<tr>
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<tr>
<td>Method-specific Competencies</td>
<td>Decision-making</td>
<td>assessed</td>
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<td>Personal Competencies</td>
<td>Problem-solving</td>
<td>assessed</td>
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<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Integrity and Work Ethics</td>
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</table>

227-0811-00L Creative Thinking Seminar

W 2 credits 2S A. C. Notz

Abstract

This seminar aims to understand better what creativity and creative thinking is by looking at the history of the creativity dispositive we are embedded in. We will look, learn and apply creative artistic practices to find innovative solutions. And we will also look beyond the artistic practices, into the creative potential of today’s technologies, especially Generative AI.

Objective

The students will gain insights into the concept and mechanics of Creative Thinking. They will trace the historical roots of creativity and its contemporary significance, explore how Creative Thinking interacts with modern innovations and technologies. The students will develop a comprehensive understanding of Creative Thinking and its practical application, start to cultivate the ability to generate innovative solutions through creative practices and will analyze the broader implications of creativity in various contexts.

Content

In the business world Creative Thinking is considered to be one of the “top ten skills” or “most In-Demand skill” in 2024. With Creative Thinking innovative solutions to problems are developed and not only a large number of ideas but also a variety and range of them are brainstormed. It seems that in today's dynamic world, creativity isn't just an asset – but actually necessity. But what exactly is Creative Thinking? In the above mentioned business context it is assumed everybody knows. And what is creativity? And how can we use it. Or not.

- Originally, connected to artistic practice, creativity is nowadays a skill and practice that can be found in all work areas, especially in innovation and maybe even in technological applications themselves. Today, not only because of creative economy, creative cities or innovation, but also because of generative AI creativity has gained new and broad attention. In the seminar we go back in history to the invention of the genius and look at different social subsystems like art, psychology, economy as well as field as fashion, advertisement and arts and crafts, how our understanding of creativity has emerged till today.

900-0100-DRL Transferable Skills Course I (1-3 days)

W 1 credit 2S Lecturers

Only for doctoral students.

Abstract

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

900-0101-DRL Transferable Skills Course II (1-3 days)

W 1 credit 2S Lecturers

Only for doctoral students.

Abstract

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Course offers in humanities, political and social sciences
(Science in Perspective)

Educational Science for Teaching Diploma and TC

Language Courses ETH/UZH: see Science in Perspective

900-0114-DRL Member of Executive Board (min 1 year)

W 2 credits 4P Lecturers

Only for doctoral students.
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**
Active participation in the presidium or executive board of a university group for at least 1 year.

**Objective**
Active participation in the presidium or executive board of a university group for at least 1 year.

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<th>Number</th>
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<th>Hours</th>
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### Integration into Scientific Community

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|           | Please select your doctoral thesis supervisor as a lecturer

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 801 of 2653
and prove your participation with the appropriate certificate.

Abstract
Participation in summer or winter schools with a minimum duration of 1 week.

Objective
Participation in summer or winter schools with a minimum duration of 1 week.

900-0159-DRL
**Summer School I (1 week, with Poster or Talk)**

**Abstract**
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**Objective**
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

W 3 credits 6K
Lecturers

900-0162-DRL
**External Conference I (incl. Poster or Talk)**

**Abstract**
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

**Objective**
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

W 1 credit 2K
Lecturers

900-0163-DRL
**External Conference II (incl. Poster or Talk)**

**Abstract**
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

**Objective**
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

W 1 credit 2K
Lecturers

Doctorate Information Technology and Electrical Engineering - Key for Type

<table>
<thead>
<tr>
<th>Z</th>
<th>Courses outside the curriculum</th>
<th>W+</th>
<th>Eligible for credits and recommended</th>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
<td>W</td>
<td>Eligible for credits</td>
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<td>O</td>
<td>Compulsory</td>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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Key for Hours

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<th>lecture</th>
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<td>G</td>
<td>lecture with exercise</td>
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<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<td>R</td>
<td>revision course / private study</td>
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ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Hacking for Science is a guide to programming with data. It is tailored to the needs of a field in which scholars’ typical curricula do not foster interdisciplinary collaboration, as source code continues to become an important communication channel.

The course contains three blocks that are mostly based on the three learning objectives presented above. Hacking for Science teaches how to use git version control to collaborate professionally, make your research reproducible and your code base persistent.

- Applied data sourcing and data transformation
- Learn how to communicate with SQL databases. Learn how to consume data from different sources using machine to machine communication interfaces (APIs) such as the OpenStreetMap geocoding API / Routing Engine or the KOF data API for macroeconomic time series.

Non-Goals:
Hacking for Science is not a Statistics, Econometrics or Machine Learning course. Though experience in these fields will help inasmuch that students will have an easier time to motivate investing in programming and to come up with their own application examples, profound methodological knowledge is not a prerequisite.

Content
Hacking for Science is a guide to programming with data. It is tailored to the needs of a field in which scholars’ typical curricula do not contain a strong programming component. Yet this course argues that what the open source community calls a ‘software carpentry’ level is totally within reach for a quantitative social scientist and well worth the investment: being able to code leverages field specific expertise and fosters interdisciplinary collaboration, as source code continues to become an important communication channel.

The course contains three blocks that are mostly based on the three learning objectives presented above. Hacking for Science explicitly plans to spread its three blocks over 1-2 months to give students the ability to work on applied examples in between sessions in order to get most out of the subsequent session.

The first block demonstrates the components of a modern data science tech stack, classifies technologies and gives a big picture overview: from languages such as R and Python to container technology such as docker. The second block focuses on git version control, the de facto industry standard to manage source code. Version control is not only crucial to knowledge management and reproducible research, but it is also the backbone of collaboration in distributed teams. The third and final block focuses on data themselves and teaches how to obtain data through machine to machine communication. Furthermore, the third block discusses data management in a research project.

Lecture notes
A free and open online book (made with quarto) is available from https://rse-book.github.io/. The book/script will be continuously updated during the course to account for questions and participants’ questions.

All course materials including, slides, resources and source code will be made available through the course Website: https://rseed.ch/h4sci.html
Abstract
The purpose of this course is to review and discuss issues in current theory and research relevant to innovation in the digital space.

Objective
Through in-depth analysis of published work, doctoral candidates will identify and appraise theoretical and empirical studies, formulate research questions, and improve the positioning of their own research within the academic debate.

Content
The Internet has a twofold impact on the way individuals and firms innovate. First, firms increasingly draw on digital technology to access and capture innovation-relevant knowledge in their environment. Second, individuals, firms, and other organizations extensively utilize the Internet to create, diffuse, and commercialize new digital products and services. During the past decade, theory and research on innovation in the digital space has flourished and generated extensive insights of relevance to both academia and management practice. This has brought us better understanding of working models, and some fundamental reasons for innovation success or failure. A host of new models and research designs have been created to explore the innovation in the digital space, but these have also brought out many open research questions. We will review some of the existing streams of work, and in the process explore a new research agenda.

Format:
The course is organized in one block of 2 days. The course is a combination of pre-readings, presentations by faculty and students, and discussions. The students prepare presentations of papers in order to facilitate analysis and discussion.
Literature

Open source (OS) as innovation model

Coordination in OS communities

Governance & Leadership

Motivation to collaborate

Methods in Management Research: Methodological Fit
364-1013-06L Marketing Theory ▬ W 2 credits 1G F. von Wangenheim
Abstract
The course is taught Florian Wangenheim (ETHZ)

Objective
The purpose of the course is to confront students with current theoretical thinking in marketing, and currently used theories for understanding and explaining buyer and customer behavior in response to marketing action.

Content
In the first class, current understanding of the marketing literature and marketing thought is discussed. In the following classes, various theories are discussed, particularly in light of their importance for marketing. Economic, psychological, and sociological theory will be related to current marketing thought.

364-1013-05L Organizational Behavior

W 1 credit 1S

Abstract
Organizational behavior concerns the study of individual and group-level processes in organizations like creativity, motivation, and leadership. In this PhD course, an overview of major concepts and research insights in organizational behavior is provided. The participants are encouraged to discuss their own work situation as PhD students in relation to the OB insights covered in the course.

Objective
The objectives of the course are:
• to provide an overview of OB research
• to discuss major research streams in OB
• to enable students to reflect their own work situation based on concepts used in OB.

Competencies Subject-specific Competencies

Concepts and Theories addressed
Techniques and Technologies fostered
Method-specific Competencies

Analytical Competencies addressed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving fostered
Project Management addressed
Social Competencies

Communication fostered
Cooperation and Teamwork fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Personal Competencies

Creative Thinking addressed
Critical Thinking fostered
Self-direction and Self-management fostered

364-1020-01L Methods in Management Research: Methodological Fit

W 1 credit 1S

Abstract
This course covers available methodologies and research design in management research, measurement and validity issues, and a broad overview of the main quantitative and qualitative methods. Students will reflect on the fit between research question and research design in their own research field.
Objective
The course aims to support students in:
- knowing basic quantitative and qualitative research methods
- understanding what data each method needs and what outcomes it can provide, as well as its advantages and disadvantages
- understanding how to link a research question to an appropriate research design and method
- acquiring a basic understanding of how each method works (e.g., which software to use)
- having an idea of how to apply these methods to one's own research
- having a group of peers to share ideas and feedback with

Content
This course covers basic methodological topics relevant to research in the management field, including available methodologies (inductive, deductive) and research design (e.g., interviews, field survey, lab experiment, secondary data), the definition and measurement of constructs, validity, the choice of data collection and data analysis methods. A broad overview of the main quantitative (ANOVA, regression, path analysis, SEM, multilevel models, growth models) and qualitative methods (thematic analysis, grounded theory) currently used in management research will also be provided, together with a brief analysis of the advantages and disadvantages of each method.

Topics related to research design, including pre-registration, power analysis, and data management, as well as level of analysis and temporal issues (in particular related to data collection) can also be discussed, depending on the interest of the class. Finally, the course will cover fit between research question, research design, and methods of data analysis.

Literature
(Refer to Syllabus and Moodle)

Prerequisites / notice
Students should: (1) Be able to read and understand academic papers, including both empirical papers and method papers, to facilitate and actively participate to the class discussions; (2) Download SPSS and R + R Studio before the course to be able to conduct hands-on exercises in class; (3) complete a short survey that the instructor will share before the course, with he goal of optimising course organisation.

Competencies

Subject-specific Competencies
Concepts and Theories 
fostered
Techniques and Technologies 
fostered

Method-specific Competencies
Analytical Competencies 
fostered
Decision-making 
fostered
Project Management 
fostered

Personal Competencies
Critical Thinking 
fostered
Self-direction and Self-management 
fostered

ECTS 3 credits

364-1154-00L Technology Innovations and Sustainability Transitions

W Dr 3 credits 2S J. Markard

Abstract
Intro to sustainability transitions: fundamental socio-technical changes in sectors such as energy or transport with the intention to improve sustainability. We discuss past and contemporary transition examples (e.g. net-zero energy transition), key concepts & frameworks and challenges for research and policy making.

Objective
The course provides a better understanding of innovation, transition and sustainability challenges. After completing this course, students will:
- understand the particularities and complexities of selected empirical examples of sustainability transitions,
- become familiar with key concepts and frameworks of research in sustainability transitions and innovation studies,
- know the relevant literature on transition studies and adjacent fields (corporate sustainability, policy analysis) and
- be able to apply the new knowledge, e.g. to design a research project in the field.

Content
Societies are confronted with major sustainability challenges such as climate change, resource depletion, water pollution, or loss of biodiversity. To address these challenges, we need fundamental changes in how we produce and consume things. We need to transform incumbent organizations vs newcomers, the multi-level perspective, politics of transitions and sustainability transition policies. We will read, present and discuss peer-reviewed literature and we will develop and discuss ideas for potential research projects.

In the course, we will familiarize ourselves with key concepts and topics including ‘classic’ innovation theory, innovation systems, incumbent organizations vs newcomers, the multi-level perspective, politics of transitions and sustainability transition policies. We will read, present and discuss peer-reviewed literature and we will develop and discuss ideas for potential research projects.

Format:
The course will consist of 2*90min sessions on Monday afternoons. There is a combination of preparatory reading, presentations by faculty and students, short papers, and discussions.

Attendance is required in all sessions.

Slides reserve Mondays, 2-5pm. Some Mondays might be free, some meetings will be shorter (also depending on enrolment).


Make sure you don’t miss the first session on February 20. This is when we will discuss and allocate student assignments.

Compétences

Subject-specific Competencies
Concepts and Theories 
fostered
Techniques and Technologies 
fostered

Method-specific Competencies
Analytical Competencies 
fostered
Problem-solving 
fostered

Social Competencies
Communication 
fostered
Cooperation and Teamwork 
fostered

Personal Competencies
Adaptability and Flexibility 
fostered
Creative Thinking 
fostered
Critical Thinking 
fostered
Self-awareness and Self-reflection 
fostered
Self-direction and Self-management 
fostered

364-1025-00L Advanced Microeconomics

E Econometrics 3 credits 2G A. Bommier

Abstract
The objective of the course is to provide students with advanced knowledge in some areas of micro economic theory. The course will focus on 1) Individual behavior 2) Collective behavior 3) Choice under uncertainty 4) Intertemporal choice.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 806 of 2653
The course is framed around papers that discuss or employ calibration, likely including:

- Calibration in Macroeconomics
- Understanding cutting-edge results of current research in the fields of the CER-ETH Professors.
- Macroeconomic models allow us to perform policy counterfactuals related to inequality, monetary policy, and trade. But to believe our predictions, the models’ parameters must be reasonable. Calibration is the process of choosing parameters (usually related to technology and preferences).
- Calibration in Macroeconomics

**Objective**

The purpose of the course is to show students how calibration is and has been used in quantitative macroeconomics. The predictions and implications of macroeconomic models – the costs of trade barriers, the causes of changes in inequality, the effects of fiscal and monetary policy shocks, and the consequences of sovereign default for example – depend on the underlying parameters. Typical parameters include consumer risk aversion and patience, firm and consumer elasticities of substitution, the variance and persistence of shocks to firms and consumers, and credit constraints. To believe the welfare implications, counterfactuals, or forecasts of our models, the parameters must be set to “reasonable” values. Calibration is the process of choosing reasonable parameters using, for example, previous research, estimates from microeconomic data, or the comparison of model moments with empirical counterparts.

Calibration is an essential tool in macroeconomics. It is employed in a large fraction of the academic literature as well as in many influential policy analyses. The course is directed towards researchers interested in the frontier of macroeconomic theory, but it is also relevant for anyone working on policy-related theoretical models in public finance, trade, and international finance.

The instructor will prepare and present lecture slides, but class discussion is strongly encouraged. Students are expected to read the papers assigned for each week. Assessment is based on a final project: each student must replicate the main result of a paper from the class or another paper approved by the instructor.

**Prerequisites / notice**

- Knowledge of graduate-level economic theory.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- Method-specific Competencies
  - Analytical Competencies: fostered
  - Decision-making: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: fostered
  - Project Management: fostered

**Literature**

- The course is framed around papers that discuss or employ calibration, likely including:

**Method-specific Competencies**

- Conceptual Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- Analytical Competencies
  - Analytical Competencies: fostered
  - Decision-making: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: fostered
  - Project Management: fostered

**Prerequisites / notice**

- Bitte spezielle Ankündigungen beachten.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- Method-specific Competencies
  - Analytical Competencies: fostered

**Abstract**

- Research Seminar of Center of Economic Research CER-ETH

**Objective**

- Understanding cutting-edge results of current research in the fields of the CER-ETH Professors.

**Content**


**Literature**

- The course is framed around papers that discuss or employ calibration, likely including:

**Prerequisites / notice**

- Studierende des GESS-Pflichtwahlfachs sollten sich vor Beginn der Seminarleitung in Verbindung setzen.
Students are expected to attend the doctoral course "Macroeconomic Dynamics" before registering for this workshop.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>Analytical Competencies</th>
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<td>Subject-specific Competencies</td>
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<tr>
<td>Method-specific Competencies</td>
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### 363-1136-00L Dynamic Macroeconomics, Innovation and Growth

**Abstract**
Introducing dynamic models and workhorses in macroeconomics, understanding the role of innovation and institutions for economic development and discussing policies to foster innovation and economic growth.

**Objective**
After the course, students will be familiar with dynamic general equilibrium theory and the basic workhorse models in macroeconomics. Participants will be able to apply the frameworks to interesting issues, such as innovation and growth. Moreover, students will understand how the world has developed over the last centuries and the proximate and fundamental causes of innovation and economic growth. Students will understand and apply the basic models of economic growth and will be able to identify policies to foster innovation and growth and to reduce the large wealth differences in the world. Finally, they will get an idea how digitization and artificial intelligence might drive economic growth.

**Content**
1. Introduction
2. The Solow Model
3. The Neoclassical Growth Model (with Mathematical Background)
4. Technological Progress and how the World has developed
5. Innovations and Growth (New Growth Theory)
6. Growth Policies and Fundamental Causes for Growth
7. Digitization and Artificial Intelligence

**Literature**
14. Current Literature on Digitization and Artificial Intelligence

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### 364-1168-00L Economics of Inequality

**Abstract**
We discuss research on inequality in different areas of economics. Possible topics include distributional national accounts, heterogeneous returns, inheritances, intergenerational mobility, gender inequality in the labor market (topics will also be decided upon depending on the students’ interests). Students will present a paper and critically comment on it (as if they would referee the paper).

**Objective**
After the course, participants will have a solid understanding of the current state of research on inequality in different fields in economics and, starting from there, will be able to develop their own research ideas. They will further learn how to critically assess and referee a paper, as it is common practice during the referee process, and they will practice their presentation skills and give feedback to each other. The students will therefore also acquire competences for conferences and participation in the scientific discourse.
The target group of this course are PhD students who are interested in writing a paper related to economic inequality. Advanced Master students who are interested in taking the course, especially those who plan to pursue a PhD in Economics, are welcome, too. The topic is intentionally kept broad to leave room for individual research interests and cover different areas. This will allow students to get to know the current state of research in different but related areas, and help them develop their own research question.

By critically examining the literature, students will also learn what makes a well-written paper. By presenting papers, students will further train their presentation skills, and we will take time to give feedback in class on the presentations, too. Oral and written presentation of research are both integral parts of a successful academic career. In the written assignment, finally, students will write a referee report or a research proposal, starting from a paper we discussed in the course.

The course will start with an introduction into the topic and an overview of inequality research in economics. Inequality has become a buzzword in many paper titles and abstracts, but different areas of economics have sometimes very different approaches to this popular topic. The main part of the course will consist of reading and presenting papers that belong to different areas of economics, including Macroeconomics, Public Economics, and Microeconomics / Labour Economics.

Below you find the "suggestive" syllabus for this course. I will provide a list of papers in each of the six blocks at the beginning of the semester, and students will choose a paper to present during the semester (suggestions to present a paper that is not on the list are welcome). Students are required to read all papers discussed in the course and active participation is expected. At the end of the semester, they will write a referee report with possible suggestions for future research or develop a research proposal. The written assignment is due by January 24, 2024.

Topics (suggestive)
- Aggregate trends in income and wealth inequality
- Top income and wealth shares
- Distributional national accounts DINA
- Wealth income ratios

Measurement of top wealth and its difficulties
- Capitalization and heterogeneous returns
- Tax data and tax evasion
- Alternative data and its limitations

Inheritances
- Their role for wealth inequality
- Optimal taxation of inheritances

Intergenerational mobility
- Measurement
- Exogenous variation and causal identification

Gender Inequality in the labour market
- Gender wage gap
- Child penalties

Pandemics and their effects on inequalities
- Covid-19
- 1918 Influenza Pandemic ("Spanish Flu")
- The plague

Competencies
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<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<td>Critical Thinking</td>
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<td>Personal Competencies</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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363-1036-00L  Empirical Innovation Economics  W  3 credits  1G  M. Wörter

Abstract
The course focuses on important factors that drive the innovation performance of firms, like innovation capabilities, the use of digital technologies, environmental and innovation policy and it shows how innovation activities relate to firm performance and to the technological dynamic of industries. We also discuss the implications of the findings for effective economic policy-making.

Objective
The course provides students with the basic skills to understand and assess empirically the technological activities of firms and the technological dynamics of industries. In addition, the aim is to promote the understanding of the essential criteria for innovation policy-making.

Content
The course consists of two parts. Part I provides an introduction into important topics in the field of the economics of innovation. Part II consists of empirical exercises based on various firm-level data sets, e.g., the KOF Innovation data, data about the digitization of firms, data about environmentally friendly innovations, or patent data. In part I, we will learn about ... a) market conditions that encourage firms to invest in R&D (Research and Development) and develop new products and processes. ... b) the role of competition and market structure for the R&D activities of companies. ... c) how digital and environmentally friendly technologies diffuse among firms. ... d) how the R&D activities of firms are affected by economic crises and how firms finance their R&D activities. ... e) how we can measure the returns to R&D activities. ... f) how environmental policies and innovation policies affect the technological activities of a firm. In part II we will use the KOF Innovation Survey data, patent data, data on digitization of firms, or other longitudinal data sources, to investigate empirically the technological activities of firms in relation to the topics introduced in part I.

Lecture notes
Will be provided in the course and in the e-learning environment: https://moodle-app2.let.ethz.ch/course/view.php?id=15120

Literature
### Prerequisites / notice

Course is directed to advanced Master-Students and PhD Students with an interest in empirical studies.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories  
- Techniques and Technologies

#### Method-specific Competencies
- Analytical Competencies  
- Decision-making  
- Media and Digital Technologies  
- Problem-solving  
- Project Management

#### Social Competencies
- Communication  
- Cooperation and Teamwork  
- Customer Orientation  
- Leadership and Responsibility  
- Self-presentation and Social Influence  
- Sensitivity to Diversity  
- Negotiation

#### Personal Competencies
- Adaptability and Flexibility  
- Creative Thinking  
- Critical Thinking  
- Integrity and Work Ethics  
- Self-awareness and Self-reflection

#### Method-specific Competencies
- Decision-making  
- Media and Digital Technologies  
- Problem-solving  
- Project Management

### 364-1015-00L KOF-ETH-UZH International Economic Policy Seminar  
(University of Zurich)

- No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
- UZH Module Code: 03SMDOEC1051

#### Abstract

In this seminar series, which is held jointly with Prof. Dr. Woltek and Prof. Dr. Hoffman from the University of Zurich, distinguished international researchers present their current research related to international economic policy. The participating doctoral students are expected to attend the presentations (bi-weekly). Moreover, a critical review has to be prepared for 1 of the papers presented.

#### Objective

On the one hand, participating students are exposed to research at the frontier of international economic policy research. On the other hand, skills such as critical thinking and preparing reviews are learned.

### 364-0581-00L Microeconomics Seminar (ETH/UZH)

- No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
- UZH Module Code: 03SMDOEC6089

#### Abstract

Research Seminar  
research papers of leading researchers in Microeconomics are presented and discussed

#### Content

Invited Speakers present current research in Microeconomics

#### Competencies

#### Subject-specific Competencies
- Concepts and Theories  
- Techniques and Technologies

#### Method-specific Competencies
- Analytical Competencies

### 364-0585-01L PhD Course: Applied Econometrics

- W 2 credits  
- 2V

#### Abstract

In this course, we will address three blocs of selected problems: (i) estimation of fixed and random effects panel data models for single equations and systems of equations; (ii) estimation of models with endogenous treatment effects or sample selection; (iii) estimation of models with interdependent data (so-called spatial models).

#### Objective

The main agenda of this course is to familiarize students with the estimation of econometric problems with three alternative types of problems: (i) estimation of fixed and random effects panel data models for single equations and systems of equations; (ii) estimation of models with endogenous treatment effects or sample selection; (iii) estimation of models with interdependent data (so-called spatial models). Students will be able to program estimation routines for such problems in STATA and apply them to data-sets. They will be given a data-set and will have to work out empirical problems in the context of a term paper.

#### Lecture notes

For panel data analysis, I will rely on the book:  

For sample selection and endogenous treatment effect analysis, I will rely on the book:  

For spatial econometrics:  
I will mostly use papers.

I will prepare a script (based on slides), covering all topics.

### 364-1090-00L Research Seminar in Contract Theory, Banking and Money (University of Zurich)

- W 3 credits  
- 2S

#### Abstract

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

#### Objective

H. Gersbach, University lecturers

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Autumn Semester 2024  
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Recent developments in the fields of contract theory, finance, banking, money and macroeconomics.

The purpose of this course is to fostered

Objective

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration

Content

This course is a mixture between a seminar primarily for PhD and postdoc students and a colloquium involving invited speakers. It consists of presentations and subsequent discussions in the area of modeling complex socio-economic systems and crises. Students and other guests are welcome.

Objective

Participants should learn to get an overview of the state of the art in the field, to present it in a well understandable way to an interdisciplinary scientific audience, to develop novel mathematical models for open problems, to analyze them with computers, and to defend their results in response to critical questions. In essence, participants should improve their scientific skills and learn to work scientifically on an internationally competitive level.

Content

This course is a mixture between a seminar primarily for PhD and postdoc students and a colloquium involving invited speakers. It consists of presentations and subsequent discussions in the area of modeling complex socio-economic systems and crises. For details of the program see the webpage of the colloquium. Students and other guests are welcome.

Lecture notes

There is no script, but a short protocol of the sessions will be sent to all participants who have participated in a particular session. Transparencies of the presentations may be put on the course webpage.

Literature

Literature will be provided by the speakers in their respective presentations.

Prerequisites / notice

Participants should have relatively good mathematical skills and some experience of how scientific work is performed.

Additional Courses

Number Title Type ECTS Hours Lecturers

Doctoral Retreat - Inaugural Workshop and Seminar on Ethics and Scientific Integrity

Pre-registration upon invitation required. Once your pre-registration has been confirmed, a registration in myStudies is possible. Information on the online Ethic Moodle course will be passed on to registered doctoral candidates in due time.

Objective

The purpose of this course is to
- introduce doctoral candidates to the world of economics, management and systems research at MTEC
- make doctoral candidates aware of silo-thinking in the specific sub-disciplines and encourage them to go beyond those silos
- discuss current issues with regard to substantive, methodological and theoretical domains of research in the respective fields
- sensitise doctoral candidates to ethical issues that may occur during their doctorate.

Content

This course is geared towards first and second-year doctoral candidates of MTEC. It is held as in a workshop style. Students attending this seminar will benefit from interdisciplinary discussions and insights into current and future work in business and economics research.

Doctoral Retreat - Inaugural Workshop and Seminar on Ethics and Scientific Integrity

Pre-registration upon invitation required. Once your pre-registration has been confirmed, a registration in myStudies is possible. Information on the online Ethic Moodle course will be passed on to registered doctoral candidates in due time.

Objective

The purpose of this course is to
- introduce doctoral candidates to the world of economics, management and systems research at MTEC
- make doctoral candidates aware of silo-thinking in the specific sub-disciplines and encourage them to go beyond those silos
- discuss current issues with regard to substantive, methodological and theoretical domains of research in the respective fields
- sensitise doctoral candidates to ethical issues that may occur during their doctorate.

Content

This course is geared towards first and second-year doctoral candidates of MTEC. It is held as in a workshop style. Doctoral candidates attending this seminar will benefit from interdisciplinary discussions and insights into current and future work in business and economics research.

The second, face-to-face part of the Ethic course focuses on discipline-specific aspects and takes place on the 2nd day of the retreat. It provides an interactive learning environment. Doctoral candidates get to apply their knowledge, and they are encouraged to reflect on ethical problems and to critically discuss them with fellow doctoral colleagues.

Transferable Skills

Number Title Type ECTS Hours Lecturers

Transferable Skills Course I (1-3 days)

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Transferable Skills Course II (1-3 days)

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.
Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

900-0102-DRL Transferable Skills Course III (1-3 days) W 1 credit 2S Lecturers
Only for doctoral students.
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

900-0103-DRL Transferable Skills Course I (1-3 days, with Poster or Talk) W 2 credits 4S Lecturers
Only for doctoral students.
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

900-0104-DRL Transferable Skills Course II (1-3 days, with Poster or Talk) W 2 credits 4S Lecturers
Only for doctoral students.
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

900-0105-DRL Transferable Skills Course III (1-3 days, with Poster or Talk) W 2 credits 4S Lecturers
Only for doctoral students.
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

900-0106-DRL Transferable Skills Course I (1 week) W 2 credits 4S Lecturers
Only for doctoral students.
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

900-0107-DRL Transferable Skills Course II (1 week) W 2 credits 4S Lecturers
Only for doctoral students.
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

900-0108-DRL Transferable Skills Course III (1 week) W 2 credits 4S Lecturers
Only for doctoral students.
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

900-0109-DRL Transferable Skills Course I (1 week, with Poster or Talk) W 3 credits 6S Lecturers
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

900-0110-DRL Transferable Skills Course II (1 week, with Poster or Talk)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

900-0111-DRL Transferable Skills Course III (1 week, with Poster or Talk)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

900-0112-DRL Participation in Commission I (min 1 year)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

Objective
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

900-0113-DRL Participation in Commission II (min 1 year)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

Objective
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

900-0114-DRL Member of Executive Board (min 1 year)
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Active participation in the presidium or executive board of a university group for at least 1 year.

Objective
Active participation in the presidium or executive board of a university group for at least 1 year.

Integration into Scientific Community

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<th>Number</th>
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<td>Participation in summer or winter schools with a maximum duration of 3 days.</td>
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<td>Objective</td>
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</table>
Abstract
Participation in summer or winter schools with a maximum duration of 3 days.

Objective
Participation in summer or winter schools with a maximum duration of 3 days.

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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Duration</th>
<th>Credits</th>
<th>Lecturers</th>
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<tr>
<td>900-0153-DRL</td>
<td>Summer School I (1-3 days, with Poster or Talk)</td>
<td>W</td>
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<td>Only for doctoral students.</td>
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<tr>
<td>900-0154-DRL</td>
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<td>Summer School III (1 week)</td>
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<td>900-0159-DRL</td>
<td>Summer School I (1 week, with Poster or Talk)</td>
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Summer School III (1 week, with Poster or Talk)

Only for doctoral students.

Abstract
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

External Conference I (incl. Poster or Talk)

Only for doctoral students.

Abstract
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

Objective
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

External Conference II (incl. Poster or Talk)

Only for doctoral students.

Abstract
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

Objective
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External Conference III (incl. Poster or Talk)

Only for doctoral students.

Abstract
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Objective
Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

Doctorate Management, Technology, and Economics - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<tr>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
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Key for Hours

<table>
<thead>
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<tr>
<td>V</td>
<td>Lecture</td>
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<td>G</td>
<td>Lecture with exercise</td>
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<td>U</td>
<td>Exercise</td>
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<td>S</td>
<td>Seminar</td>
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<td>K</td>
<td>Colloquium</td>
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<td>P</td>
<td>Practical/laboratory course</td>
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<td>A</td>
<td>Independent project</td>
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<td>D</td>
<td>Diploma thesis</td>
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<tr>
<td>R</td>
<td>Revision course / private study</td>
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ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Doctorate Mechanical and Process Engineering


Subject Specialisation

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>151-0111-00L</td>
<td>Research Seminar in Fluid Dynamics *</td>
<td>E-</td>
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<td>2S</td>
<td>F. Coletti, P. Jenny, O. Supponen</td>
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<tr>
<td></td>
<td>Internal research seminar for graduate students and scientific staffs of the IFD</td>
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<td>Objective</td>
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<td></td>
<td>Current research projects at the Institute of Fluid Dynamics are presented and discussed.</td>
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<td></td>
<td>Exchange on current internal research projects. Training of presentation skills.</td>
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<td>151-0123-00L</td>
<td>Experimental Methods for Engineers</td>
<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>D. J. Norris, F. Coletti, M. Lukatskaya, A. Manera, O. Supponen, M. Tübbi</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>The course presents an overview of measurement tasks in engineering environments. Different concepts for the acquisition and processing of typical measurement quantities are introduced. Following an initial in-class introduction, laboratory exercises from different application areas (especially in thermofluidics, energy, and process engineering) are attended by students in small groups.</td>
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<td></td>
<td>Introduction to various aspects of measurement techniques, with particular emphasis on thermo-fluidic, energy, and process-engineering applications.</td>
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<td>Understanding of various sensing technologies and analysis procedures.</td>
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<td>Exposure to typical experiments, diagnostics hardware, data acquisition, and processing.</td>
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<td>Content</td>
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<td></td>
<td>In-class introduction to representative measurement techniques in the research areas of the participating institutes (fluid dynamics, energy technology, and process engineering).</td>
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<td>Student participation in ~6 laboratory experiments (study groups of ~3 students, dependent on the number of course participants and available experiments).</td>
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<td></td>
<td>Lecture notes</td>
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<td>Presentations, handouts, and instructions are provided for each experiment.</td>
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<td>Prerequisites / notice</td>
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<td>Basic understanding in the following areas:</td>
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<td>- fluid mechanics, thermodynamics, heat and mass transfer</td>
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<td>- electrical engineering / electronics</td>
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<td>- numerical data analysis and processing (e.g. using MATLAB)</td>
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<td>Subject-specific Competencies</td>
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<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Cooperation and Teamwork</td>
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<td>Self-direction and Self-management</td>
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<td>151-0225-00L</td>
<td>Material Characterization by X-ray Techniques:</td>
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<td>4</td>
<td>3G</td>
<td>P. M. Abdala, D. Piankova</td>
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<td></td>
<td>Diffraction, Absorption, Total Scattering</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>The course introduces the basics of X-ray powder diffraction, pair distribution function (PDF) of X-ray total scattering and X-ray absorption spectroscopy analyses to determine the structure of inorganic functional materials.</td>
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<td>Introduction basics of the structural characterization of materials using X-rays: covering the local and average structures. specifically: X-ray , -powder diffraction -total scattering and -absorption spectroscopy.</td>
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<td>Content</td>
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<td>The course outlines experimental techniques based on X-rays to investigate the atomic structure of materials covering the local- mid- and long-range order. It covers:</td>
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<td>1- Review of fundamentals of materials science and the structure of solids.</td>
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<td>2- Overview of the different characterization methods to investigate the structure of functional materials, spanning the local to long-range order structure.</td>
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<td>3- X-ray powder diffraction.</td>
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<td>4- X-ray total scattering and pair distribution function analysis.</td>
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<td>5- X-ray absorption spectroscopy.</td>
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<td>6- Practical sessions on X-ray powder diffraction and PDF experiments.</td>
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<td>Literature will be given during the course.</td>
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<td>151-0529-00L</td>
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<td>Note: The previous course title until HS23 &quot;Computational Mechanics II: Nonlinear FEA&quot;</td>
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<td>Abstract</td>
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<td>The course provides an introduction to non-linear finite element analysis. The treated sources of non-linearity are related to material properties (hyperelasticity, plasticity), kinematics (large deformations, instability problems) and boundary conditions (contact).</td>
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<td>Objective</td>
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<td>To be able to address all major sources of non-linearity in theory and numerics, and to apply this knowledge to the solution of relevant problems in solid mechanics.</td>
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## 151-0563-01L Dynamic Programming and Optimal Control

**Abstract**
Introduction to Dynamic Programming and Optimal Control.

**Objective**
Covers the fundamental concepts of Dynamic Programming & Optimal Control.

**Content**
Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

**Literature**

**Prerequisites / notice**
Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

## 151-0593-00L Embedded Control Systems

**Abstract**
This course provides a comprehensive overview of embedded control systems. The concepts introduced are implemented and verified on a microprocessor-controlled haptic device.

**Objective**
Familiarize students with main architectural principles and concepts of embedded control systems.

**Content**
An embedded system is a microprocessor used as a component in another piece of technology, such as cell phones or automobiles. In this intensive two-week block course the students are presented the principles of embedded digital control systems using a haptic device as an example for a mechatronic system. A haptic interface allows for a human to interact with a computer through the sense of touch.

**Lecture notes / notice**
Lecture notes will be provided. However, students are encouraged to take their own notes.

## 151-0623-00L ETH Zurich Distinguished Seminar in Robotics, Systems and Controls

**Abstract**
This course consists of a series of seven lectures given by researchers who have distinguished themselves in the area of Robotics, Systems, and Controls.

**Objective**
Obtain an overview of various topics in Robotics, Systems, and Controls from leaders in the field. Please see http://www.msrl.ethz.ch/education/distinguished-seminar-in-robotics--systems--controls--151-0623-0.html for a list of upcoming lectures.

**Content**
Familiarize students with main architectural principles and concepts of embedded control systems.

**Prerequisites / notice**
Prerequisite courses are Control Systems I and Informatics I.

## 151-1053-00L Thermo- and Fluid Dynamics

**Abstract**
Current advanced research activities in the areas of thermo- and fluid dynamics are presented and discussed, mostly by external speakers.

**Objective**
Knowledge of advanced research in the areas of thermo- and fluid dynamics.

## 151-8101-00L International Engineering: from Hubris to Hope

**Abstract**
Since Europe surrendered their colonial assets, engineers from rich countries have returned to the African continent to address the real and perceived ills that they felt technology could solve. And yet, 70 years on, the promise of technology has largely failed to deliver widespread, substantive improvements in the quality of life. Why?

**Objective**
This course is restricted to 33 students due to limited lab infrastructure. Interested students please contact Marianne Schmid Daners (E-Mail: marischm@ethz.ch) After your reservation has been confirmed please register online at www.mystudies.ethz.ch.

Detailed information can be found on the course website http://www.idsc.ethz.ch/education/lectures/embedded-control-systems.html

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After completing the course, participants will be able to:

- critique the jargon and terms used by the international community, i.e. "development", "aid", "cooperation", "assistance" “third world”
- developing “global south” “low and middle-income” and justify their own chosen terminology
- recognize the role of racism and white-supremacy in the development of the Aid industry
- understand the political, financial, and cultural reasons why technology and infrastructure have historically failed
- Debate the merits of international engineering in popular culture and media
- Propose improved SDG indicators that address current shortcomings
- Compare the engineering curricula of different countries to identify relative strengths and shortcomings
- Explain the inherent biases of academic publishing and its impact on engineering failure
- Analyze linkages between the rise of philanthropy and strategic priority areas
- Recommend equitable, just funding models to achieve more sustainable outcomes
- Formulate a vision for the international engineer of the future
Content
Role of international engineering during colonialism
Transition of international engineering following colonialism
White saviourism and racism in international engineering
International engineering in popular culture
The missing role of Engineering Education
Biases in academic publishing
The emerging role in Global Philanthropy
The paradox of International funding

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151-9901-00L  Scientific Writing for Publication in Engineering  

W 2 credits 1G

Number of participants limited to: 15

For the participation in the course, payment of a course fee is required. To register for the course, you need to obtain from your supervisor the confirmation that s/he is willing to pay for your course fee.

Abstract
Scientific Writing for Publication in Engineering is a short course (7 half-day workshops) designed to help junior researchers develop the skills needed to write their research articles in English.

Objective
The course deals with topics such as:
- Fitting texts to target readerships and journals
- Managing the writing process efficiently
- Structuring each section of the text effectively
- Producing fluent and reader-focused sentences and paragraphs
- Editing the text before submission
- Revising in response to reviewers’ comments.

Content
Participants produce a number of short texts as homework assignments and receive detailed individual feedback as well as peer feedback on these during the course. The course takes place at times and locations chosen to suit MAVT doctoral researchers. Content and materials deal specifically with the demands of writing in engineering research fields. Wherever feasible, elements of participants’ future research articles are developed as assignments within the course, so it is particularly useful for those who have their data and are about to begin the writing process.

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151-9905-00L  Applied Category Theory for Engineering I  

W 4 credits 3G  A. Censi, J. Lorand

Abstract
Applied Category Theory is an exciting multidisciplinary field of research which harnesses the mathematical language of category theory for applications across a broad range of disciplines. This course is a gentle introduction focused on applications in engineering and the “compositional approach” to systems analysis, co-design, and computation.

Objective
1) Learn basic concepts from algebra and category theory, together with ways to make use of these concepts for engineering applications.

2) Become familiar with case studies of applied category theory, for instance involving dynamical systems, databases, and complex system co-design (e.g. in the context of autonomous vehicles).

3) Be able to recognize compositional structures in concrete scenarios at different levels of abstraction.

4) Understand the “compositional way of thinking” as an approach to systems analysis, co-design, and computation.
Content
Review of basic algebraic structures [sets, relations, (semi)groups, monoids, actions, order theory]

Gentle introduction to category theory [series and parallel composition, feedback, actions, functors, universal properties]

Many simple applied examples illustrating concepts along the way. Extended examples from dynamical systems, databases, and systems co-design in engineering.

Homework will consist of 1) basic exercises to check one’s understanding of core concepts, and 2) a choice between either A) coding exercises (in python) to learn how to implement concepts in software or B) further theory exercises to deepen mathematical understanding.

Homework will be graded on a schedule that allows some flexibility, and it will constitute 100% of the grade (no exam).

Lecture notes
Slides and a (work-in-progress) textbook for the course will be provided (A. Censi, J. Lorand, G. Zardini, “Applied Compositional Thinking for Engineers”).

Literature

Supplementary references include the following books:
Fong, Spivak, “An invitation to applied category theory: Seven sketches in compositionality”
Spivak, “Category theory for the sciences”

Prerequisites / notice
A knowledge of algebra at the level of a bachelor’s degree in engineering/computer science.

Competencies
Subject-specific Competencies
Concepts and Theories
Method-specific Competencies
Analytical Competencies

Social Competencies
Communication
Personal Competencies
Creative Thinking

Personal Competencies
Critical Thinking

Analytical Competencies
Problem-solving

Personal Competencies
Integrity and Work Ethics

Self-direction and Self-management

351-0778-00L Discovering Management

W 3 credits 3G B. Clarysse, S. Brusoni, V. Hoffmann, T. Netland

Abstract
Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

Objective
The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
(1) broaden understanding of management principles and frameworks
(2) advance insights into the sources of corporate and entrepreneurial success
(3) develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

Content
The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. The theory sessions will be assessed via a multiple choice exam.

Lecture notes
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

Competencies
Subject-specific Competencies
Concepts and Theories
Method-specific Competencies
Analytical Competencies

Social Competencies
Communication
Person Competencies
Self-presentation and Social Influence

Self-direction and Self-management

351-0511-00L Managerial Economics

W 4 credits 3V O. Krebs, P. Egger, M. Köthenbürger

Abstract
"Managerial Economics" provides an introduction to the theories and methods from Economics and Management Science to analyze economic decision-making in the context of markets. The course targets students with no prior knowledge in Economics and Management.
The objective of this course is to provide an introduction to microeconomic thinking. Based on the fundamental principles of economic analysis (optimization and equilibrium), the focus lies on understanding key economic concepts relevant for understanding and analyzing economic behavior of firms and consumers in the context of markets. Market demand and supply are derived from the individual decision-making of economic agents and market outcomes under different assumptions about the market structure and market power (perfect competition, monopoly, oligopoly, game theory) are studied. This introductory course aims at providing essential knowledge from the fields of Economics and Management relevant for economic decision-making in the context of both the private and public sector.

Prerequisites / notice

The course targets both Bachelor and Master students. No prior knowledge in the areas of Economics and Management is required.

Competencies

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<td>Method-specific Competencies</td>
<td>飞速发展与技术创新管理, P. Bachmann</td>
<td>Decision-making</td>
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<td>Technology and Innovation Management</td>
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<tr>
<td>Abstract</td>
<td>This course focuses on the sources of innovation (with a specific focus on digital technologies), the tools and techniques that organizations deploy to innovate routinely, and the strategic implications of technical change at different levels of analysis: individuals, firms and whole ecosystems.</td>
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<tr>
<td>Objective</td>
<td>This course intends to enable all students to:</td>
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<td>- Acquire and understand the basic jargon, concepts and methods necessary to discuss, in a precise and concise manner, innovation processes and their outcomes at different levels of analysis.</td>
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<td>- Evaluate critically the potential of different (digital) technologies to impact business organizations.</td>
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<td>Content</td>
<td>Organizations and people are faced with a fundamental decision: they have to allocate resources between well-known tasks that reliably generate positive results; or explore new ways of doing things, new technologies, products and services. The latter is a high risk choice. Its rewards can be high, but the chances of success are small. How do firms organize to take these decisions? What kind of management skills are necessary to take them? What kind of tools and methods are deployed to sustain managerial decision-making in highly volatile environments? These are the central questions on which this course focuses, relying on a combination of lectures, case-based discussion, and guest speakers.</td>
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<tr>
<td>Literature</td>
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Introduction to Marketing

363-0403-00L Introduction to Marketing W 3 credits 2G F. von Wangenheim, P. Bachmann

Abstract

This course provides an overview on essential perspectives of marketing and how marketing adds value to a business. It will teach concepts, frameworks and methods for marketing decision making. The course will also look at issues related to marketing implementation. Thereby, a particular focus will be on how data and data analytics can help to support marketers in their decision making.

Objective

After taking the class, students will be able to

1) Understand how marketing adds value to a business.
2) Provide an overview of key concepts in marketing that are applicable to any business.
3) Understand how consumers behave and how this impacts marketing
4) Learn how analytics and quantitative methods can help to improve decision making in marketing.
5) Get to know the elements that shape a firm’s marketing strategy (segmentation, targeting, positioning) and marketing tactics (product, price, promotion, place).

Content

The class will center on the importance of marketing as an activity that creates long-term value for the benefit of organizations and their customers. It will teach concepts, frameworks and methods for marketing decision making.

Specifically, the course is aimed to provide students with a) an overview on the role of marketing within a business, b) details on strategic marketing management decisions and tools, c) a profound knowledge on the individual elements of the marketing mix (product, price, promotion, place), d) an awareness of specific contexts of marketing, and e) first-hand experience on data-driven techniques to support marketers’ decision making.

Thus, this course will introduce key analytical tools to help solving respective managerial tasks. This is a lecture with integrated exercises. Access to a laptop is required for the exercises. The class might be thought in an in-person, remote or in a hybrid format. Students might also be taught via pre-recorded videos and assigned material for self-study.

Literature


The course might comprise mandatory and supplemental reading material. Other literature may be assigned in class.
This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to everyday economic problems. After attending the class, you should be able to:

- understand the accounting system, the reporting process, and be able to prepare financial statements
- feel comfortable reading and using the information presented in companies’ annual reports
- understand cost concepts and conduct cost analyses
- become familiar with several classic decisions using managerial accounting information
- comment on the current events related to these topics.

The set-up of the course will closely follow the book of N. Gregory Mankiw and Mark P. Taylor (2023), Economics, Cengage Learning, 6th Edition. This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filippini).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions. The set-up of the course will closely follow the book of N. Gregory Mankiw and Mark P. Taylor (2023), Economics, Cengage Learning, 6th Edition. This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filippini).

This course is a prerequisite for the course Financial Management.

The course Accounting for Managers offers an introduction to financial and managerial accounting, especially for students who aspire for a career in business and management with a science or engineering background. After attending the class, you should be able to:

- feel comfortable reading and using the information presented in companies’ annual reports
- understand cost concepts and conduct cost analyses
- become familiar with several classic decisions using managerial accounting information
- comment on the current events related to these topics.

Accounting plays a critical role in the effective functioning of the financial market as well as the long-term success of a company. This course intends to provide an introduction to accounting for those who wish to pursue a career in business, and need the skills and knowledge to understand, analyze, and interpret accounting information to make informed decisions. The course is divided into two parts. In the first part, we focus on financial reporting and start with the basic accounting concepts and the accounting cycle, to learn how the financial system is set up in a company and how financial statements are prepared. We then delve deeper into each major account, and discuss how revenues and expenses are recognized, and how assets, liabilities, and equities are reported. In the second part, we focus on managerial accounting for internal managerial/operational decisions including fundamental topics such as cost behavior, cost estimation, CVP analyses, and relevant costing. We then cover budgeting and standard costing, which are important parts of accounting system in companies.

This course is a prerequisite for the course Financial Management.
### Technology Entrepreneurship (363-0790-00L)

**Abstract**
Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding.

**Objective**
This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures. A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases.

**Content**
Weekly sessions - recorded.

10+ sessions carried out by guest lecturers: experts in the broad field of technology entrepreneurship (e.g., serial entrepreneurs, venture capitalists, (E)MBA professors, company builders, patent experts, scale-up executives, …). Final session: multiple choice semester assignment (100% of grade).

Typical lecture format (2h):
- 15': Introduction
- 60': Guest testimonial
- 15': Discussion related to topic (in groups)
- 10': Plenary discussion
- 20': Q&A with (guest) lecturer

**Lecture notes**
Lecture slides and case material

**Competencies**

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<td>Critical Thinking</td>
<td>Assessed</td>
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</table>

### Monetary Policy (363-1021-00L)

**Abstract**
The main aim of this course is to analyse the goals of monetary policy and to review the instruments available to central banks in order to pursue these goals. It will focus on the transmission mechanisms of monetary policy and the differences between monetary policy rules and discretionary policy. It will also make connections between theoretical economic concepts and current real world issues.

**Objective**
This lecture will introduce the fundamentals of monetary economics and explain the working and impact of monetary policy. The main aim of this course is to describe and analyze the goals of monetary policy and to review the instruments available to central banks in order to pursue these goals. It will focus on the transmission mechanisms of monetary policy, the effectiveness of monetary policy actions, the differences between monetary policy rules and discretionary policy, as well as in institutional issues concerning central banks, transparency of monetary authorities and monetary policy in a monetary union framework. Moreover, we discuss the implementation of monetary policy in practice and the design of optimal policy.

**Content**
For the functioning of today’s economy, central banks and their policies play an important role. Monetary policy is the policy adopted by the monetary authority of a country, the central bank. The central bank controls either the interest rate payable on very short-term borrowing or the money supply, often targeting inflation or the interest rate to ensure price stability and general trust in the currency. This monetary policy course looks into today’s major questions related to policies of central banks. It provides insights into the monetary policy process using core economic principles and real-world examples.

**Lecture notes**
The course Moodle page contains announcements, course information and lecture slides.

**Literature**
The course will be based on chapters of:

**Prerequisites / notice**
Basic knowledge in international economics and a good background in macroeconomics.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Taught</th>
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<tbody>
<tr>
<td>Decision-making</td>
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<tr>
<td>Media and Digital Technologies</td>
<td>Fostered</td>
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<tr>
<td>Problem-solving</td>
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<tr>
<td>Communication</td>
<td>Fostered</td>
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<tr>
<td>Cooperation and Teamwork</td>
<td>Fostered</td>
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<tr>
<td>Sensitivity to Diversity</td>
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</tr>
<tr>
<td>Critical Thinking</td>
<td>Assessed</td>
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</tbody>
</table>

### Applied Analysis of Variance and Experimental Design (401-0625-01L)

**Abstract**
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

**Objective**
Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.
Content
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Literature

Prerequisites / notice
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making

Personal Competencies
- Critical Thinking

Literature

Prerequisites / notice
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making

Personal Competencies
- Critical Thinking

Abstract
Knowledge in the field of intellectual property, especially of patents and trademarks, with particular emphasis on pharmaceutics.

Introduction into intellectual property; prosecution of patent applications; patent information; exploitation and enforcement of patents; peculiarities in pharmaceutics and medicine; social, political and ethical aspects; Trademarks.

Objective
Basic knowledge in the field of industrial property, especially of patents and trademarks, with particular emphasis on the chemical, pharmaceutical and biotech field.

Content
1. Introduction into industrial property (patents, trademarks, industrial designs);
2. Prosecution of patent applications (patentability);
3. Patent information (patent publications, databases, searches);
4. Exploitation and enforcement of patents (possibilities of exploitation, licenses, parallel imports, scope of protection, patent infringement);
5. Peculiarities in pharmaceutics and medicine (supplementary protection certificates, experimental use exemption, therapy and diagnosis, medical indication);
6. Social, political and ethical aspects (patents and prices for medicinal products, traditional knowledge and ethnomedicine, bioprospecting and biopiracy, human DNA inventions);
7. Trademarks, types of trademarks, grounds for refusal, peculiarities of pharma-trademarks.

Lecture notes
A script is provided in electronic form during the lecture.

Literature

Prerequisites / notice
None

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Transferable Skills
Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
327-2226-00L | Ethics and Scientific Integrity for Doctoral Students (MaP Doctoral School) | W | 1 credit | 2U | M. Trassin, K. M. Berg, A. Lauria, S. Stepanow

Abstract
This course sensitises doctoral students to ethical issues that may occur during their doctorate. After an introduction to ethics and good scientific practice, students are familiarised with resources that can assist them with ethical decision-making. Students get the chance to apply their knowledge in a discipline specific context.

Objective
Doctoral students learn how to identify, analyse and address ethical issues in their own scientific research. In addition, they will reflect on their professional role as scientific researchers.
Content
Part I
The self-paced e-learning course consists of 5 modules:
(1) Ethics: Introduction to moral theory (with emphasis on practical guidance regarding decision making)
(2) Ethics in Scientific Research: Introduction to ethical issues that occur within scientific research (i.e. regarding authorship, cooperation, data use and sharing, and other aspects that are subject to scientific integrity and good scientific practice).
(3) Collecting Resources: A variety of tools and resources that help identify ethical issues are presented and explained
(4) Setting up a Strategy: Example examination of a case regarding its ethical scope (students develop their own strategy to examine situations for their ethical implications).
(5) Making Decisions: Different ways of addressing ethical issues are presented and explained (i.e. how to make hard choices, or solve ethical dilemmas. But also where to seek advice if needed).

Part II
The second, face-to-face part of this course focuses on discipline-specific aspects of Materials, Processes and Manufacturing Technologies. It provides an interactive learning environment. Participants get to apply their knowledge, and they are encouraged to reflect on ethical problems and critically discuss them with fellow doctoral students.

Prerequisites / notice
For doctoral students only

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credit</th>
<th>Minimum</th>
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Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

900-0106-DRL  Transferable Skills Course I (1 week)
Only for doctoral students.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

900-0107-DRL  Transferable Skills Course II (1 week)
Only for doctoral students.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

900-0108-DRL  Transferable Skills Course III (1 week)
Only for doctoral students.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

900-0109-DRL  Transferable Skills Course I (1 week, with Poster or Talk)
Only for doctoral students.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

900-0110-DRL  Transferable Skills Course II (1 week, with Poster or Talk)
Only for doctoral students.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

900-0111-DRL  Transferable Skills Course III (1 week, with Poster or Talk)
Only for doctoral students.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

900-0112-DRL  Participation in Commission I (min 1 year)
Only for doctoral students.

Objective
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

900-0113-DRL  Participation in Commission II (min 1 year)
Only for doctoral students.

Objective
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

### Objective
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

#### 900-0114-DRL

**Member of Executive Board (min 1 year)**

*Only for doctoral students.*

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**
Active participation in the presidium or executive board of a university group for at least 1 year.

**Objective**
Active participation in the presidium or executive board of a university group for at least 1 year.

### Integration into Scientific Community

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<td>Summer School I (1-3 days)</td>
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<td>Lecturers</td>
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</table>

*Only for doctoral students.*

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**
Participation in summer or winter schools with a maximum duration of 3 days.

**Objective**
Participation in summer or winter schools with a maximum duration of 3 days.

| 900-0151-DRL | Summer School II (1-3 days)                        | W    | 1 credit | 2K    | Lecturers |

*Only for doctoral students.*

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**
Participation in summer or winter schools with a maximum duration of 3 days.

**Objective**
Participation in summer or winter schools with a maximum duration of 3 days.

| 900-0152-DRL | Summer School III (1-3 days)                        | W    | 1 credit | 2K    | Lecturers |

*Only for doctoral students.*

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**
Participation in summer or winter schools with a maximum duration of 3 days.

**Objective**
Participation in summer or winter schools with a maximum duration of 3 days.

| 900-0153-DRL | Summer School I (1-3 days, with Poster or Talk)     | W    | 2 credits | 4K    | Lecturers |

*Only for doctoral students.*

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

**Objective**
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

| 900-0154-DRL | Summer School II (1-3 days, with Poster or Talk)     | W    | 2 credits | 4K    | Lecturers |

*Only for doctoral students.*

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

**Objective**
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

| 900-0155-DRL | Summer School III (1-3 days, with Poster or Talk)     | W    | 2 credits | 4K    | Lecturers |

*Only for doctoral students.*

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

**Objective**
Participation in summer or winter schools with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

| 900-0156-DRL | Summer School I (1 week)                           | W    | 2 credits | 4K    | Lecturers |

*Only for doctoral students.*

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**
Participation in summer or winter schools with a minimum duration of 1 week.

**Objective**
Participation in summer or winter schools with a minimum duration of 1 week.

| 900-0157-DRL | Summer School II (1 week)                           | W    | 2 credits | 4K    | Lecturers |

*Only for doctoral students.*

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Abstract**
Participation in summer or winter schools with a minimum duration of 1 week.

**Objective**
Participation in summer or winter schools with a minimum duration of 1 week.
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

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<th>3 credits</th>
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<th>2K</th>
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<td>Abstract</td>
<td>Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.</td>
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Doctorate Mechanical and Process Engineering - Key for Type

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<th>W+</th>
<th>Eligible for credits and recommended</th>
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<tbody>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<table>
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<td>Compulsory</td>
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Key for Hours

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<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</tbody>
</table>

| P  | practical/laboratory course         |
| A  | independent project                 |
| D  | diploma thesis                      |
| R  | revision course / private study      |

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Problem-solving assessed Seminar for PhD students and researchers in condensed-matter physics.

This short course is designed to help junior researchers in Materials Science develop the skills needed to write their first research articles.

E-Materials Colloquium

The Materials Colloquium is a platform for PhD students, postdoctoral researchers, group leaders, senior scientists, and professors to present their own and their group's research to their colleagues. The apero following the colloquium has the purpose to stimulate discussions and to promote networking in a relaxed, more informal environment. The Colloquium is open to all who are interested.

Subject-specific Competencies

Writing for Publication in Materials Science is a short course (5 x 4-lesson workshops) designed to help junior researchers develop the skills needed to write their first research articles. The course deals with topics such as:

- identifying target readerships and selecting outlets,
- managing the writing process efficiently,
- structuring the text effectively,
- producing logical flow in sentences and paragraphs,
- editing the text before submission, and
- revising the text in response to reviewers' comments.

Participants are advised to take this course once they have enough research to begin writing so as to be able to get feedback on work in progress. They will be expected to produce a number of short texts as homework assignments and will receive individual feedback from the instructor and peer feedback on these during the course. Wherever feasible, elements of participants' future research articles can be developed for these assignments, so it is likely to be particularly useful for those who have their data and are about to begin the writing process.

Content

Part 1: Part 1 will provide an introduction to the course, and will then focus on using model texts, improving vocabulary and phrasing, and constructing reader-friendly sentences.

Part 2: We will discuss structural decisions about research articles in different journals, review the basics of paragraph structure and organization, and examine how to create better flow in a text.

Part 3: We will work on creating successful introductions, integrating the literature, and writing abstracts.

Part 4: Part 4 will address the main content and grammar concerns of writing about methods and results, and review key grammar concepts for writing complex sentences.

Part 5: We will look at how to construct discussion and conclusion sections and how to strike the right tone of caution/confidence. We will then discuss the editing process, preparing articles for submission, and responding to reviewers' comments.

Prerequisites / notice

All sessions will involve group work and peer review of participants' writing.

This short course is designed to help junior researchers in Materials Science develop the skills needed to write their first research articles.

Microscopy Training SEM I - Introduction to SEM

The number of participants is limited. In case of overbooking, the course will be repeated once. All registrations will be recorded on the waiting list.

For PhD students, postdocs and others, a fee will be charged (https://scopem.ethz.ch/education/MTP.html).

All applicants must additionally register on this form:
This introductory course on Scanning Electron Microscopy (SEM) emphasizes hands-on learning. Using ScopeM SEMs, students have the opportunity to study their own samples (or samples provided) and solve practical problems by applying knowledge acquired during the lectures. At the end of the course, students will be able to apply SEM for their (future) research projects.

Objective
- Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize microscope performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.

Content
During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications. This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

Practicals:
- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast (and image processing)
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Practice on real-world samples and report results

Literature
- P. Zeng, E. J. Barthazy Meier, 3P

No mandatory prerequisites.
Advanced Polymer Synthesis

Modern polymer synthesis (based on recent development of new organic reactions) is discussed to enable students to develop synthesis schemes for certain target structures. Both chain (ionic, coordination; ROMP, radical, catalyst-transfer) and step-growth polymerizations (transition metal catalysis) including how to achieve living polymerization or improve selectivity will be discussed.

Objective

Students should be able to: Identify important polymerization procedures and types of polymerization. Predict activities of monomers based on the chemical structures. Devise synthetic pathways to produce a given polymer structure. Evaluate properties of macromolecules based on structure and synthesis method. Develop synthesis schemes for target structures and discuss potential applications of polymers.

Content

Polymerization is a series of continuous organic transformation and connects small molecules. The course will give an overview of the following important polymerization procedures:

- Modern Step-growth polymerization
- Living Anionic polymerization
- Group transfer polymerization (GTP)
- Controlled cationic polymerization
- Controlled radical polymerization
- Coordination polymerization: Ziegler-Natta and Metallocene catalysts
- Olefin metathesis polymerization: ROMP, ADMET and cyclopolymerization
- Synthesis of conjugated polymers based on transition metal catalysis
- Complex macromolecules including brush and dendronized polymers

Students will learn how to deal with chemical structures and reactivities, and be able to suggest reasonable synthetic pathways to a given polymer structure, like conjugated polymers based on transition metal catalysis or complex macromolecules including brush and dendronized polymers. Aspects like controlling molar masses and structure perfection play a role throughout. The course provides the students with a high-level overview of modern methods of polymer synthesis both in theoretical and practical aspects. It should enable them to develop reasonable synthesis schemes for certain target structures and also to predict the properties of given macromolecules. For all polymers presented, potential or real applications will be discussed.

Lecture notes

They will be uploaded on Moodle

Literature

Lecture notes will be given

Prerequisites / notice

Strong basic knowledge of Organic Chemistry. Any course on Introductory Polymer Chemistry such as "Advanced Building Blocks for Soft Materials" or "Introduction to Macromolecular Chemistry" or equivalent (bachelor level is also sufficient). Please discuss with the lecturer if one is not certain about the prerequisites.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making

Social Competencies

- Communication
- Customer Orientation

Personal Competencies

- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

FIRST Introduction Day

The FIRST Introduction Day comprises general and access information, cleanroom basics, infrastructure information, safety training, cleanliness seminar, chemistry seminar and safety test. The introduction day is mandatory for each user who intends to use the FIRST cleanrooms independently of level of experience.

Objective

Access to the FIRST cleanroom.

Content

The FIRST Introduction Day comprises general and access information, cleanroom basics, infrastructure information, safety training, cleanliness seminar, chemistry seminar and safety test. The introduction day is mandatory for each user who intends to use the FIRST cleanrooms independently of level of experience.

Lecture notes

https://moodle-app2.let.ethz.ch/user/index.php?id=12731

Advanced Manufacturing (MaP Doctoral School)
Objective

This course aims to provide a graduate-level introduction to machine learning, with a particular focus on scientific machine learning for applications in the design and construction phases of projects from architecture and civil engineering.

Upon completion of the course, the students will be able to:
1. Understand main ML background theory and methods.
2. Asses a problem and apply ML and DL in a computational framework accordingly.
3. Incorporate scientific domain knowledge in the SciML process.
4. Define, plan, conduct and present a SciML project.

Content

The course will include theory and algorithms for SciML, programming assignments, as well as a final project assessment.

The topics to be covered are:
2. Incorporation of Domain Knowledge into ML and DL.
4. ML training, validation and testing pipelines for academic and research projects.

Lecture notes

The course script is composed by lecture slides, which are available online and will be continuously updated throughout the duration of the course.

Literature

Suggested Reading:
Marc Peter Deisenroth, A Aldo Faisal, and Cheng Soon Ong Mathematics for Machine Learning
S. Guido, A. Müller: Introduction to machine learning with python. O'Reilly Media, 2016
O. Martin: Bayesian analysis with python. Pacont Publishing Ltd, 2016

Prerequisites / notice

Familiarity with Python is advised.

Competencies

Subject-specific Competencies
Concepts and Theories: assessed
Techniques and Technologies: assessed

Method-specific Competencies
Analytical Competencies: fostered
Decision-making: fostered
Media and Digital Technologies: fostered
Problem-solving: assessed
Project Management: assessed

Social Competencies
Communication: fostered
Cooperation and Teamwork: fostered

Personal Competencies
Creative Thinking: fostered
Critical Thinking: fostered
Self-direction and Self-management: fostered

101-0167-01L Fibre Composite Materials in Structural Engineering W 3 credits 2G M. Motavalli

Abstract

1) Lamina and Laminate Theory
2) FRP Manufacturing and Testing Methods
3) Design and Application of Externally Bonded Reinforcement to Concrete, Timber, and metallic Structures
4) FRP Reinforced Concrete, All FRP Structures
5) Measurement Techniques and Structural Health Monitoring

Objective

At the end of the course, you shall be able to:
1) Design advanced FRP composites for your structures,
2) To consult owners and clients with necessar testing and SHM techniques for FRP structures,
3) Continue your education as a phd student in this field.

Content

Fibre Reinforced Polymer (FRP) composites are increasingly being used in civil infrastructure applications, such as reinforcing rods, tendons and FRP profiles as well as wraps for seismic upgrading of columns and repair of deteriorated structures. The objective of this course is on one hand to provide new generation of engineering students with an overall awareness of the application and design of FRP reinforcing materials for internal and external strengthening (repair) of reinforced concrete structures. The FRP strengthening of other structures such as metallic and timber will also be shortly discussed. On the other hand the course will provide guidance to students seeking additional information on the topic. Many practical cases will be presented analysed and discussed. An ongoing structural health monitoring of these new materials is necessary to ensure that the structures are performing as planned, and that the safety and integrity of structures is not compromised. The course outlines some of the primary considerations to keep in mind when designing and utilizing structural health monitoring technologies. During the course, students will have the opportunity to design FRP strengthened concrete beams and columns, apply the FRP by themselves, and finally test their samples up to failure.

Lecture notes

3) fib bulletin 19, Externally applied FRP reinforcement for concrete structures, technical report, 2019
1) Laboratory Tours and Demonstrations: Empa Structural Engineering Laboratory including FRP Composites, Shape Memory Alloys, Timber Elements, Large Scale Testing of Structural Components
2) Working with Composite Materials in the Laboratory (application, testing, etc)

Prerequisites / notice

1) Laboratory Tours and Demonstrations: Empa Structural Engineering Laboratory including FRP Composites, Shape Memory Alloys, Timber Elements, Large Scale Testing of Structural Components
2) Working with Composite Materials in the Laboratory (application, testing, etc)

102-0357-00L Waste Recycling Technologies W 3 credits 2G M. Haupt, V. Burg

Abstract

Waste Recycling Technology (WRT) is a sub-discipline of Mechanical Process Engineering. WRT is employed in production plants processing contaminated soil, construction wastes, scrap metal, recovered paper and the like. While WRT is well established in Central Europe, it is only just now catching on in emerging markets as well.

Objective

At the core of this course is the separation of mixtures of solids bulk materials according to physical properties such as color, electrical conductivity, magnetism and so forth. After having taken this course, the students should have concept not only of the unit operations employed in WRT but also of how these unit operations are integrated into the flow sheets of production plants.

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Introduction
Waste Recycling: Scope and objectives
Waste recycling technologies in Switzerland

Fundamentals
Properties of particles: Liberation conditions, Particle size and shape, Porosity of bulk materials
Fluid dynamics of particles: Stationary particle beds, Fluidized beds, Free settling particles
Flow sheet basics: Balancing mass flows
Standard processes: batch vs. continuous
Assessment of separation success: Separation function; grade vs. recovery

Separation Processes
Separation according to size and shape (Classification): Screening, Flow separation
Separation according to material properties (Concentration): Manual Sorting, Gravity concentration; Magnetic separation, Eddy current separation; Electrostatic separation, Sensor technology; Froth flotation

Lecture notes
The script consists of the slides shown during the lectures. Background material will be provided on the script-server.

Literature
A list of recommended books will be provided.

Prerequisites / notice
The topic will be discussed not from the perspective of theory, but rather in the context of practical application. However, solid fundamentals in physics (in particular in mechanics) are strongly recommended.

151-0293-00L
Combustion and Reactive Processes in Energy and Materials Technology

Abstract
This course will provide an introduction to the fundamentals and the applications of combustion in energy conversion and nanoparticles synthesis. The content is highly relevant for technologies which cannot be electrified such as long distance aviation and shipping, and which will more and more rely on carbon-neutral synthetic fuels.

Objective
The main learning objectives of this course are: 1. Understand the thermodynamic, fluid-dynamic and chemical kinetics fundamentals of combustion processes. 2. Predict relevant parameters for combustion systems, such as laminar and turbulent flame speeds, adiabatic flame temperature or quenching distance. 3. Understand the causal relations of relevant combustion parameters such as the pressure influence on the laminar flame speed. 4. Analyze the challenges of developing sustainable combustion technologies based on carbon-neutral synthetic fuels.

Content

Lecture notes
No script available. Instead, material will be provided in lecture slides and the following text book (which can be downloaded for free) will be followed:


Teaching language, assignments and lecture slides in English

Literature


151-0317-00L
Visualization, Simulation and Interaction - Virtual Reality II

Abstract
This lecture provides deeper knowledge on the possible applications of virtual reality, its basic technology, and future research fields. The goal is to provide a strong knowledge on Virtual Reality for a possible future use in business processes.

Objective
Virtual Reality can not only be used for the visualization of 3D objects, but also offers a wide application field for small and medium enterprises (SME). This could be for instance an enabling technology for net-based collaboration, the transmission of images and other data, the interaction of the human user with the digital environment, or the use of augmented reality systems.

The goal of the lecture is to provide a deeper knowledge of today’s VR environments that are used in business processes. The technical background, the algorithms, and the applied methods are explained more in detail. Finally, future tasks of VR will be discussed and an outlook on ongoing international research is given.

Content
Introduction into Virtual Reality; basics of augmented reality; interaction with digital data, tangible user interfaces (TUI); basics of simulation; compression procedures of image-, audio-, and video signals; new materials for force feedback devices; introduction into data security; cryptography; definition of free-form surfaces; digital factory; new research fields of virtual reality

Lecture notes
The handout is available in German and English.

Prerequisites / notice
"Visualization, Simulation and Interaction - Virtual Reality I" is recommended, but not mandatory.

Didactical concept:
The course consists of lectures and exercises.

Competencies
Subject-specific Competencies: Concepts and Theories evaluated
Method-specific Competencies: Techniques and Technologies evaluated
Social Competencies: Communication evaluated
Personal Competencies: Critical Thinking evaluated

151-0353-00L
Mechanics of Composite Materials

Abstract
The courses treats aspects related to elastic behavior of unidirectional and multidirectional laminates, micromechanics, failure and damage analysis, analysis and design of composite structures. The focus is on laminated fiber-reinforced polymer composites.

Objective
The objective is to introduce the basic concept of composite materials and provide a thorough understanding of the mechanical response of such materials and structures particularly made from fibre reinforced polymer composites, including elastic behavior, failure, fracture and damage analysis as well as structural design aspects. The ultimate goal is to provide the necessary skills to address the design and analysis of modern lightweight composite structures.
The course is addressing following topics:
- Introduction
- Elastic anisotropy
- Micromechanics & Homogenization
- Classical Lamine Theory (CLT)
- Strength, failure and damage analysis
- Thin ply composite shells & effects of material non-linearity
- Analysis and design of composite structures

No textbook is available for the course (unfortunately), since it is a dynamic and relatively new topic. In addition to the material presented in the course slides, suggestions/recommendations for additional literature/publications will be given (for each individual topic).
This course consists of a series of seven lectures given by researchers who have distinguished themselves in the area of Robotics, Systems, and Controls. The students learn the correct use of (Who? When? How?) of the event-driven and computer-based simulation in the illustration of the Concepts and Theories.

A bibliography will be handed out during the lectures.

The students learn the application of the event-based and computer-based simulation for layout and improvement of production facilities by operating simulation in the productions, logistic and scheduling will be shown by means of practical examples.

Further, the lecture gives insights into the methods-time measurement (MTM) for evaluating human work places as basis for the simulation and learn how this is performed using virtual reality.

The knowledge is enhanced by practice-oriented exercises and an excursion. A guest speaker will present a practical example.

Operational Simulation of Production Lines

151-0623-00L

The students learn the correct use of (Who? When? How?) of the event-driven and computer-based simulation in the illustration of the operating procedures and the production facilities. The simulation is an important basis for creating a digital twin in the context of Industry 4.0.

The students should make their first experiences in the use of computer-based simulation.

Further, the lecture gives insights into the methods-time measurement (MTM) for evaluating human work places as basis for the simulation and learn how this is performed using virtual reality.

The knowledge is enhanced by practice-oriented exercises and an excursion. A guest speaker will present a practical example.

The students learn the application of the event-based and computer-based simulation for layout and improvement of production facilities by means of practical examples and by using the so-called «Digital Twin» within the context of «Industry 4.0». They learn how virtual and mixed reality tools can be used together with the Digital Twin to plan and support the operation of a production line.

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Further, the lecture gives insights into the methods-time measurement (MTM) for evaluating human work places as basis for the simulation and learn how this is performed using virtual reality.

The knowledge is enhanced by practice-oriented exercises and an excursion. A guest speaker will present a practical example.
This course focuses on the design, manufacture and testing of components produced using additive manufacturing (AM) technologies.

B. Berisha

The course covers fundamentals of computational optimization methods in the context of engineering design. It develops skills to formally state and model engineering design tasks as optimization problems and select appropriate methods to solve them.

W. Meboldt

In parallel to the lectures, the students design, manufacture and test prototypes in a project at different stages of product development.

K. Shea, D. Mohr

Design for Additive Manufacturing

Please write a short motivation letter to apply for the course. The motivation letter should state why you wish to attend the course. Please also mention any experience you have with relevant topics such as CAD, project work, additive manufacturing (AM), simulation or experimental design. Please also mention in the letter if you already have a proposal for an AM component to be designed as part of the project, or if you have a real-world challenge that you could address using AM. Please send your letter to Julian Farchow (email: farchow@ethz.ch).

M. Meboldt, J. Farchow

This course focuses on the design, manufacture and testing of components produced using additive manufacturing (AM) technologies. The course includes a project based on a real-world challenges where students design, fabricate and iteratively optimize functional AM parts using an appropriate AM technology.

This course provides a basic knowledge of design for additive manufacturing (AM). The course will prepare students to

- Apply basic AM processes (metal and plastic)
- Apply AM design guidelines
- Adopt AM in an industrial environment
- Apply design tools and methods in AM
- Create value from AM
- Work in a project based product development team

In parallel to the lectures, the students design, manufacture and test prototypes in a project at different stages of product development.

The course covers the following topics:

- State-of-the-art AM processes for metals and plastics: PBF (also known as SLM, SLS), BJT, MJF, MEX (FDM)
- Design guidelines in AM
- Industrial adoption of AM
- Value creation and business models for AM
- Design tools and methodologies for AM
- Quality management in AM
- Industrial cases of AM applications
- Problem solving and creativity
- Agile development

Script and handouts are available in PDF-format.
**Abstract**
This core course provides insights into the basic theories, principles, concepts, and techniques used to design, analyze, and improve the operational capabilities of an organization.

**Objective**
This course provides students with a broad theoretical basis for understanding, designing, analyzing, and improving manufacturing operations. After completing this course:

1. Students can apply key concepts of POM to detail an operations strategy.
2. Students can do simple forecasting of demand and plan the needed capacity to meet it.
3. Students can conduct process mapping analysis, use it to design and improve processes and layouts, and elaborate on the limitations of the chosen method.
4. Students can choose IT, OT, and automation technology for manufacturing applications.
5. Students can design information flows, manage master data, and use it to plan and control a factory.
6. Students can design material flows in and beyond factories.
7. Students can design performance management systems.
8. Students can select and use problem-solving tools to improve quality and productivity.
9. Additional skills: Students acquire experience in teamwork.

**Content**
The course covers the most fundamental strategic and tactical concepts in production and operations management (POM).

Production and Operations Management (POM) is at the heart of any business. It is concerned with the business processes that transform input into output and deliver products and services to customers. Factory management is an important part of POM, but it is much more than what takes place inside the production facilities of companies like ABB, Boeing, BMW, LEGO, Nestlé, Roche, TESLA, and Toyota. Did you know that the largest portion of assets and employees in most organizations are engaged in the operations function? Although this course focuses on manufacturing, all types of organizations depend on their operational capabilities. With the ongoing globalization and digitization of manufacturing, POM has won a deserved status for providing a competitive advantage.

This course covers the following topics: Introduction to POM, Manufacturing strategy, Forecasting and capacity, Process design, Layout, Industry 4.0, Information flow, Material flow, Logistics/SCM, Performance management, Performance improvement, Quality management, and Maintenance.

This course is administered via Moodle. The course is designed around five elements:

2. Video lectures. Short video lectures presenting basic POM concepts.
3. Class lectures. Deep-dives with case examples on select topics.
4. FactoryVR group assignment. FactoryVR allows students to visit factories virtually.
5. Quizzes. A few quizzes during the semester help students check their progress and prepare for the written exam.

**Literature**
Suggested literature is provided in the syllabus.
Introduction to the fundamentals of lasers and their applications with an emphasis on micro- and nanostreamructuring. Several applications which are still in the research state, e.g. non-optical lithographies, will be discussed together with industrial applications, such as microolithography and laser welding. Other aspects are the materials that are applied in these applications, e.g. photoresists, and their functioning.

Content
Introduction to lasers. Overview of micro- and nanotechnology, microolithography, photoresists: classical types and new developments, laser cutting and welding, laser cleaning, laser ablation, polymer ablation: designed polymers, lasers and surfaces, laser spectroscopy, laser chemical vapor deposition, pulsed laser deposition (PLD), special materials by PLD, alternative structuring methods.

Literature
FSRM, CD-ROM: An Introduction to the World of Microsystems, Neuchatel.

Prerequisites: Basic chemistry and chemical engineering knowledge (Diffusion, Thermodynamics, Kinetics,...).

Lecture notes
The script (a copy of the slides) will be handed out during the first lecture.

To the question of ‘what should we make?’ to the question of ‘how do we make something?’ to the question of what we make?
As information technology continues its fast-paced evolution, solid-state devices and systems increase in complexity. Engineers and scientists are thus increasingly facing the need to model and simulate their problems numerically where analytic textbook solution cease to exist. Moreover, boundaries between traditional disciplines are harder to maintain, as a proper description of the system might involve phenomena from several domains. Examples include—but not limited to—mechatronics which relies on mechanical, electrical and electronic engineering, and transducers (sensors and actuators) which are by definition devices that convert signals from one physical domain to another. Simulation platforms such as Comsol Multiphysics have truly opened the way to easy multi-domain numerical simulation, offering tools that cover all operations from geometry definition, to meshing, to physics and boundary conditions setting to simulation and result post-processing and analysis in a unified, domain-independent fashion. However, this high degree of freedom has its price, as inexperienced users may face cryptic error messages, incomprehensible or even incorrect results. It is the mission of this course to teach you how to properly set up a problem by exposing some of the most common misconceptions and pitfalls in multiphysics modeling. Good practices will be taught that should simplify the modeling process and increase the likelihood of correct results. Examples will mainly come from the fields of mechanics (continuum solid mechanics), electromagnetism (electrostatics and conductive media), heat transfer (conductive not convective) and combinations of these domains.

The course will provide you with the fundamentals of the new and exciting field of ultrasound-based microbots to treat various diseases. Furthermore, we will explore how ultrasound can be used in additive manufacturing for tissue constructs and robotics.

**Prerequisites:** Basic chemistry and chemical engineering knowledge (Diffusion, Thermodynamics, Kinetics,...).
Objective
The course is designed to equip students with skills in the design and development of ultrasound-based manipulation devices and microrobots for applications in medicine and additive manufacturing.

Content
Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices

Lecture notes

Literature

Prerequisites / notice
Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-direction and Self-management: assessed
- Sensitivity to Diversity: fostered
- Negotiation: fostered

151-0604-00L  Microrobotics  W  4 credits  3G  B. Nelson

Abstract
Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Objective
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

Content
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microrobots

Lecture notes
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

Prerequisites / notice
The lecture will be taught in English.

151-0620-00L  Embedded MEMS Lab  W  5 credits  3P  C. Hierold, A. Güntner, M. Haluska

Abstract
Practical course: Students are introduced to the process steps required for the fabrication of MEMS (Micro Electro Mechanical System) and carry out the fabrication and testing steps in the clean rooms by themselves. Additionally, they learn the requirements for working in clean rooms. Processing and characterization will be documented and analyzed in a final report.

Objective
Students learn the individual process steps that are required to make a MEMS (Micro Electro Mechanical System). Students carry out the process steps themselves in laboratories and clean rooms. Furthermore, participants become familiar with the special requirements (cleanliness, safety, operation of equipment and handling hazardous chemicals) of working in the clean rooms and laboratories. The entire production, processing, and characterization of the MEMS is documented and evaluated in a final report.

Content
With guidance from a tutor, the individual silicon microsystem process steps that are required for the fabrication of an accelerometer are carried out:
- Photolithography, dry etching, wet etching, sacrificiary layer etching, various cleaning procedures
- Packaging and electrical connection of a MEMS device
- Testing and characterization of the MEMS device
- Written documentation and evaluation of the entire production, processing and characterization

Lecture notes
A document containing theory, background and practical course content is distributed at the Introductory lecture day of the course.

Literature
The document provides sufficient information for the participants to successfully participate in the course.
**Prerequisites / notice**

Participating students are required to attend all scheduled lectures and meetings of the course.

Participating students are required to provide proof that they have personal accident insurance prior to the start of the laboratory portion of the course.

For safety and efficiency reasons the number of participating students is limited. We regret to restrict access to this course by the following rules:

Priority 1: master students of the master's program in "Micro and Nanosystems"

Priority 2: master students of the master's program in "Mechanical Engineering" with a specialization in Microsystems and Nanoscale Engineering (MAVT-tutors Prof. Daraio, Dual, Hierold, Kouroutsakos, Nelson, Norris, Poulikakos, Pratsinis, Stemmer), who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.

Priority 3: master students, who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.

Priority 4: all other students (PhD, bachelor, master) with a background in silicon or microsystems process technology.

If there are more students in one of these priority groups than places available, we will decide by (in following order) best achieved grade from 151-0621-00L Microsystems Technology, registration to this practicum at previous semester, and by drawing lots.

Students will be notified at the first lecture of the course (introductory lecture) as to whether they are able to participate.

The course is offered in autumn and spring semester.

### 151-0621-00L Microsystems I: Process Technology and Integration

**Abstract**

Students are introduced to the fundamentals of semiconductors, the basics of micromachining and silicon process technology and will learn about the fabrication of microsystems and devices by a sequence of defined processing steps (process flow).

**Objective**

Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystem devices by the combination of unit process steps (= process flow).

**Content**

- Introduction to microsystems technology (MST) and micro electro mechanical systems (MEMS)
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.
- Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties.

Application of selected technologies will be demonstrated on case studies.

**Lecture notes**

Handouts (available online)

**Literature**

- S.M. Sze: Semiconductor Devices, Physics and Technology
- W. Menz, J. Mohr, O. Paul: Microsystem Technology
- Hong Xiao: Introduction to Semiconductor Manufacturing Technology
- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications

**Prerequisites / notice**

Prerequisites: Physics I and II

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### 151-0913-00L Introduction to Photonics

**Abstract**

This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

**Objective**

Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.
I- BASICS OF WAVE THEORY
1) General concepts
2) Differential wave equation
3) Wavefront
4) Plane waves and Fourier decomposition of optical fields
5) Spherical waves and Huygens-Fresnel principle

II- ELECTROMAGNETIC WAVES
1) Maxwell equations
2) Wave equation for EM waves
3) Dielectric permittivity
4) Refractive index
5) Nonlinear optics
6) Polarisation and polarisation control

III- PROPAGATION OF LIGHT
1) Waves at an interface
2) The Fresnel coefficients
3) Total internal reflection
4) Evanescent waves
5) Dispersion diagram

IV- INTERFERENCES
1) General considerations
2) Temporal and spatial coherence
3) The Young double slit experiment
4) Diffraction gratings
5) The Michelson interferometer
6) Multi-wave interference
7) Antireflecting coating and interference filters
8) Optical holography

V- LIGHT MANIPULATION
1) Optical waveguides
2) Photonic crystals
3) Metamaterials and metasurfaces
4) Optical cavities

VI- OPTICAL FORCES AND OPTICAL TWEEZERS
1) History of optical forces
2) Theory of optical trapping
3) Atom cooling
4) Optomechanics
5) Applications of optical tweezers

VII- INTRODUCTION TO OPTICAL MICROSCOPY
1) Basic concepts
2) Direct and Fourier imaging
3) Image formation
4) Fluorescence microscopy
5) Scattering-based microscopy
6) Digital holography
7) Computational imaging

Lecture notes
Class notes and handouts

Literature
Optics (Hecht) - Pearson

Prerequisites / notice
Physics

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed
Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

227-0053-00L High-Frequency Design Techniques W 4 credits 2V+2U C. Bolognesi, T. Popovic

Abstract
Introduction to the basics of high-frequency circuit design techniques used in the realization of high-bandwidth communication systems and devices. Modern society depends on increasingly large data masses that need to be transmitted/processed as rapidly as possible: higher carrier frequencies allow wider bandwidth channels which enable higher data transmission rates.

Objective
Familiarize students with the essential tools and principles exploited in the high-frequency design. Introduction to circuit simulation. Introduction to amplifier design.

Content
Introduction to wireless, radio spectrum. Review of vectors and complex numbers, AC circuit analysis, matching networks, distributed circuit design, transmission lines and transmission line equations, reflection coefficients, the Smith Chart and its software, voltage standing wave ratio (VSWR), skin effect, matrix analysis, scattering parameters, electromagnetic fields and waves, amplifier design. Hands-on experience with measurement equipment.

Lecture notes
A detailed script is provided for each lecture, including the exercises and their solutions.

Literature
The main topics are: transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model, and device physics is provided. Computer simulations of the most important devices and of interesting physical effects supplement the lectures.

The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

Lecture notes

Lectures notes and slides will be handed out during the lectures.

Prerequisites


Method-specific Competencies

Analytical Competencies

Problem-solving

Social Competencies

Communication

Cooperation and Teamwork

Personal Competencies

Creative Thinking

Critical Thinking

227-0110-00L Electromagnetic Waves: Materials, Effects, and Antennas

W 6 credits 4G

Abstract

This course provides profound knowledge about electromagnetic waves. Various types of materials, nonlinear and resonant effects, and antenna applications are discussed.

Objective

You can describe wave propagation in classical and nonclassical materials and know the fundamental solutions. You know how waves interact with matter and about nonlinear, scattering and resonant effects. You can apply the acquired knowledge in scattering, waveguiding, radiation, and antenna problems.

Content

The lecture covers the following topics:

- Generic time-harmonic electromagnetic fields
- Fundamental solutions of the wave equation
- Wave propagation in various types of materials
- Interaction of waves with matter
- Nonlinear effects
- Resonant effects
- Applications like scattering, waveguiding, radiation
- Radio frequency and optical antennas

Lecture notes

Lecture notes and slides will be handed out during the lectures.

Prerequisites

- Required background: Calculus, Linear Algebra, basic knowledge of vector calculus, knowledge of basic circuit theory.
- Familiarity with the electromagnetic field, photons, and radiation physics is helpful.

227-0157-00L Semiconductor Devices: Physical Bases and Simulation

W 4 credits 3G

Abstract

The course addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical simulation. Necessary basic knowledge on quantum-mechanics, semiconductor physics, and device physics is provided. Computer simulations of the most important devices and of interesting physical effects supplement the lectures.

Objective

The course aims at the understanding of the principle physics of modern semiconductor devices, of the foundations in the physical modeling of transport and its numerical simulation. During the course also basic knowledge on quantum-mechanics, semiconductor physics, and device physics is provided.

Content

The main topics are: transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model, hydrodynamic model), physical characterization of silicon (intrinsics properties, scattering processes), mobility of cold and hot carriers, recombination (Shockley-Read-Hall statistics, Auger recombination), impact ionization, metal-semiconductor contact, metal-insulator-semiconductor structure, and heterojunctions. The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

Lecture notes

The script (in book style) can be downloaded from: https://iis-students.ee.ethz.ch/lectures/

Prerequisites


227-0311-00L Qubits, Electrons, Photons

W 6 credits 3V+2U

Abstract

In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis).

Objective

Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics. Starting from the axioms of quantum mechanics, we will derive the fascinating theory describing spin and qubits, electron transitions and transfer, photons and LASER: quantum mechanics is different because it mocks our daily Euclidean intuition!

In this way, students will work out a robust quantum mechanics (theoretical!!!) basis which will help them in their advanced studies of the following masters: EEIT (batteries), Biomedical Engineering (NMR, bioelectronics), Quantum Engineering, Micro- and Nanosystems.

IMPORTANT: "qubits" from the point of view of NMR (and NOT from that of quantum computing!).

Content

- Lagrangian and Hamiltonian: Symmetries and Poisson Brackets
- Postulates of QM: Hilbert Spaces and Operators
- Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator
- Density Operator
- Spin: Qubits, Bloch Equations, and NMR
- Entanglement
- Symmetries and Corresponding Operators
- Schrödinger's Wave Mechanics: Electrons in a Periodic Potential and Energy Bands
- Harmonic Oscillator: Creation and Annihilation Operators
- Identical Particles: Bosons and Fermions
- Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER
- Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener
No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

??? I am using OneNote. All lectures and exercises will be broadcast via ZOOM, while corresponding videos of the previous years are available in Moodle ???!

### Literature

Supplementary material will be uploaded in Moodle.

+ (as rigorous and profound presentation of the mathematical framework) G. Dell'Antonio, "Lectures on the Mathematics of Quantum Mechanics I", 2015, Springer
+ (as account of those formidable years) G. Gamow, "Thirty Years that Shook Physics", 1985, Dover Publications Inc.

### Prerequisites / notice
The course has been intentionally conceived to be self-consistent with respect to QM for those master students not having encountered it in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) QM introduction course like the D-ITET "Physics II".

A solid base of Analysis I & II as well as of Linear Algebra is really helpful.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: assessed

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

#### Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

### 227-0615-00L Simulation of Photovoltaic Devices - From Materials to Modules
**Abstract**
The lecture provides an introduction to the theoretical foundations and numerical approaches for the simulation of photovoltaic power conversion, from the microscopic description of component materials to macroscopic continuum modelling of solar cells and network simulation or effective models for performance prediction of entire solar modules.

**Objective**
Get an overview of the current status of photovoltaic technology. Understand the physics of photovoltaic energy conversion and solar cell device operation. Know how to obtain and assess by simulation the key material properties and device parameters. Be able to use standard device simulation tools to analyze, optimize, and predict the performance of solar cells and modules.

**Content**
Photovoltaic technology: history and overview; The solar spectrum; Thermodynamics of solar energy conversion; Detailed balance models and efficiency limit; Microscopic rates of charge carrier generation and recombination; Optical simulation of solar cells; Models for charge transport in semiconductor devices; High-efficiency wafer-based (silicon) photovoltaics; Thin film photovoltaics based on disordered materials (amorphous silicon, organic PV); High-efficiency thin film photovoltaics (CIGS, CdTe, metal-halide perovskites); PV beyond the single junction detailed balance (Shockley-Queisser) limit; Simulation of photovoltaic modules; Energy yield and performance modelling for PV systems; Quantum simulation of nanostructure-based solar cell devices (bonus lecture)

**Literature**
- M. A. Green, „Solar cells: operating principles, technology, and system applications“, Prentice Hall, 1982.

**Prerequisites / notice**
Undergraduate physics (including basic quantum mechanics), mathematics, semiconductor devices, optics. Knowledge of some scripting language (e.g. python) is of advantage.
This course explores the exciting realm of carbon-based nanoelectronics, where the remarkable quantum properties of materials like graphene, carbon nanotubes, graphene nanoribbons, and single molecules are used for building electronic devices.

Objective

The objective of this course is to understand how the electronic properties of carbon-based materials can be exploited for fabricating quantum devices. We will delve into both the theoretical and experimental aspects, discussing how these materials' unique properties can be translated into device functionality.

On the theoretical side, we'll cover how the chemical structure of the material and its dimensionality, ranging from 0D to 2D, affects the electronic properties. We'll also discuss how charge carriers flow through the devices and what charge transport mechanisms are at play.

On the experimental side, we'll cover how such devices are fabricated, including how the materials are synthesized. We'll also discuss how to characterize the devices and assess their performance.

Content

The course will cover the following carbon-based materials:
- Single-molecule
- Graphene (single layer, bilayer, twisted bilayer)
- Graphene nanoribbons
- Carbon nanotubes

For each material, we will discuss:
- Electronic structure and charge transport properties
- Material synthesis and characterization
- Device integration and characterization

The course also includes a presentation by each student in which a related scientific publication is discussed. This presentation is compulsory and accounts for 50% of the grade.

Lecture notes

Lecture slides are distributed every week. In addition, relevant scientific articles and book chapters will be provided for self-study.

Literature

In addition to the slides, the following supplementary books can be recommended:

Prerequisites / notice

A basic knowledge of solid-state physics and quantum mechanics is required. The course is taught in English.
Students without a background in Electrical Engineering must take "Electric Circuits" before taking "Introduction to Electric Power Transmission: System & Technology".

Abstract
Introduction to analysis methods and network theorems to describe operation of electric circuits. Theoretical foundations are essential for the analysis of the electric power transmission and distribution grids as well as many modern technological devices – consumer electronics, control systems, computers and communications.

Objective
At the end of this course, the student will be able to: understand variables in electric circuits, evaluate possible approaches and analyze simple electric circuits with RLC elements at steady state and during transients, apply circuit theorems to simple meshed circuits, analyze AC circuits and understand the connection of the explained principles to the modelling of 3-phase electric power systems.

Content
Course will introduce electric circuits variables, circuit elements (resistive, inductive, capacitive), resistive circuits and theorems (Kirchhoff's laws, Norton and Thevenin equivalents), nodal and mesh analysis, superposition principle; it will continue by discussing the complete response of RL, RC and RLC circuits during transients, sinusoidal analysis – AC steady state (complex power, reactive, active power) and conclude with the introduction to 3-phase analysis; Mathematical foundations of the circuit analysis, such as matrix operations and complex numbers will be briefly reviewed. This course is targeting students who have no prior background in electrical engineering.

Lecture notes
Lecture and exercises slides will be distributed after each lecture via Moodle platform; additional materials to be accessed online (wileyplus)

Literature
Richard C. Dorf, James A. Svoboda
Introduction to Electric Circuits, 9th Edition
Online materials: https://www.wileyplus.com/
Lecture slides and exercises slides

Prerequisites / notice
This course is primarily intended for students outside of D-ITET. No prior course in electrical engineering is required.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Technics and Technologies</td>
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<td>Method-specific Competencies</td>
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<td>Problem-solving</td>
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327-0505-00L Surfaces and Interfaces I: Fundamentals, Analytics and Applications  W 6 credits 3G L. Isa, M. P. Heuberger

Extended course starting HS23. Old title: Surfaces, Interfaces and their Applications I. Students who obtained credit points for the old course cannot retake it.

Objective
Students are able to:
- describe the physical and chemical properties of surfaces and interfaces,
- analyze and compare analytical tools for surfaces,
- choose and combine appropriate surface-analytical approaches for solving problems connected to applications,
- understand and explain the importance of surfaces and interfaces in a broad range of phenomena and applications.

Content
- Introduction to surfaces and interfaces
- Surface forces
- Basic physical concepts
- Thermodynamics of surfaces and interfaces
- Measurement of intermolecular and surface forces
- Dynamics and history effects
- Surface analytics: X-ray Photoelectron Spectroscopy (XPS) – principles and modern developments
- Surface analytics: Secondary Ion Mass Spectroscopy (SIMS) and IR Spectroscopy – Principles and examples
- Atomic Force Microscopy (AFM): Principles and modes of operation
- Tribology: Adhesion, Friction and Lubrication
- Contact mechanics
- Micro and macroscale friction
- Boundary lubrication
- Wetting
- Contact angles
- Phoretic phenomena
- Electric double layer and electrophoresis
- Electro-osmosis
- Other types of phoresis
- Case studies

Lecture notes
Script Download: https://moodle-app2.let.ethz.ch/course/view.php?id=17455

Literature
Script Download: https://moodle-app2.let.ethz.ch/course/view.php?id=17455

Prerequisites / notice
Chemistry:
General undergraduate chemistry including basic chemical kinetics and thermodynamics

Physics:
General undergraduate physics including basic theory of interatomic and intermolecular forces, atomic and crystalline structure of materials and their mechanical and electronic properties

Competencies

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<td>Problem-solving</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td>Critical Thinking</td>
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Electron Microscopy in Material Science

Abstract
A comprehensive understanding of the interaction of electrons and ions with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

Objective
A comprehensive understanding of the interaction of electrons and ions with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

Content
This course provides a general introduction into electron- and ion-microscopy of organic and inorganic materials. In the first part, the basics of transmission- and scanning electron microscopy are presented. The second part includes the most important aspects of specimen preparation, imaging and image processing. In the third part, focused ion-beam and atom probe microscopes are presented. Throughout the semester, various applications in materials science, solid state physics, structural biology, structural geology, and structural chemistry will be reported.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking

Lecture notes
will be distributed in English.

Literature
- Erni: Aberration-corrected imaging in transmission electron microscopy, Imperial College Press (2010, and 2nd ed. 2015)

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Scattering Techniques for Material Characterization

Abstract
The lecture presents the currently most efficient experimental techniques for microstructure material characterization: X-ray diffraction (XRD) and transmission electron microscopy (TEM). The theoretical basics, instrumentation, complementarity and exclusivity of both techniques will be taught. The course includes practical elements and examples of current research projects at D-MATL.

Objective
Students are able to do:
- systematically characterise the microstructure and phases of a given material with X-rays and electrons
- select the right tool (source, instrument, measurement strategy) and design a workflow for solving a microstructure or phase analysis problem
- describe possibilities and limitations of a given characterisation method
- comprehensively store experimentally collected data in a repository following modern data management rules such that data can be evaluated by students not involved in the experiment
- qualitatively and quantitatively evaluate and present experimental data and results collected by others

Content
The main objective of this hands-on practical course is to give students a comprehensive insight into the most important aspects of microstructure characterization using electron and X-ray scattering. The focus is on the complementarity and exclusivity of the two techniques. We will introduce the most important material characterization tasks, present the relevant physical and crystallographic fundamentals, and discuss how the tasks can be solved with electron and X-ray scattering. We will discuss intrinsic and extrinsic advantages and limitations of the methods and explain essential instrumentation requirements specific to each setup. Another essential facet of the course is the link to everyday D-MATL project problems presented by the lecturers or researchers from D-MATL. The lecture is accompanied by hands-on experiments on samples of D-MATL projects using state-of-the-art instruments.

Literature

Prerequisites / notice
Crystallography, X-ray diffraction and electron microscopy on the BSc level. All enrolled students are initially placed on the "waiting list" until the registration deadline. In the case of more than 12 applicants, the students will be selected by the lecturers before the start of the lecture according to the priority criteria: master students before doctoral students, Material Science students before students of other departments.

Competencies

Subject-specific Competencies
- Concepts and Theories

Method-specific Competencies
- Analytical Competencies

Personal Competencies
- Creative Thinking

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Order in Materials

Abstract

Objective

Content

Competencies

Subject-specific Competencies
- Concepts and Theories

Method-specific Competencies
- Analytical Competencies

Personal Competencies
- Creative Thinking

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Abstract
The aim is an overview of the different ordering phenomena that occur in materials: magnetic, electrical, mechanical, structural. Special emphasis is placed on a comprehensive definition of the term "ferroic". Novel forms of order, such as multiferroicity, are of particular interest. Their exploration and the material functionalities derived from these are a central theme in our Department.

Objective
Ferromagnetism is known to humankind for 2500 years, but there are many other forms of spontaneously ordered states in nature that wait to be explored. One of these is ferroelectricity, the spontaneous electric order of a material, which rapidly gains importance in science and technology. It is the aim of this course to learn what actually defines a state as ferroic, what forms of ordering are known or newly proposed, and what kind of materials and functionalities are related to ferroic materials. We also explore the transition from order to disorder, which is fluent and offers materials properties that are not found in the fully ordered or disordered state.

It is an equally important goal that attendees learn to work critically and creatively with the "unfinished knowledge" of a "hot" research field that is in continuous and rapid development. Realizing that scientific results are not eternally true, but need to be constantly challenged and revised if necessary is very important in becoming a researcher working at the forefront of science.

Content
The power of symmetry analysis, aspects of crystallography and group theory, definition and concept of ferroic order. Forms of ferroic order in nature, domains and domain walls, multiferroics and magnetoelectric correlations, dynamical processes and functionalities in ferroic materials, the transition from order to disorder, thermodynamics of such transitions and associated material properties, tour through the Laboratory for Multifunctional Ferroic Materials.

Lecture notes
There is no actual script because one of the main goals of this lecture is to work critically and creatively with the "unfinished knowledge" of a "hot" research field that is in continuous and rapid development. It is important that attendees of the lecture form their own view of this field rather than following the filtered and biased view presented in a script.

Literature
V. K. Wadhawan, Introduction to Ferroic Materials, (Gordon and Breach 2000)
M. Fiebig, Nonlinear Optics on Ferroic Materials, (Willey 2023)
R. R. Birss, Symmetry and Magnetism, (North Holland 1966)

Prerequisites / notice
Knowledge of the physics of materials, as provided by the ETH Zurich B.S. curriculum in Materials Science. Interdisciplinary or Physics students are also welcome. This lecture is on a "hot" research field that is in continuous and rapid development, so students are encouraged to provide continuous feedback so that the topics covered by the lecture can be constantly adopted. The lecture can only be as good as the constructive/critical feedback that is received.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection

327-2210-00L Thin Films Technology - From Fundamentals to Oxide Electronics

Students who already took "327-2104-00L Inorganic Thin Films: Processing, Properties and Applications" AND "327-2132-00 Multifunctional Ferroic Materials: Growth and Characterisation" are not allowed to attend this course.

Abstract
Oxide films with a thickness of just a few atoms can now be grown with a precision matching that of semiconductors. This opens up a whole world of functional device concepts and fascinating phenomena that would not occur in the expanded bulk crystal.

We will give an introduction to thin films deposition techniques and applications with a focus on the growth of multifunctional oxide thin films.

Objective
In this course students will obtain an overarching view on thin film deposition techniques with a focus on epitaxial deposition processes.

The main learning objectives are:
- Identification of most relevant deposition technique for a given application.
- Understanding of growth mechanism and growth modes.
- Understanding strategies for engineering the functionalities of the films using the deposition process.
- Selection of the most appropriate characterization technique.
- Understanding device concepts and fundamental limits in the technology relevant ultra-thin limit.
- Assessing the relevance of scientific literature dealing with complex oxide thin films.

Content
A lab visit will be organized and students will participate to the design of thin films with atomic precision.

General description of the leading deposition routes including physical and chemical vapor deposition techniques (PVD and CVD) as well as so called "wet techniques" (e.g. spin coating and spray pyrolysis).

Growth modes and processes.

Part of the course discusses vacuum technologies.

Fundamental characterization techniques for application-relevant thin films as well as state of the art approaches for in situ and ex-situ determination of the structural, chemical and ferroic (ferromagnetic and ferroelectric) properties of films: (XRD for thin films, RHEED, EDX, scanning probe microscopy techniques, laser-optical characterization and many more)

Epitaxy for the advanced design and characterization of high quality thin films for energy efficient oxide electronics.

Types of ferroic order, multiferroics, multifunctional oxide materials, epitaxial strain related effects, oxide thin film based devices and examples.

Regular discussions on preselected scientific literature and mini-seminars will be organized.
Building upon new technologies to engineer and functionalize well-defined nanostructured materials, a plethora of exciting discoveries were made and found their way in our daily live. These customized nanomaterials provide extraordinary properties and make them attractive for many innovative applications. Exactly these new properties may have the potential to be responsible for unforeseen side effects, which hamper a straightforward translation into new products. Therefore, the safety research provide the evidence for a responsible and sustainable use of nanomaterials.

The lecture will focus on basic principles of nanotoxicology, provide the understanding of the potential side effects of nanomaterial in a context-specific way addressing the main exposure routes such as inhalation, ingestion, topical applications and intravenous injection. This course is multi-disciplinary and covers a broad range of techniques. For each lecture, a brief historical perspective is given to illustrate by whom and how the techniques were invented.

The course should familiarize the students with the techniques used in micro/nanotechnology, cleanroom microfabrication, and show them how micro/nanotechnology pervades throughout life sciences. Microfluidics will be emphasized due to their increasing importance in research and for medical applications.

The second objective is to have life sciences students less intimidated by micro/nanotechnology and make them able to link instruments and techniques to specific problems that they might have in their projects/studies. This will also help students getting access to the ETHZ/IBM Nanotech Center infrastructure if needed.

The course should familiarize the students with the techniques used in micro/nanotechnology, cleanroom microfabrication, and show them how micro/nanotechnology pervades throughout life sciences. Microfluidics will be emphasized due to their increasing importance in research and for medical applications.

In terms of technical content, the lectures will cover:
- an overview of the microelectronics industry, Moore’s law, field-effect transistors, next-generation DNA sequencing
- liquid crystal displays, organic light emitting diodes, electrophoretic displays, micromirrors and beamsers, photopatterning of proteins and cells, optogenetics, and flexible displays and electronics
- hard disk drives and the giant magnetoresistance effect, magnetic nanoparticles, photonics, magnetic sensing and optical biosensing
- cleanroom techniques and instruments, from design to microfabrication of simple devices and microfluidics, examples of DNA microarrays
- the principles of microfluidics, microfluidic functions and fabrication, from microfluidics for research to point-of-care diagnostics, and the (infamous) history of Theranos, as well as some discussions on diagnostics for COVID, R0, and (im)precision of diagnostic devices and why it matters
- 2 × 45 min will be covered by Yuksel Temiz, a master of Arduino programming and do-it-yourself electronics, who will present how to technology and makes a short report and presentation describing how it works, its strengths and weaknesses, and describes what problem it solves.

The course is multi-disciplinary and covers a broad range of techniques. For each lecture, a brief historical perspective is given to illustrate by whom and how the techniques were invented.
Lecture notes
Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website.

Prerequisites / notice
course “Introduction to Toxicology”

Competencies

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<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Social Competencies</td>
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402-0317-00L Semiconductor Materials: Fundamentals and Fabrication
W 6 credits 2V+1U S. Schön, W. Wegscheider

Abstract
This course gives an introduction into the fundamentals of semiconductor materials. The main focus is on state-of-the-art fabrication and characterization methods. The course will be continued in the spring term with a focus on applications.

Objective
Basic knowledge of semiconductor physics and technology. Application of this knowledge for state-of-the-art semiconductor device processing.

Content
1. Fundamentals of Solid State Physics
   1.1 Semiconductor materials
   1.2 Band structures
   1.3 Carrier statistics in intrinsic and doped semiconductors
   1.4 p-n junctions
   1.5 Low-dimensional structures
2. Bulk Material growth of Semiconductors
   2.1 Czochalski method
   2.2 Floating zone method
   2.3 High pressure synthesis
3. Semiconductor Epitaxy
   3.1 Fundamentals of Epitaxy
   3.2 Molecular Beam Epitaxy (MBE)
   3.3 Metal-Organic Chemical Vapor Deposition (MOCVD)
   3.4 Liquid Phase Epitaxy (LPE)
4. In situ characterization
   4.1 Pressure and temperature
   4.2 Reflectometry
   4.3 Ellipsometry and RAS
   4.4 LEED, AES, XPS
   4.5 STM, AFM
5. The invention of the transistor - Christmas lecture

Lecture notes
https://moodle-app2.let.ethz.ch/course/view.php?id=20749

Prerequisites / notice
The “compulsory performance element” of this lecture is a short presentation of a research paper complementing the lecture topics. Several topics and corresponding papers will be offered on the moodle page of this lecture.

Competencies

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402-0402-00L Ultrafast Laser Physics
W 10 credits 3V+2U L. P. Gallmann, S. Johnson, U. Keller

Abstract
Introduction to ultrafast laser physics with an outlook into cutting edge research topics such as attosecond science and coherent ultrafast sources from THz to X-rays.

Objective
Understanding of basic physics and technology for pursuing research in ultrafast laser science. How are ultrashort laser pulses generated, how do they interact with matter, how can we measure these shortest man-made events and how can we use them to time-resolve ultrafast processes in nature? Fundamental concepts and techniques will be linked to a selection of hot topics in current research and applications.

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This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics covered include the quantum nature of light, semi-classical and quantum mechanical description of light-matter interaction, laser manipulation of atoms and ions, quantum description of light matter interaction: the Jaynes-Cummings model, photon blockade, laser manipulation of atoms and ions: laser cooling and trapping, atom interferometry, further topics: Rydberg atoms, optomechanics, quantum computing, complex quantum systems.

Prerequisites: Basic knowledge of quantum electronics (e.g., 402-0275-00L Quantenelektronik).

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<th>Competencies</th>
<th>Subject-specific Competencies</th>
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<tr>
<td>Objective</td>
<td>The course aims to provide the knowledge necessary for pursuing research in the field of Quantum Optics. Fundamental concepts and techniques of Quantum Optics will be linked to modern experimental research. During the course the students should acquire the capability to understand currently published research in the field.</td>
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<td>Content</td>
<td>This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics that are covered include:</td>
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<td>- coherence properties of light</td>
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<td>- quantum nature of light: statistics and non-classical states of light</td>
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<td>- light matter interaction: density matrix formalism and Bloch equations</td>
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<td>- quantum description of light matter interaction: the Jaynes-Cummings model, photon blockade</td>
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<td>- laser manipulation of atoms and ions: laser cooling and trapping, atom interferometry,</td>
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<td>- further topics: Rydberg atoms, optomechanics, quantum computing, complex quantum systems.</td>
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Selected book chapters will be distributed.

Text-books:
- G. Grynberg, A. Aspect and C. Fabre, Introduction to Quantum Optics
- R. Loudon, The Quantum Theory of Light
- Advances in Atomic Physics, Claude Cohen-Tannoudji and David Guéry-Odelin
- C. Cohen-Tannoudji et al., Atom-Photon-Interactions
- M. Scully and M.S. Zubairy, Quantum Optics
- Y. Yamamoto and A. Imamoglu, Mesoscopic Quantum Optics

Lecture notes

Autumn Semester 2024
Throughout the past 20 years, the realm of quantum physics has entered the domain of information technology in more and more prominent ways. Enormous progress in the physical sciences and in engineering and technology has allowed us to build novel types of information processors based on the concepts of quantum physics. In these processors, information is stored in the quantum state of physical systems forming quantum bits (qubits). The interaction between qubits is controlled and the resulting states are read out on the level of single quanta in order to process information. Realizing such challenging tasks is believed to allow constructing an information processor much more powerful than a classical computer. This task is taken on by academic labs, startups, and major industry. The aim of this class is to give a thorough introduction to physical implementations pursued in current research for realizing quantum information processors. The field of quantum information science is one of the fastest growing and most active domains of research in modern physics.

The topics covered in the course will include quantum circuits, gate decomposition, and universal sets of gates. Efficiency of quantum information processing problems. They are able to adapt and apply these concepts and methods to analyze and discuss quantum algorithms and other information-processing protocols.

The course covers the key concepts and formalism of quantum information processing. Topics include quantum algorithms, quantum error correction, quantum cryptography, and quantum metrology, with an emphasis on the power of quantum information processing beyond that of classical information processing. The formalism of quantum states, measurements, and channels is developed in detail.

By the end of the course students are able to explain the basic mathematical formalism of quantum mechanics and apply it to quantum information processing problems. They are able to adapt and apply these concepts and methods to analyze and discuss quantum algorithms and other information-processing protocols.

A good understanding of finite dimensional linear algebra is recommended.

More information on this class can be found on the web site www.qudev.ethz.ch.
402-0464-00L  Light-Matter Interaction in Semiconductors: Physics and Applications

Abstract
The course presents fundamental aspects of light-matter interaction in semiconductor materials, from basic research topics to opto-electronic devices.

Objective
The rich physics of the optical properties of semiconductors, as well as the advanced processing available on these materials, enabled numerous applications as well as the realization of new physical concepts. In this course, we will learn the principles of light-matter interaction in semiconductors for single and multiple particle excitations, and cover opto-electronic applications based on these principles.

Content
Electronic states in III-V materials and quantum structures, optical transitions, excitons and polaritons, novel two dimensional semiconductors, spin-orbit interaction, magneto-optics and opto-electronic devices.

Prerequisites / notice
Prerequisites: Quantum Mechanics II, Introduction to Solid State Physics, Quantum Electronics

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Social Competencies
- Self-presentation and Social Influence

Personal Competencies
- Creative Thinking

402-0465-58L  Intersubband Optoelectronics

Abstract
Intersubband transitions in quantum wells are transitions between states created by quantum confinement in ultra-thin layers of semiconductors. Because of its inherent taylorability, this system can be seen as the “ultimate quantum designer's material”.

Objective
The goal of this lecture is to explore both the rich physics as well as the application of these system for sources and detectors. In fact, devices based on intersubband transitions are now unlocking large area of the electromagnetic spectrum.

Content
The lecture will treat the following chapters:
- Introduction: intersubband optoelectronics as an example of quantum engineering
- Technological aspects
- Electronic states in semiconductor quantum wells
- Intersubband absorption and scattering processes
- Mid-IR and THz ISB Detectors
- Mid-infrared and THz photonics: waveguides, resonators, metamaterials
- Quantum Cascade lasers:
  - Mid-IR QCLs
  - THZ QCLs (direct and non-linear generation)
- Further electronic confinement: interlevel Qdot transitions and magnetic field effects
- Strong light-matter coupling in Mid-IR and THz range

Lecture notes
The reference book for the lecture is "Quantum Cascade Lasers" by Jerome Faist, published by Oxford University Press.

Literature
Mostly the original articles, other useful reading can be found in:
- E. Rosencher and B. Vinter, Optoelectronics, Cambridge Univ. Press
- G. Bastard, Wave mechanics applied to semiconductor heterostructures, Halsted press

Prerequisites / notice
Requirements: A basic knowledge of solid-state physics and of quantum electronics.

402-0526-00L  Ultrafast Processes in Solids

Abstract
Ultrafast processes in solids are of fundamental interest as well as relevant for modern technological applications. The dynamics of the lattice, the electron gas as well as the spin system of a solid are discussed. The focus is on time resolved experiments which provide insight into pico- and femtosecond dynamics.

Objective
After attending this course you understand the dynamics of essential excitation processes which occur in solids and you have an overview over state of the art experimental techniques used to study fast processes.

Content
1. Experimental techniques, an overview
2. Dynamics of the electron gas
   2.1 First experiments on electron dynamics and lattice heating
   2.2 The finite lifetime of excited states
   2.3 Detection of lifetime effects
   2.4 Dynamical properties of reactions and adsorbents
3. Dynamics of the lattice
   3.1 Phonons
   3.2 Non-thermal melting
4. Dynamics of the spin system
   4.1 Laser induced ultrafast demagnetization
   4.2 Ultrafast spin currents generated by lasers
   4.3 Landau-Lifschitz-Dynamics
   4.4 Laser induced switching
5. Correlated materials

Lecture notes
will be distributed

Literature
relevant publications will be cited

Prerequisites / notice
The lecture can also be followed by interested non-physics students as basic concepts will be introduced.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

Social Competencies
- Communication

Personal Competencies
- Creative Thinking

Autumn Semester 2024
Abstract

This course tackles the fundamental question of why only a few materials exhibit magnetism in Nature. The origin of atomic magnetic moments and the key mechanisms that govern their interactions are justified starting from fundamental principles. In addition, the influence of thermal fluctuations on magnetic ordering is discussed as well as the formalism to describe magnetic resonance phenomena.

Objective

By the end of this course, students will develop the ability to utilize quantum mechanics concepts to estimate the strength of atomic magnetic moments and understand their reciprocal interactions. They will gain proficiency in interpreting experimental measurements on model systems in terms of material composition and an appropriate, phenomenological spin Hamiltonian. For instance, students will be able to recognize whether the magnetic hysteresis observed in some samples arises from slow dynamics or from a phase transition. Lastly, they will be capable of interpreting the occurrence of abrupt transitions or the emergence of characteristic length scales as resulting from the interplay between competing interactions. Altogether, students will acquire the basic knowledge needed to develop a research project in the field of magnetism or to attend effectively more advanced courses on this topic.

Content

The lecture “Introduction to Magnetism” aims at letting students familiarize themselves with the basic principles of quantum and statistical physics that determine the behavior of real magnets. Understanding why only a few materials are magnetic at finite temperature will be the leitmotiv of the course. We will see that defining in a formal way what “being magnetic” means is essential to address this question properly. Theoretical concepts will be applied to a few selected nano-sized magnets, which will serve as clear reference systems.

Topics:
- Magnetism in atoms (quantum-mechanical origin of atomic magnetic moments, intra-atomic exchange interaction)
- Magnetism in solids (mechanisms producing inter-atomic exchange interaction in solids, crystal field)
- Magnetic order at finite temperatures (Ising, XY, and Heisenberg models, low-dimensional magnetism)
- Spin precession and relaxation (Larmor precession, resonance phenomena, quantum tunneling, Bloch equation, superparamagnetism)

Lecture notes

Learning material will be made available through Moodle and through the ETH JupyterHub.

Prerequisites / notice

Students are assumed to possess a basic background knowledge in quantum mechanics, solid-state and statistical physics as well as classical electromagnetism. Students will have the opportunity to self-assess their understanding through quizzes and interactive tutorials, mostly inspired by topics of current research in nanoscale magnetism.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Media and Digital Technologies: fostered
- Problem-solving: fostered

Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: assessed
- Self-direction and Self-management: fostered

402-0595-00L Semiconductor Nanostructures

Abstract

The course covers the foundations of semiconductor nanostructures, e.g., materials, band structures, bandgap engineering and doping, field-effect transistors. The physics of the quantum Hall effect and of common nanoscale phenomena based on two-dimensional electron gases will be discussed, i.e., quantum point contacts, Aharonov-Bohm rings and quantum dots.

Objective

At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:

1. The integer quantum Hall effect
2. Conductance quantization in quantum point contacts
3. The Aharonov-Bohm effect
4. Coulomb blockade in quantum dots

Content

1. Introduction and overview
2. Semiconductor crystals: Fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k.p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

Lecture notes


In addition to the lecture notes, the following supplementary books can be recommended:


Prerequisites / notice

The lecture is suitable for all physics students, students of Quantum Engineering, and students of Micro- and Nanosystems beyond the bachelor of science degree. Basic knowledge of solid state physics is a prerequisite. Very ambitious students in the third year of Physics may be able to choose the lecture can be chosen as part of the PhD-program. The course is taught in English.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Media and Digital Technologies: assessed
- Problem-solving: fostered

Social Competencies
- Communication: fostered
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-direction and Self-management: fostered
Advanced Magnetic Resonance - DNP Instrumentation

Abstract
The course is for advanced students and covers selected topics from magnetic resonance spectroscopy. The following topics will be covered:
- DNP theory & instrumentation
- Microwave theory & technology
- Biological applications of solid-state DNP

Objective
The course aims at enabling students to understand the key theoretical points of DNP and to design DNP experiments. Students will be familiarized with the structure of the state-of-the-art DNP instrumentation and will be introduced to the technological challenges towards the development of advanced instrumentation for the future DNP experiments. A special focus will be given in the technology of microwave source.
Furthermore, students will become familiar with pulse sequences used in biomolecular applications and understand how they are constructed. Students will be able to identify the strengths and weaknesses of biomolecular DNP and how to design DNP experiments for biological applications including sample preparation and choice of NMR experiment and related parameters.

Content
The course is separated in three well separated parts.

- The first part will cover DNP concept and mechanisms, while a special focus will be given in DNP instrumentation, such as MAS technology, and the NMR probe. Several details will be also presented on the development high field NMR magnet.

- The second part of the course is dedicated to the microwave technology and theory. This part starts with an introduction of the two different types of microwave sources, such as the solid-state devices and vacuum tubes, which are extensively used in DNP and EPR spectroscopy. A special focus will be given to the vacuum tube’s theory and technology. In this context, the Maxwell equations and the propagation of the transverse electric and transverse magnetic modes in circular waveguides will be taught. This material will be the basis for understanding the resonance theory and the fundamentals of the microwave’s generation in vacuum tubes. Based on the theoretical background gained in the previous lectures it will be possible to understand the operation principle of the slow wave devices, such as Klystron, Traveling Wave Tube (TWT), Backward Wave Oscillator (BWO) and Surface Wave Structure (SWS), as well as, the fast wave devices, such as gyro-devices, Free Electron Laser, etc. Finally, some details on the structure of a real DNP gyrotron will be presented.

- The third part of the course will cover CPMAS and homonuclear and heteronuclear recoupling schemes and their use in correlation spectroscopy for structure and molecular interaction determination. Sample preparation with particular emphasis of glassing agents and their relationship to DNP enhancements will be discussed. Resolution under DNP including a discussion about inhomogeneous and homogeneous broadening at cryogenic temperatures. Methods for circumventing low resolution at cryogenic temperatures will be discussed including site specific isotope labeling, bio-orthogonal labeling and site specific radical labeling/targeting. Concepts around the role of spin diffusion in DNP, direct and indirect DNP, paramagnetic broadening, longitudinal T1 and methyl quenching in biological NMR will also be discussed. These concepts will then be tied together through discussions of biomolecular applications of solid-state DNP including membrane proteins, in-cell DNP and viruses.

Lecture notes
A script which covers the topics will be accessible through the course Moodle

Prerequisites / notice
Prerequisite: A basic knowledge of Magnetic Resonance, e.g. as covered in the Lecture Physical Chemistry IV, or the book “Spin Dynamics” by Malcolm Levitt.

529-0455-00L Laser for Micro- and Nanostructuring

Abstract
Introduction to the fundamentals of lasers and their applications with an emphasis on micro- and nano-structuring. Several applications which are still in the research state, will be discussed together with industrial applications, such as microlithography and laser welding. Other aspects are the materials that are applied in these applications, e.g. photoresists, and their functioning.

Objective
Introduction to the fundamentals of lasers and their applications with an emphasis on micro- and nano structuring. Several applications which are still in the research state, e.g. non-optical lithographies, will be discussed together with industrial applications, such as microlithography and laser welding. Other aspects are the materials that are applied in these applications, e.g. photoresists, and their functioning.

Content
Introduction to lasers. Overview of micro- and nanotechnology, microlithography, photolithography, photoresists: classical types and new developments, laser cutting and welding, laser cleaning, laser ablation, polymer ablation: designed polymers, lasers and surfaces, laser spectroscopy, laser chemical vapor deposition, pulsed laser deposition (PLD), special materials by PLD, alternative structuring methods.

Lecture notes
The script (a copy of the slides) will be handed out during the first lecture.

Literature
FSRM, CD-ROM: An Introduction to the World of Microsystems, Neuchatel.
## Competencies

### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

### Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

### Personal Competencies
- Adaptability and Flexibility: fostered
- Critical Thinking: assessed
- Creativity: assessed
- Creativity: assessed
- Integrity and Work Ethics: assessed
- Leadership and Responsibility: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### Competency Levels
- **Assessed**
- **Fostered**

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### Microtechnology

**W 636-0103-00L**

<table>
<thead>
<tr>
<th>Abstract</th>
<th>Students are introduced to the basics of microtechnology, cleanroom, semiconductor and silicon process technologies. They will get to know the fabrication of mostly silicon-based microdevices and systems and all related microfabrication processes.</th>
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<tbody>
<tr>
<td>Objective</td>
<td>Students are introduced to the basics of microtechnology, cleanroom, semiconductor and silicon process technologies. They will get to know the different fabrication methods for various microdevices and systems.</td>
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<tr>
<td>Content</td>
<td>Introduction to microtechnology, semiconductors, and micro electro mechanical systems (MEMS)</td>
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<td>- Fundamentals of semiconductors and band model</td>
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<td>- Fundamentals of devices: transistor and diode.</td>
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<td></td>
<td>- Silicon processing and fabrication steps</td>
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<tr>
<td></td>
<td>- Silicon crystal structure and manufacturing</td>
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<td></td>
<td>- Thermal oxidation</td>
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<td></td>
<td>- Doping via diffusion and ion implantation</td>
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<tr>
<td></td>
<td>- Photolithography</td>
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<tr>
<td></td>
<td>- Thin film deposition: dielectrics and metals</td>
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<tr>
<td></td>
<td>- Wet etching &amp; bulk micromachining</td>
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<tr>
<td></td>
<td>- Dry etching &amp; surface micromachining</td>
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<tr>
<td></td>
<td>- Microtechnological processing and fabrication sequence</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Handouts in English</td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Fundamentals in physics and physicochemistry (orbital models etc.) are required, a repetitorium of fundamental physics and quantum theory at the semester beginning can be offered.</td>
</tr>
</tbody>
</table>

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### Anthropogenic Particles in the Environment

**W 701-1351-00L**

<table>
<thead>
<tr>
<th>Abstract</th>
<th>The lecture provides an overview on the behavior and effects of anthropogenic particles in the environment, covering engineered nanoparticles, micro/nanoplastics, tire wear, soot and pigments. The course will cover key concepts of particle behavior and analysis, fate in technical and natural systems, toxicity and environmental risk assessment and sustainability aspects and regulation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>- Successful application of knowledge gained in traditional disciplines of environmental sciences (e.g. biogeochemistry, environmental chemistry) to elucidate particle fate and behavior in the environment</td>
</tr>
<tr>
<td></td>
<td>- Identify key parameters that potentially influence the environmental fate and behavior of anthropogenic particles</td>
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<tr>
<td></td>
<td>- Get acquainted with the most common analytical tools for the quantification of anthropogenic particles in the environment</td>
</tr>
<tr>
<td></td>
<td>- Critical assessment of current state of research, including the sometimes controversial literature data</td>
</tr>
<tr>
<td>Content</td>
<td>- Definitions, particle types</td>
</tr>
<tr>
<td></td>
<td>- Particle behavior: colloidal behavior, transport, transformation</td>
</tr>
<tr>
<td></td>
<td>- Sources and release: Material flow modeling</td>
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<td></td>
<td>- Fundamentals of particle analysis</td>
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<td>- Release and emission</td>
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<tr>
<td></td>
<td>- Fate in the environment: water, soil, air</td>
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<td></td>
<td>- Fate in technical systems: water treatment, waste incineration</td>
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<td></td>
<td>- Uptake and toxicity of particles</td>
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<td></td>
<td>- Environmental risk assessment</td>
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<td>- Life cycle assessment</td>
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<tr>
<td>Lecture notes</td>
<td>Handouts will be provided</td>
</tr>
<tr>
<td>Literature</td>
<td>will be provided during lecture</td>
</tr>
</tbody>
</table>
### Soft Materials (MaP Doctoral School)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0213-00L</td>
<td>Fluid Dynamics with the Lattice Boltzmann Method</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>I. Karlin</td>
</tr>
</tbody>
</table>

**Abstract**
The course provides an introduction to theoretical foundations and practical usage of the Lattice Boltzmann Method for fluid dynamics simulations.

**Objective**
Methods like molecular dynamics, DSMC, lattice Boltzmann etc are being increasingly used by engineers all over and these methods require knowledge of kinetic theory and statistical mechanics which are traditionally not taught at engineering departments. The goal of this course is to give an introduction to ideas of kinetic theory and non-equilibrium thermodynamics with a focus on developing simulation algorithms and their realizations.

During the course, students will be able to develop a lattice Boltzmann code on their own. Practical issues about implementation and performance on parallel machines will be demonstrated hands on.

Central element of the course is the completion of a lattice Boltzmann code (using the framework specifically designed for this course).

The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, micromodels, and others.

Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.

**Content**
The course builds upon three parts:

1. **Elementary kinetic theory and lattice Boltzmann simulations introduced on simple examples.**
2. **Theoretical basis of statistical mechanics and kinetic equations.**
3. **Lattice Boltzmann method for real-world applications.**

The central elements of the course include:

1. **Background:** Elements of statistical mechanics and kinetic theory:
   - Particle's distribution function, Liouville equation, entropy, ensembles; Kinetic theory: Boltzmann equation for rarefied gas, H-theorem, hydrodynamic limit and derivation of Navier-Stokes equations, Chapman-Enskog method, Grad method, boundary conditions; mean-field interactions, Vlasov equation;
   - Kinetic models: BGK model, generalized BGK model for mixtures, chemical reactions and other fluids.

2. **Basics of the Lattice Boltzmann Method and Simulations:**
   - Minimal kinetic models: lattice Boltzmann method for single-component fluid, discretization of velocity space, time-space discretization, boundary conditions, forcing, thermal models, mixtures.

3. **Hands on:**
   - Development of the basic lattice Boltzmann code and its validation on standard benchmarks (Taylor-Green vortex, lid-driven cavity flow etc).

4. **Practical issues of LBM for fluid dynamics simulations:**
   - Lattice Boltzmann simulations of turbulent flows; numerical stability and accuracy.

5. **Microflow:**
   - Rarefaction effects in moderately dilute gases; Boundary conditions, exact solutions to Couette and Poiseuille flows; micro-channel simulations.

6. **Advanced lattice Boltzmann methods:**
   - Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

7. **Introduction to LB models beyond hydrodynamics:**
   - Lecture notes on the theoretical parts of the course will be made available.
   - Selected original and review papers are provided for some of the lectures on advanced topics.
   - Handouts and basic code framework for implementation of the lattice Boltzmann models will be provided.

**Lecture notes**
Relativistic fluid dynamics; flows with phase transitions.

**Prerequisites / notice**
The course addresses mainly graduate students (MSc/Ph D) but BSc students can also attend.

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### Continuum Mechanics I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0524-00L</td>
<td>Continuum Mechanics I</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>A. E. Ehret</td>
</tr>
</tbody>
</table>

**Abstract**
The lecture deals with constitutive models that are relevant for the design and analysis of components and structures. These include anisotropic linear elasticity, linear viscoelasticity, plasticity and viscoplasticity. The basic concepts of homogenization and laminate theory are introduced. Theoretical models are complemented by examples of engineering applications and experiments.

**Objective**
After successful completion of the course students are able to

- explain basic theories for solving continuum mechanics problems
- proficiently apply these theories by solving application-related academic examples
- relate the theories and examples to real engineering applications and challenges
- distinguish between different mechanical behaviors of materials
- systematically select appropriate constitutive theories suitable to analyze and model these materials

**Content**
- Anisotropic Elasticity, Linear Elastic and Linear Viscous Material Behavior, Viscoelasticity, Micro-Macro Modelling, Lamine Theory, Plasticity, Viscoplasticity, Examples of Engineering Applications, Comparison with Experiments

**Lecture notes**
yes
### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed

**Personal Competencies**
- Creative Thinking: fostered
- Critical Thinking: fostered

### Bioelectronics and Biosensors

**W** 6 credits 2V+2U  J. Vörös, M. F. Yanik

**Abstract**
The course introduces bioelectricity and the sensing concepts that enable obtaining information about neurons and their networks. The sources of electrical fields and currents in the context of biological systems are discussed. The fundamental concepts and challenges of measuring bioelectronic signals and the basic concepts to record optogenetically modified organisms are introduced.

**Objective**
During this course the students will:
- learn the basic concepts in bioelectronics including the sources of bioelectronic signals and the methods to measure them
- be able to solve typical problems in bioelectronics
- learn about the remaining challenges in this field

**Content**

1. **Introduction**
   - Sources of bioelectric signals
   - 2. Membrane and Transport
   - 3-4. Action potential and Hodgkin-Huxley

2. **Measuring bioelectronic signals**
   - 5. Detection and Noise
   - 6. Measuring currents in solutions, nanopore sensing and patch clamp pipettes
   - 7. Measuring potentials in solution and core conductance model
   - 8. Measuring electronic signals with wearable electronics, ECG, EEG
   - 9. Measuring mechanical signals with bioelectronics

3. **In vivo stimulation and recording**
   - 10. Functional electric stimulation
   - 11. In vivo electrophysiology

**Lecture notes**
A detailed script is provided to each lecture including the exercises and their solutions.

**Literature**
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

**Prerequisites / notice**
The course requires an open attitude to the interdisciplinary approach of bioelectronics. In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).
Content

- Introduction to surfaces and interfaces
- Structure of surfaces over different length scales: from macroscopic roughness to atomic structure
- Surface modifications
- Adsorption and adsorption models
- Surface forces
- Basic physical concepts
- Thermodynamics of surfaces and interfaces
- Measurement of intermolecular and surface forces
- Dynamics and history effects
- Surface analytics: X-ray Photoelectron Spectroscopy (XPS) – principles and modern developments
- Surface analytics: Secondary Ion Mass Spectroscopy (SIMS) and IR Spectroscopy – Principles and examples
- Atomic Force Microscopy (AFM): Principles and modes of operation
- Tribology: Adhesion, Friction and Lubrication
- Contact mechanics
- Micro and macroscale friction
- Boundary lubrication
- Wetting
- Contact angles
- Phoretic phenomena
- Electric double layer and electrophoresis
- Electro-osmosis
- Other types of phoresis
- Case studies

Lecture notes
Script Download: https://moodle-app2.let.ethz.ch/course/view.php?id=17455

Literature
Script Download: https://moodle-app2.let.ethz.ch/course/view.php?id=17455

Prerequisites / notice
Chemistry:
General undergraduate chemistry including basic chemical kinetics and thermodynamics

Physics:
General undergraduate physics including basic theory of interatomic and intermolecular forces, atomic and crystalline structure of materials and their mechanical and electronic properties

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed
- Project Management: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed

327-1207-00L Soft Materials Engineering and Characterization W 5 credits 4G J. Vermant, L. Isa

Abstract
In this course, we discuss engineering aspects of soft materials. First, we cover different classes of soft matter systems, e.g. suspensions, gels, emulsion and foams, and introduce scaling principles to design their structural, mechanical and functional properties. Second, we cover essential characterisation techniques to interrogate the structure-property relations in soft materials.

Objective
The learning goals of the course are to introduce the students to soft matter and its technological applications, to see how the structure-property relations depend on fundamental formulation properties and processing steps. Students should also be able to select a measurement technique to evaluate the properties.

Lecture notes
slides with text notes accompanying each slide are presented.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Leadership and Responsibility: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered


Abstract
This course explores the mechanisms that govern the adaptive functions of out-of-equilibrium systems in living organisms at the molecular scale and the microstructural design principles of biological materials at larger length scales. Throughout the course, we will also explore how these design principles can be incorporated into synthetic systems to improve targeted functions.

Objective
Students will gain the ability to analyze and integrate bio-inspired adaptive functions into synthetic material systems, as well as interpret the correlation between function, microstructure, and performance of biological and bio-inspired materials. Through engaging activities, students will also develop strategies to create bio-inspired solutions for typical engineering problems and predict the performance of bio-inspired materials.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 858 of 2653
This course is divided into two main blocks. The first block focuses on the primary molecular adaptations of living organisms, while the second block covers the fundamental microstructural design principles present in biological materials.

**Block I: Molecular Adaptations of Living Organisms and Creation of Adaptive Bio-inspired Materials**
- Temporal regulation in biological and bio-inspired molecular systems;
- Autonomous molecular structures and out-of-equilibrium systems;
- Molecular motion and work generation mechanisms in biological and bio-inspired systems;
- Sensing, adaptation, and communication in biological and bio-inspired material systems;

**Block II: Principles of Microstructural Design in Biological Materials and Their Synthetically Engineered Counterparts**
- Fundamentals of engineering in biological and bio-inspired materials;
- Replicating biological design principles in synthetic materials (structural, optical, surface properties, etc.);
- Bio-inspired design and systems (mechanical actuation and bio-inspiration in the built environment).

The course is mainly based on the references listed below. Additional references will be provided during the lectures.


**Lecture notes**
Copies of the slides will be made available for download before each lecture.

**Literature**

3.2145-00L Advanced Polymer Synthesis

**Abstract**
Modern polymer synthesis (based on recent development of new organic reactions) is discussed to enable students to develop synthesis schemes for certain target structures. Both chain (ionic, coordination, ROMP, radical, catalyst-transfer) and step-growth polymerizations (transition metal catalysis) including how to achieve living polymerization or improve selectivity will be discussed.

**Objective**
Students should be able to: Identify important polymerization procedures and types of polymerization. Predict activities of monomers based on the chemical structures. Devise synthetic pathways to produce a given polymer structure. Evaluate properties of macromolecules based on structure and synthesis method. Develop synthesis schemes for target structures and discuss potential applications of polymers.

**Content**
Polymerization is series of continuous organic transformation and connects small molecules. The course will give an overview of the following important polymerization procedures:
- Modern Step-growth polymerization
- Living Anionic polymerization
- Group transfer polymerization (GTP)
- Controlled cationic polymerization
- Controlled radical polymerization
- Coordination polymerization: Ziegler-Natta and Metallocene catalysts
- Olefin metathesis polymerization: ROMP, ADMET and cyclopolymerization
- Synthesis of conjugated polymers based on transition metal catalysis
- Complex macromolecules including brush and dendronized polymers

Students will learn how to deal with chemical structures and reactivities, and be able to suggest reasonable synthetic pathways to a given polymer structure, like conjugated polymers based on transition metal catalysis or complex macromolecules including brush and dendronized polymers. Aspects like controlling molar masses and structure perfection play a role throughout. The course provides the students with a high-level overview of modern methods of polymer synthesis both in theoretical and practical aspects. It should enable them to develop reasonable synthesis schemes for certain target structures and also to predict the properties of given macromolecules. For all polymers presented, potential or real applications will be discussed.

**Lecture notes**
They will be uploaded on Moodle

**Literature**
Lecture notes will be given

**Prerequisites / notice**
Strong basic knowledge of Organic Chemistry. Any course on Introductory Polymer Chemistry such as “Advanced Building Blocks for Soft Materials” or “Introduction to Macromolecular Chemistry” or equivalent (bachelor level is also sufficient). Please discuss with the lecturer if one is not certain about the prerequisites.

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376-0021-00L Materials and Mechanics in Medicine

Abstract
Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Objective
Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Content
Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

Lecture notes
course website on Moodle

Literature

Academic Press

376-1103-00L Frontiers in Nanotechnology

Abstract
Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.

Objective
Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within mammade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

Content
Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

Lecture notes
All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.

376-1351-00L Micro/Nanotechnology and Microfluidics for Biomedical Applications

Abstract
This course is an introduction to techniques in micro/nanotechnology and to microfluidics. It reviews how many familiar devices are built and can be used for research and biomedical applications. Transistors for DNA sequencing, beamers for patterning proteins, hard disk technology for biosensing and microfluidics for point-of-care diagnostics are just a few examples of the covered topics.

Objective
The main objective of the course is to introduce micro/nanotechnology and microfluidics to students having any technical background. The course is multi-disciplinary and covers a broad range of techniques. For each lecture, a brief historical perspective is given to illustrate by whom and how the techniques were invented.

The course should familiarize the students with the techniques used in micro/nanotechnology, cleanroom microfabrication, and show them how micro/nanotechnology pervades throughout life sciences. Microfluidics will be emphasized due to their increasing importance in research and for medical applications.

The second objective is to have life sciences students less intimidated by micro/nanotechnology and make them able to link instruments and techniques to specific problems that they might have in their projects/studies. This will also help students getting access to the ETHZ/IBM Nanotech Center infrastructure if needed.

Content
Mostly formal lectures (2 × 45 min), with few specific guest lectures on topics of particular relevance. For example, an introduction to cleanroom and micro/nanotechnology instruments and 3D printing will be provided. Last 3 weeks would be dedicated to the presentation and evaluation of projects by students (2 to 3 students per team). For this, about 12 recent technologies are listed and each team picks a technology and makes a short report and presentation describing how it works, its strengths and weaknesses, and describes what problem it solves.

In terms of technical content, the lectures will cover:
- an overview of the microelectronic industry, Moore’s law, field-effect transistors, next-generation DNA sequencing
- liquid crystal displays, organic light emitting diodes, electrophoretic displays, micromirrors and beamers, photopatterning of proteins and cells, optogenetics, and flexible displays and electronics
- hard disk drives and the giant magnetoresistance effect, magnetic nanoparticles, photonics, magnetic sensing and optical biosensing
- cleanroom techniques and instruments, from design to microfabrication of simple devices and microfluidics, examples of DNA microarrays
- the principles of microfluidics, microfluidic functions and fabrication, from microfluidics for research to point-of-care diagnostics, and the (infamous) history of Theranos, as well as some discussions on diagnostics for COVID, R0, and (im)precision of diagnostic devices and why it matters
- 2 × 45 min will be covered by Yüksel Temiz, a master of Arduino programming and do-it-yourself electronics, who will present how to make 20$ electronic components that are synergistic to microfluidic devices and that can be controlled using a smartphone
The course covers the following topics:

1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Content
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Literature:

(available online via ETH library)

For more information about the lecture: www.csms.ethz.ch/education/CSBMS

529-0004-01L Classical Simulation of (Bio)Molecular Systems

Abstract
Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Objective
Introduction to classical (atomistic) computer simulation of (bio)molecular systems, development of skills to carry out and interpret these simulations.

Content
Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Lecture notes
The powerpoint slides of the lectures will be made available weekly on the website in pdf format (on the day preceding each lecture).

Prerequisites / notice
Since the exercises on the computer do convey and test essentially different skills than those being conveyed during the lectures and tested at the oral exam, the results of the exercises are taken into account when evaluating the results of the exam (learning component, possible bonus of up to 0.25 points on the exam mark).

For more information about the lecture: www.csms.ethz.ch/education/CSBMS

529-0433-01L Advanced Physical Chemistry: Statistical Thermodynamics

Abstract

Content

Lecture notes
See homepage of the lecture.

Prerequisites / notice
Chemical Thermodynamics, Reaction Kinetics, Molecular Quantum Mechanics and Spectroscopy; Mathematical Foundations (Analysis, Combinatorial Relations, Integral and Differential Calculus).

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Media and Digital Technologies
- Adaptability and Flexibility
- Creative Thinking

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Personal Competencies
- Communication
- Critical Thinking

529-0455-00L Laser for Micro- and Nanostructuring

Abstract

Objective
The objective of this course is to provide an overview of laser technology and its applications in micro- and nanofabrication. Students will learn about different laser systems, their properties, and how they interact with materials. The course will cover laser ablation, selective laser melting, and other laser-based micro- and nanofabrication techniques.

Content

Lecture notes
The lecture notes will be made available online (moodle).

529-0004-01L Classical Simulation of (Bio)Molecular Systems

Abstract
Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Objective
Introduction to classical (atomistic) computer simulation of (bio)molecular systems, development of skills to carry out and interpret these simulations.

Content
Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Lecture notes
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Prerequisites / notice
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For more information about the lecture: www.csms.ethz.ch/education/CSBMS
Abstract

Introduction to the fundamentals of lasers and their applications with an emphasis on micro- and nano-structuring. Several applications which are still in the research state, will be discussed together with industrial applications, such as microolithography and laser welding. Other aspects are the materials that are applied in these applications, e.g. photoresists, and their functioning.

Objective

Introduction to the fundamentals of lasers and their applications with an emphasis on micro- and nano-structuring. Several applications which are still in the research state, e.g. non-optical lithographies, will be discussed together with industrial applications, such as microolithography and laser welding. Other aspects are the materials that are applied in these applications, e.g. photoresists, and their functioning.

Content

Introduction to lasers, Overview of micro- and nanotechnology, microolithography, photoresists: classical types and new developments, laser cutting and welding, laser cleaning, laser ablation, polymer ablation: designed polymers, lasers and surfaces, laser spectroscopy, laser chemical vapor deposition, pulsed laser deposition (PLD), special materials by PLD, alternative structuring methods.

Lecture notes

The script (a copy of the slides) will be handed out during the first lecture.

Literature

FSRM, CD-ROM: An Introduction to the World of Microsystems, Neuchatel.

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies fostered
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving assessed

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

529-0615-01L Biochemical and Polymer Reaction Engineering W 6 credits 3G P. Arosio, P. Fleckenstein

Abstract


Objective

The aim of the course is to learn how to design polymerization reactors and bioreactors to produce polymers and proteins with the specific product qualities that are required by different applications in chemical, pharmaceutical and food industry. This activity includes the post treatment of polymer latexes, the downstream processing of proteins and the analysis of their colloidal behavior.

Content

We will cover the fundamental processes and the operation units involved in the production of polymeric materials and proteins. In particular, the following topics are discussed: Overview on the different polymerization processes. Kinetics of free-radical polymerization and use of population balance models. Production of polymers with controlled characteristics in terms of molecular weight distribution. Kinetics and control of emulsion polymerization. Surfactants and colloidal stability. Aggregation kinetics and aggregate structure in conditions of diffusion and reaction limited aggregation. Modeling and design of colloid aggregation processes. Physico-chemical characterization of proteins and description of enzymatic reactions. Operation units in bioprocessing: upstream, reactor design and downstream. Industrial production of therapeutic proteins. Characterization and engineering of protein aggregation. Protein aggregation in biology and in biotechnology as functional materials.

Lecture notes

Scripts are available on the web page of the Arosio-group: http://www.arosiogroup.ethz.ch/education.html
Additional handout of slides will be provided during the lectures.

Literature

H.W. Blanch, D. S. Clark, Biochemical Engineering, CRC Press, 1995

529-0837-01L Biomicrofluidic Engineering W 6 credits 3G A. de Mello

Abstract

Microfluidics describes the behaviour, control and manipulation of fluids geometrically constrained within sub-uL environments. Microfluidic devices enable physical and chemical processes to be controlled with exquisite precision and in an fast and efficient manner. This course introduces the underlying concepts, features and applications of microfluidic systems in the chemical and life sciences.

Objective

We will investigate the theoretical concepts behind microfluidic device operation, the methods of microfluidic device manufacture and the application of microfluidic architectures to important problems faced in modern day chemical and biological analysis.

A central component of this course is a research project. This will allow students to develop a practical understanding of the benefits of miniaturization in chemical and biological experimentation. Projects will be performed in groups of between four and six students and will include both experimental and simulation aspects. Each group, under the guidance of a mentor, will plan and execute a novel research project. The results of this activity will be disseminated through an "academic-style" research article and a "conference-style" oral presentation. Course grades will be evaluated through both a written exam and the project grade.
Specific topics covered in the course include, but are not limited to:

1. Theoretical Concepts
   Scaling laws, features of thermal/mass transport, diffusion, basic description of fluid flow in small volumes, microfluidic mixing strategies.

2. Microfluidic Device Manufacture
   Basic principles of conventional lithography of rigid materials, 'soft' lithography, polymer machining (injection molding, hot embossing, and 3D-printing).

3. Electrokinetics
   Principles of electrophoresis, electroosmosis, high performance capillary electrophoresis, electrokinetic scaling laws, chip-based electrophoresis and isoelectric focusing.

4. Mass Transfer Phenomena
   Key features of mass transport in microfluidic systems, diffusive transport, diffusion-convection, Pécel number, Taylor-Aris diffusion, chaotic mixing and Damköhler numbers.

5. Heat Transfer Phenomena
   Key features of thermal transport in microfluidic systems, conduction, convection, heat transfer by convection in internal flows, heat transfer processes in microfluidic devices.

6. Microfluidic Systems for Materials Synthesis
   Microfluidic reactors for the controlled synthesis of colloidal nanomaterials, advanced automation for bespoke materials discovery & characterization.

7. Point-of-Care Diagnostics
   Microscale tools for diagnostics, challenges associated with point-of-care (PoC) diagnostic testing, requirements for PoC devices, common PoC device formats, applications of PoC diagnostics in the developing world.

8. Microscale DNA Amplification
   Amplification and analysis of nucleic acids using batch, continuous flow and droplet-based microfluidic reactors.

9. Small volume Molecular Detection
   Spectroscopic approaches for analyte detection in small volumes with a particular focus on single molecule detection.

10. Droplets and Segmented Flows
    Formation, manipulation and use of liquid/liquid segmented flows in chemical and biological experimentation.

11. Single Cell Analysis
    Applications of microfluidic tools in cellular analysis, flow cytometry, enzymatic assays and single cell analysis.

Lecture notes
Lecture handouts, background literature, problem sheets and notes will be provided electronically through the course Moodle site.

Literature
There is no set text for the course. All relevant literature will be provided electronically through the course Moodle site.

Competencies

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management

Social Competencies
Communication
Cooperation and Teamwork

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking

Cellular Matters: Properties, Functions and Applications of Biomolecular Condensates
The number of participants is limited to 30 and will only take place with a minimum of 6 participants.

At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate this, students must confirm their registration by the beginning of the 3rd week of semester.

Abstract
This Master level course delves into the emerging field of biomolecular condensates - membrane-less organelles in cells. Using interdisciplinary concepts from biology, chemistry, biophysics, and soft matter, we will explore the biological properties of these condensates, their functions in health and disease, and their potential as new biomimetic materials for various applications.

551-0357-00L
Cellular Matters: Properties, Functions and Applications of Biomolecular Condensates

Autumn Semester 2024
In the last decade, a novel type of cell compartments called biomolecular condensates have been discovered. This discovery is radically changing our understanding of the cell, its organization, and dynamics. The emerging picture is that the cytoplasm and nucleoplasm are highly complex fluids that can (meta)stably segregate into membrane-less compartments, similar to emulsions.

This interdisciplinary course encompasses milestone works and cutting-edge research questions in the young field of biomolecular condensates, including their properties, functions, and applications. The course begins with a lecture series that introduces the topic of condensates to an interdisciplinary audience and provides a theoretical foundation for understanding current research questions in the field. The lectures provide a base for student presentations of recent publications in the field, and for research seminars given by course lecturers, who are all active researchers with diverse expertise. Through this exciting interdisciplinary understanding of biomolecular condensates, bridging biology, chemistry, biophysics, and soft matter.

Students will not only learn how to critically read and evaluate scientific literature but will also gain valuable experience in giving scientific presentations to an interdisciplinary audience. Each presentation will require an introduction, critical analysis of the results, and a discussion of their significance, allowing student to substantiate their statements with a critical mindset that considers the pros and cons of chosen approaches and methods, as well as any limitations or possible follow-up experiments. This process will enable student to ask relevant queries and actively participate in class discussions, further enhancing their scientific skills.

In preparing the presentations, the students will have the unique opportunity to interact closely with each other and with the lecturers, who are all internationally well-established experts, and receive guidance in select a topic for the final presentation and supporting literature.

The topic of biomolecular condensates goes beyond the boundaries of traditional disciplines and requires a multi-disciplinary approach that leverages and cross-fertilizes biology, physical chemistry, biophysics, and soft matter. This course will explore the properties, functions and potential applications of biomolecular condensates, including their role in neurodegenerative diseases such as Alzheimer’s and Parkinson’s, as well as their use as smart biomimetic materials.

This course is divided into two parts. The first part will introduce the basic concepts essential to the study of biomolecular condensates and phase separation. Topics include: fundamental units and scales in soft matter, phase transitions in biology, biopolymers and molecular self-assembly, introduction to active matter. This will establish a foundation for the second part, which will explore milestone works and current research in the field of biomolecular condensates. Each lecture of this second part will consist of:

1) a short literature seminar, where student groups will present and discuss a milestone paper assigned in advance and
2) a research seminar, where one of the course lecturers will present their own state-of-the-art research in the field, building upon the milestone literature.

At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate this, students must confirm their registration by the beginning of the 3rd week of semester.

Lecture notes

Lecture slides and some scripts will be provided.

Literature

No compulsory textbooks. Literature will be provided during the course.

Compencies

| Subject-specific Competencies | Concepts and Theories | assessed |
| Method-specific Competencies | Analytical Competencies | assessed |
| Project Management | fostered |
| Social Competencies | Communication | assessed |
| Leadership and Responsibility | Self-presentation and Social Influence | fostered |
| Personal Competencies | Adapatability and Flexibility | fostered |
| Critical Thinking | assessed |
| Work Ethics | Self-awareness and Self-reflection | fostered |
| Negotiation | Self-direction and Self-management | fostered |

752-2000-00L Food Materials Science W 4 credits 3G R. Mezzenga, G. Nyström, M. Radiom

Abstract

Principles of soft condensed matter applied to food polymers, surfactants and colloids

Objective

Students will be able to:

- Describe the fundamental physical principles ruling the self-assembly, aggregation, processing and structure-properties relationship in food systems constituted by polysaccharides (polymers), proteins (colloids) and lipids (surfactants).
- Assess and recommend the best set of parameters controlling structure in foods
- Integrate physical and chemical principles to optimize food properties to meet specific requirements of defined food products

Competencies

| Subject-specific Competencies | Concepts and Theories | assessed |
| Method-specific Competencies | Analytical Competencies | assessed |
| Problem-solving | fostered |
| Personal Competencies | Creative Thinking | assessed |
| Critical Thinking | assessed |

752-2314-00L Physics of Food Colloids W 3 credits 2V P. A. Fischer, R. Mezzenga, M. Radiom

Abstract

In Physics of Food Colloids the principles of colloid science will be applied to the aggregation of food materials based on proteins, polysaccharides, and emulsifiers. Mixtures of such raw material determine the appearance and performance of our daily food. In a number of examples, colloidal laws are linked to food science and the manufacturing and processing of food.

Objective

The aggregation of food material determines the appearance and performance of complex food system as well as nutritional aspects. The underlying colloidal laws reflect the structure of the individual raw material (length scale, time scale, and interacting forces). Once these concepts are appreciated the aggregation of most food systems falls into recognizable patterns that can be used to modify and structure exiting food or to design new products. The application and use of these concepts are discussed in light of common food production.
Content

Lectures include interfacial tension (4h), protein aggregation in bulk and interfaces (4h), Pickering emulsions (2h), gels (2h), aggregation of complex mixtures (4h), and the use of light scattering in investigation complex food structures (8h). Most chapters include some hand-ons examples of the gain knowledge to common food products.

Lecture notes

Notes will be handed out during the lectures.

Literature

Provided in the lecture notes.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
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<th>assessed</th>
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<tbody>
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<td>Techniques and Technologies</td>
<td>assessed</td>
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Method-specific Competencies

| Analytical Competencies       | Decision-making          | fostered |
| Problem-solving               |                          | assessed |

Personal Competencies

| Communication                  | Critical Thinking        | fostered |

752-3103-00L

**Food Rheology**

W 3 credits 2V  P. A. Fischer

**Abstract**

Rheology is the science of flow and deformation of matter such as polymers, dispersions (emulsions, foams, suspensions), and colloidal systems. The fluid dynamical basis, measuring techniques (rheometry), and the flow properties of different fluids (Newtonian, non-Newtonian, viscoelastic) are introduced and discussed.

**Objective**

The course provides an introduction on the link between flow and structural properties of flowing material. Rheometrical techniques and appropriate measuring protocols for the characterization of complex fluids will be discussed. The concept of rheological constitutive equations and the application to different material classes are established.

**Content**

Lectures will be given on general introduction (4h), fluid dynamics (2h), complex flow behavior (4h), influence of temperature (2h), rheometers (4h), rheological tests (6h) and structure and rheology of complex fluids (4h).

**Lecture notes**

Notes will be handed out during the lectures.

**Literature**

Provided in the lecture notes.

**Competencies**

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</table>

Method-specific Competencies

| Analytical Competencies       | Decision-making          | fostered |
| Problem-solving               |                          | assessed |

Personal Competencies

| Communication                  | Critical Thinking        | fostered |

**Strength & Durability of Materials (MaP Doctoral School)**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0120-00L</td>
<td>Structural Glass Design and Façade Engineering</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td>V.-A. Silvestru</td>
</tr>
</tbody>
</table>

**Abstract**

The course gives an introduction to structural glass design and related façade engineering aspects. It will focus on the properties of the material glass and glass products, as well as on the structural design of glass elements and their supporting systems and connections.

**Objective**

After successful completion of the course, students will be able to:

- Understand and apply the fundamentals of the material glass and glass products, the basic principles for using glass as a load-carrying building material for structural applications and the types of connections used for glass elements;
- Recognize requirements for glass elements depending on their application area and chose the appropriate glass products and assemblies accordingly;
- Structurally design out-of-plane loaded glass elements based on available standards, both by hand calculations and specific software applications;
- Apply selected approaches for the structural design of in-plane loaded glass elements;
- Select suitable supporting systems (post-and-beam façade, curtain wall, etc.) and connections (point fixings, brackets, etc.) for the glass elements and structurally design them.
- Understand and apply the fundamentals of the material glass and glass products, the basic principles for using glass as a load-carrying building material for structural applications and the types of connections used for glass elements;
- Recognize requirements for glass elements depending on their application area and chose the appropriate glass products and assemblies accordingly;
- Structurally design out-of-plane loaded glass elements based on available standards, both by hand calculations and specific software applications;
- Apply selected approaches for the structural design of in-plane loaded glass elements;
- Select suitable supporting systems (post-and-beam façade, curtain wall, etc.) and connections (point fixings, brackets, etc.) for the glass elements and structurally design them.

**Content**

This course introduces civil engineering students to structural glass design and related façade engineering aspects. It aims to provide the students the knowledge required in engineering offices to design glass elements but at the same time, the necessary fundamentals for later performing research in this field. To achieve this, the course includes lectures, design exercises and a design project.

**Lectures**

The lectures will cover the following contents:

- Production methods and properties of the material glass and glass products and their structurally relevant properties (annealed glass, thermally tempered glass, chemically tempered glass, laminated glass, insulating glass, curved glass);
- Connection principles and types for glass elements (mechanical fixing, adhesive bonding);
- Requirements for glass elements depending on the application area (vertical glazing, overhead glazing, walk-on glazing, barrier glazing);
- Structural design of glass elements based on standards and research results (out-of-plane loaded glass elements and in-plane loaded glass elements);
- Typologies and design of structural systems for transparent façades;
- Requirements and functions for transparent façades.

**Design exercises**

The principles and methods presented in the lectures are practiced with the students in design exercises. Hand calculation methods and their limitations as well as the software for structural glass design SJ Mepla are used for out-of-plane loaded glass elements. For in-plane loaded glass elements, the specifics of numerical calculation procedures are exemplified with the software Abaqus.

**Design project**

The students will consolidate the knowledge gained in the theory-lectures and in the design exercises by working on a small design task (e.g. a glass canopy, a glass façade, a glass pavilion) in the form of a group work (ideally groups of 2-3 students). Within this task, the students will: conceptually design the structure and selected connection details; identify requirements for the glass elements and define their assembly; structurally design selected glass components, their support systems and their connections. The students will work on the design task in the second half of the semester and will get feedback on their progress in weekly review sessions. At the end of the semester, the groups will submit a project report and give an oral presentation of their projects.
Literature

Recommended and supplementary literature:

Prerequisites / notice

Prior knowledge of structural analysis, especially steel structures is necessary. Prior basic knowledge on the method of finite elements is recommended.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Creative Thinking
- Critical Thinking

101-0127-00L Advanced Structural Concrete

Abstract
This course supplements the courses Structural Concrete I and II regarding the analysis and dimensioning of reinforced and prestressed concrete structures. It focuses on limit analysis methods for walls, beams, slabs and shells, particularly regarding their applicability to the safety assessment of existing structures and their computer-aided implementation.

Objective
Within this course, the students are able to:
- deepen their understanding of structural concrete models and apply them to general design problems, including the assessment of existing structures.
- enhance their knowledge about the load-deformation response of reinforced and prestressed concrete structures.
- identify and assess the limits of applicability of limit analysis methods.
- recognise the assumptions of models suitable for computer-aided structural design and use in a critical way structural concrete design software.
- evaluate the long-term behaviour and the behaviour under fire conditions of concrete structures.
- assess the behaviour of fibre reinforced concrete structures.

Content
Fundamentals (structural analysis, theorems of limit analysis, applicability of limit analysis methods); walls and beams (stress fields and strut-and-tie models, compatibility and deformation capacity, membrane elements with yield conditions and load-deformation behaviour, computer-aided structural design); slabs (equilibrium solutions, yield conditions, shear and punching shear, sustainability); long term effects; steel fibre reinforced concrete (mechanical behaviour, applications); fire behaviour.

Lecture notes
Lecture notes see: http://www.concrete.ethz.ch

Literature

Prerequisites / notice

Students are assumed to be proficient in the material taught in the following courses offered in the BSc in Civil Engineering at ETH Zurich (or have acquired equivalent knowledge elsewhere):
- Theory of structures I+II
- Structural Concrete I+II (incl. prestressed concrete)

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

101-0129-00L Non Destructive Evaluation & Rehabilitation of Existing Structures

Abstract
Introduction to non destructive evaluation tools and quantitative structural analyses and verifications for condition assessment of existing structures and subsequent decisions on their rehabilitation.

Objective
The goal is for students to familiarize themselves with the handling of assessment and rehabilitation of existing structures from the perspective of a consulting engineer, following a systematic approach as described in current codes and to further learn how to use new non destructive evaluation technologies.

Content
This course is organized in two main pillars. The first pillar describes the technologies that are available for non destructive evaluation of structures and delves into description of the principle of operation of such methods (e.g. wave propagation, acoustic emission analysis, tomography). The second pillar, overviews the current implementation of condition assessment processes in codes and standards. Complementary to the topic of structural evaluation, the topic of interventions, rehabilitation and retrofitting of existing structures for different construction materials is next addressed.

Lecture notes
Lecture notes

Literature
- Swiss Standards SIA 269, 269/1 to 269/7
- SIA-Document D 0239 « Existing Structures – Introduction » (in German/French)
- SIA-Document D 0239 « Existing Structures – Consolidation and Practice » (in German/French)
In Steel Structures III, students will deepen and expand their theoretical background and practical knowledge of the design and construction of steel and composite structures. Special composite structures, such as thin-walled cold-formed sections, crane girders, masts, tanks & silos, are covered. The focus of the course lies on design tasks and solutions in modern, multi-storey, steel-framed buildings driven by architectural needs, as well as certain special fields of application of steel structures. Students will learn how to solve complex structural engineering tasks in larger building projects, e.g. through the use and correct design of large-span slim-floor girders and ultra-slim-composite columns, or the use of glazing and cable structures as principal load-carrying components. They learn how steel structures behave under fire conditions and how they can be protected and designed accordingly. Finally, students learn about the fundamental aspects governing the design of specialty steel structures, such as thin-walled cold-formed sections, crane girders, masts and storage tanks.

The examples of scientific and standardisation work provided in the lectures give the students the opportunity to learn about the most current developments and see how these are used to shape the future practice in the structural engineering field.

### Content

Steel Structures III provides an in-depth theoretical background and practical knowledge on advanced design topics in steel and composite structures. The focus of the course lies on design tasks and solutions in modern, multi-storey, steel-framed buildings driven by architectural needs, as well as some critical fields of application of steel structures. The course discusses the use and design of large-span slim-floor girders and ultra-slim-composite columns, as well as the use of glazing and cable structures as principal load-carrying components. The course covers the design of steel structures under elevated temperatures (fire conditions) is treated, as well as certain special topics for design of serviceability. In addition, fundamental concepts of the design of cold-formed steel framed structures are discussed. Finally, the course will give an overview on the design of specialty steel structures, such as crane girders, masts and storage tanks.

### Literature

- **Stahlbaukalender (various editions), Ernst + Sohn, Berlin**
- **Nonlinear Finite Elements of Continua and Structures, T. Belytschko, W.K. Liu, and B. Moran.**

### Useful (optional) Reading:

Prerequisites / notice

- **Prerequisites:**
  - 101-0158-01 Method of Finite Elements I (FS)
  - A good knowledge of Python is necessary for attending this course.

Competencies

**Subject-specific Competencies**
- Concepts and Theories

**Method-specific Competencies**
- Analytical Competencies
- Problem-solving

**Social Competencies**
- Cooperation and Teamwork

**Personal Competencies**
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

**Method-specific Competencies**
- Problem-solving

**Social Competencies**
- Cooperation and Teamwork

**Personal Competencies**
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

101-0167-01L Fibre Composite Materials in Structural Engineering W 3 credits 2G M. Motavalli

**Abstract**

1) Lamina and Laminate Theory
2) FRP Manufacturing and Testing Methods
3) Design and Application of Externally Bonded Reinforcement to Concrete, Timber, and metallic Structures
4) FRP Reinforced Concrete, All FRP Structures
5) Measurement Techniques and Structural Health Monitoring

**Objective**

At the end of the course, you shall be able to

1) Design advanced FRP composites for your structures,
2) To consult owners and clients with necessary testing and SHM techniques for FRP structures,
3) Continue your education as a PhD student in this field.

**Content**

Fibre Reinforced Polymer (FRP) composites are increasingly being used in civil infrastructure applications, such as reinforcing rods, tendons and FRP profiles as well as wraps for seismic upgrading of columns and repair of deteriorated structures. The objective of this course is on one hand to provide new generation of engineering students with an overall awareness of the application and design of FRP reinforcing materials for internal and external strengthening (repair) of reinforced concrete structures. The FRP strengthening of other structures such as metallic and timber will also be shortly discussed. On the other hand the course will provide guidance to students seeking additional information on the topic. Many practical cases will be presented, analysed and discussed. An ongoing structural health monitoring of these new materials is necessary to ensure that the structures are performing as planned, and that the safety and integrity of structures is not compromised. The course outlines some of the primary considerations to keep in mind when designing and utilizing structural health monitoring technologies. During the course, students will have the opportunity to design FRP strengthened concrete beams and columns, apply the FRP by themselves, and finally test their samples up to failure.

**Lecture notes**

Power Point Presentations available online at www.empa.ch/abt303

**Literature**

3) fib bulletin 19, Externally applied FRP reinforcement for concrete structures, technical report, 2019
4) SIA166 (2004) Klebewerbewehrungen (Externally bonded reinforcement), Schweizerischer Ingenieur- und Architektenverein SIA

Prerequisites / notice

1) Laboratory Tours and Demonstrations: Empa Structural Engineering Laboratory including FRP Composites, Shape Memory Alloys, Timber Elements, Large Scale Testing of Structural Components
2) Working with Composite Materials in the Laboratory (application, testing, etc)

101-0527-10L Materials and Constructions W 4 credits 2G G. Habert, M. Posani

**Abstract**

Building materials with a special focus on regenerative materials: earth, bio-based and reuse. Looking at material sourcing, properties and performance, as well as how they are integrated in the buildings (building envelope and detailing).

Choice of material is done out of sustainability concern. Comfort, moisture transfer and building physics with hygroscopic materials.

**Objective**

Special focus on regenerative materials: earth, bio-based and reuse

The students will acquire knowledge in the following fields:

- Fundamentals of material performance
- Introduction to durability problems of building facades

Materials for the building envelope:
- Overview of structural materials and systems: concrete, steel, stone, earth, wood and bamboo
- Insulating materials (bio-based vs conventional)

Assessment of materials and components behaviour and performance

Degradation risks connected to insulation and post-insulation

Aspects of sustainability and durability

Special focus on comfort, moisture transfer and building physics with hygroscopic materials will be done.

**Content**

Introduction Sustainable cement and concrete
Earth construction
Stone
Steel
Bamboo
Timber construction
Building physic and conventional insulation
Bio-based insulation and degradation risks with insulation
Hygrothermal properties of building materials and dynamic numerical simulations
Efficiency and sustainability of modern window glazing

Course will have general lectures
+ hands on lab @home experiments
+ group project for implementation of regenerative materials.
Competencies

Subject-specific Competencies
Techniques and Technologies assessed

Method-specific Competencies
Decision-making fostered
Problem-solving assessed

Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Self-awareness and Self-reflection fostered

Abstract
The course on Advances in Building Materials provides an introductive overview of the needs and future of materials science in the building sector. Focus topics concern sustainability, durability, thermal insulation, coatings, sealants, adhesives, flame retardancy and the future perspective and developments of concrete and wood with regard to smart material development and ecological concerns.

Objective
In this course, the students will gain a broad overview of the use of materials in the building sector, with a particular focus on concrete and wood. Current limitations and in particular sustainability related challenges will be detailed with the objective of laying the grounds to discuss future developments anticipated in this field.

Content
This course for civil engineers lays the grounds in the specialization Materials and Mechanics and complements the second introductory course of the specialization on Numerical Mechanics of Materials. The course also addresses master students in Materials Science and other study programs interested in deepening their understanding of application-relevant properties of engineering materials and sustainability related challenges.

The following topics are covered:
1. Material selection
2. Materials and sustainability 1
3. Materials and sustainability 2
4. Recyclability
5. Material science of wood durability
6. Material science of concrete durability
7. Foams in construction and thermal insulation
8. Sealants and adhesives in construction
9. Coatings
10. Flame retardants
11. Future of wood – 1
12. Future of wood – 2
13. Future of concrete – 1
14. Future of concrete – 2

Lecture notes
Handouts will be provided for each lecture.

Abstract
Introduction to computational sciences with focus on numerical modeling of the mechanics of materials. Simulation of material damage, fracture and failure with various material models.

Objective
Learning from mistakes and failures is as old as the engineering discipline. Understanding why things went wrong is essential for improvement, but often impossible without the help of numerical modelling. Real world problems are often highly nonlinear, dependent on multiple physical fields, involve fundamental material behavior far from equilibrium and reversibility, and can often only be understood by addressing different relevant scales.

In this course, we will use real-life cases to learn how to deal with such problems. Starting from the problem description with governing equations, you will learn how to tackle non-linear and multi-field problems using numerical simulations. A particular focus will be on fracture. We will investigate the conditions and mechanisms that lead to material failure and analyze the contributions of plastic behavior, size effects, randomness in the underlying material micro-structure, and various other non-linear material behavior. You will learn various approaches to model the mechanics of complex heterogeneous materials and to implement your model in Python code to run numerical simulations.

Content
1 Introduction to (numeric) forensic engineering
2 The nature of engineering problems (governing equations)
3 Numerical recipes for dealing with non-linear problems
4 Multi-field problems (HTM)
5 Creep and relaxation
6 On the nature of failure - Physics of damage and fracture
7 Cracks and growth in structures (LEFM and beyond)
8 Damage and fracture in heterogeneous materials
9 Mechanics of fatigue
10 Student -Project presentation

Lecture notes
Will be provided during the lecture via moodle.

Literature
Will be provided during the lecture.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Social Competencies
Communication assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-direction and Self-management fostered

Abstract
Learning from mistakes and failures is as old as the engineering discipline. Understanding why things went wrong is essential for improvement, but often impossible without the help of numerical modelling. Real world problems are often highly nonlinear, dependent on multiple physical fields, involve fundamental material behavior far from equilibrium and reversibility, and can often only be understood by addressing different relevant scales.

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Content
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8 Damage and fracture in heterogeneous materials
9 Mechanics of fatigue
10 Student -Project presentation

Lecture notes
Will be provided during the lecture via moodle.

Literature
Will be provided during the lecture.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Social Competencies
Communication assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-direction and Self-management fostered
We look at the durability of reinforced concrete structures, covering common deterioration processes such as reinforcement corrosion, frost damage, ASR, etc. The course spans the range from fundamental mechanisms to aspects of engineering practice. New methods and materials for preventative measures, condition assessment and repair techniques are treated. Examples from real cases are shown.
Objective
After this course you will have profound understanding about:
- the different mechanisms of deterioration of concrete structures, in particular reinforcement corrosion
- the relevant parameters affecting durability of reinforced concrete (cover depth, concrete quality, moisture, etc.)

Furthermore, you will know:
- current engineering approaches for durability design (according to standards) and their limitations
- refined models for enhanced durability design and service life predictions
- preventive measures to improve durability (e.g. stainless steel reinforcement, concrete surface coatings, etc.)
- the particular durability challenges with post-tensioned structures and ways to overcome them (electrically isolated tendons)
- methods for inspection and condition assessment of existing, ageing structures (including non-destructive techniques and monitoring with sensors)
- repair methods for deteriorated concrete structures such as conventional repair and electrochemical methods (in particular cathodic protection)
- possible future problems for durability that may arise with modern materials and construction technologies

Content
- Socio-economic challenges related to ageing infrastructures
- Degradation mechanisms for concrete: sulphate attack, ASR, frost attack.
- Inspection and condition assessment: Chloride analyses, carbonation depth, etc. Non-destructive tests, particularly potential mapping to detect corrosion. New developments (for example, monitoring with sensors).
- Stainless steel as reinforcing steel for concrete: Different types of stainless steels. Coupling with black reinforcing steel. Examples of application. Life-cycle-costs.
- Modern materials and construction technologies: Discussion of expected implications for the durability of structures today and in the future.

Excursion:
- We generally try to organize a site-visit (depending on availability of construction sites). Presumably, we will visit an installation site of cathodic protection on a concrete structure in the Zurich area.

Lecture notes
The course is based on the book

Slides of the lectures will be distributed in advance

Literature
The course is based on the book

Slides of the lectures will be distributed in advance

Prerequisites / notice
Special handouts and reprints for particular topics will be distributed

Form of teaching:
The course is a lecture that contains frequent discussion and interaction between students and lecturer. You will see and work on many examples from engineering practice, both during the lectures and in the form of exercises to be solved at home.

Report:
Each student will work on a small case study and deliver a report during the semester. The report will be graded.

Excursion:
We generally try to organize a site-visit (depending on availability of construction sites). Presumably, we will visit an installation site of cathodic protection on a concrete structure in the Zurich area.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

101-0677-00L Concrete Technology W 2 credits 2G F. Nägeli, G. Martinola, T. Wangler

Abstract
Opportunities and limitations of concrete technology. Commodities and leading edge specialties.

Objective
Advanced education in concrete technology for civil engineers who are designing, specifying and executing concrete structures.
Based on the lecture 'Werkstoffe' students receive deep concrete technology training. Comprehensive knowledge of the most important properties of conventional concrete and the current areas of research in concrete technology will be presented. The course covers various topics, including:

- concrete components
- concrete properties
- concrete mix design
- production, transport, casting
- demoulding, curing and additional protective measures
- durability
- standards
- chemical admixtures
- alternative binders
- specialty concretes such as: self compacting concrete, fiber reinforced concrete, fast setting concrete
- the role of sustainability in concrete technology
- new research in digital fabrication with concrete

Lecture notes
Slides provided for download.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Problem-solving assessed

Social Competencies
Communication assessed
Cooperation and Teamwork assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed

151-0353-00L Mechanics of Composite Materials
W 4 credits 2V+1U G. Pappas

Abstract
The courses treats aspects related to elastic behavior of unidirectional and multidirectional laminates, micromechanics, failure and damage analysis, analysis and design of composite structures. The focus is on laminated fiber-reinforced polymer composites.

Objective
The objective is to introduce the basic concept of composite materials and provide a thorough understanding of the mechanical response of such materials and structures particularly made from fiber reinforced polymer composites, including elastic behavior, failure, fracture and damage analysis as well as structural design aspects. The ultimate goal is to provide the necessary skills to address the design and analysis of modern lightweight composite structures.

Content
The course is addressing following topics:
- Introduction
- Elastic anisotropy
- Micromechanics & Homogenization
- Classical Laminate Theory (CLT)
- Strength, failure and damage analysis
- Thin ply composite shells & effects of material non-linearity
- Analysis and design of composite structures

Lecture notes
Script, handouts, exercises and additional material are available in PDF-format on the moodle page of the lecture.

Literature
The lecture material is covered by a script/lecture notes compiled by CMASLab and further literature is referenced therein.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management fostered

151-0524-00L Continuum Mechanics I
W 4 credits 2V+1U A. E. Ehret

Abstract
The lecture deals with constitutive models that are relevant for the design and analysis of components and structures. These include anisotropic linear elasticity, linear viscoelasticity, plasticity and viscoplasticity. The basic concepts of homogenization and laminate theory are introduced. Theoretical models are complemented by examples of engineering applications and experiments.

Objective
After successful completion of the course students are able to
- explain basic theories for solving continuum mechanics problems
- proficiently apply these theories by solving application-related academic examples
- relate the theories and examples to real engineering applications and challenges
- distinguish between different mechanical behaviors of materials
- systematically select appropriate constitutive theories suitable to analyze and model these materials

Content
Anisotropic Elasticity, Linear Elastic and Linear Viscous Material Behavior, Viscoelasticity, Micro-Macro Modelling, Laminate Theory, Plasticity, Viscoplasticity, Examples of Engineering Applications, Comparison with Experiments

Lecture notes
yes
Creative Thinking

Analytical Competencies

Subject-specific Competencies

Method-specific Competencies

Personal Competencies

Comprehensiveness

Prerequisites / notice

151-0525-00L Dynamic Behavior of Materials

Lectures and computer labs concerned with the modeling of the deformation response and failure of engineering materials (metals, polymers and composites) subject to extreme loadings during manufacturing, crash, impact and blast events.

Objective

Students will learn to apply, understand and develop computational models of a large spectrum of engineering materials to predict their dynamic deformation response and failure in finite element simulations. Students will become familiar with important dynamic testing techniques to identify material model parameters from experiments. The ultimate goal is to provide the students with the knowledge and skills required to engineer modern multi-material solutions for high performance structures in automotive, aerospace and naval engineering.

Content

Topics include temperature and strain rate dependent elasto-plasticity, dynamic brittle and ductile fracture; impulse transfer, impact and wave propagation in solids; computational aspects of material model implementation; simulation of dynamic failure of structures;

Lecture notes / Literature

Various books will be recommended pertaining to the topics covered.

Prerequisites

Course in continuum mechanics (mandatory), finite element method (recommended)

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Decision-making

Problem-solving

Personal Competencies

Creative Thinking

Critical Thinking

151-0529-00L Nonlinear FEA

Does not take place this semester.

Note: The previous course title until HS23 "Computational Mechanics II: Nonlinear FEA"

Abstract

The course provides an introduction to non-linear finite element analysis. The treated sources of non-linearity are related to material properties (hyperelasticity, plasticity), kinematics (large deformations, instability problems) and boundary conditions (contact). It aims to provide the students with the knowledge and skills required to address all major sources of non-linearity in theory and numerics, and to apply this knowledge to the solution of relevant problems in solid mechanics.

Objective

To be able to address all major sources of non-linearity in theory and numerics, and to apply this knowledge to the solution of relevant problems in solid mechanics.

Content

1. Introduction; various sources of non-linearities and implications for FEA.

Prerequisites / notice

Lecture notes / Literature

Lecture notes will be provided. However, students are encouraged to take their own notes.

Prerequisites

Mechanics 1, 2, Dynamics, Continuum Mechanics I and Introduction to FEA. Ideally also Continuum Mechanics II.

151-0544-00L Metal Additive Manufacturing - Mechanical Integrity and Process Simulation

Note: The previous course title until HS22 "Metal Additive Manufacturing - Mechanical Integrity and Numerical Analysis"

Abstract

An introduction to Metal Additive Manufacturing (MAM) (e.g. different techniques, the metallurgy of common alloy-systems, existing challenges) will be given. The focus of the lecture will be on the employment of different simulation approaches to address MAM challenges and to enable exploiting the full advantage of MAM for the manufacture of structures with desired property and functionality.

Objective

The main objectives of this lecture are:
- Acknowledging the possibilities and challenges for MAM (with a particular focus on mechanical integrity aspects),
- Understanding the importance of material science and metallurgical considerations in MAM,
- Appreciating the importance of thermal, fluid, mechanical and microstructural simulations for efficient use of MAM technology,
- Using commercial analysis tools (e.g. ABAQUS) for simulation of the MAM process.

Content

- Introduction to MAM (concept, application examples, pros & cons),
- Powder-bed and powder-blown metal additive manufacturing,
- Thermo-fluid analysis of additive manufacturing,
- Continuum-based thermal modelling and experimental validation techniques,
- Residual stress and distortion simulation and verification methods,
- Microstructural simulation (basics, analytical, kinetic Monte Carlo, cellular automata, phase-field),
- Mechanical property prediction for MAM,
- Microstructure and mechanical response of MAM material (stainless steel, Ti6Al4V, Inconel 718),
- Design for additive manufacturing,
- Artificial intelligence for AM

Exercise sessions use ABAQUS for analysis of MAM process. Detailed video instructions will be provided to enable students to set up their own simulations. Students can install the packages on their own systems.

Prerequisites / notice

Handouts of the presented slides.

No textbook is available for the course (unfortunately), since it is a dynamic and relatively new topic. In addition to the material presented in the course slides, suggestions/recommendations for additional literature/publications will be given (for each individual topic).
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

151-0550-00L Adaptive Materials for Structural Applications W 4 credits 3G A. Bergamini

Abstract
Adaptive materials offer appealing ways to extend the design space of structures by introducing time-variable properties into them. In this course, the physical working principles of selected adaptive materials are analyzed and simple models for describing their behavior are presented. Some applications are illustrated, also with laboratory experiments where possible.

Objective
The study of adaptive materials covers topics that range from chemistry to theoretical mechanics.

Content
This course will provide the students with an insight into the properties and physical phenomena which lead to the features of adaptive materials. Starting from chemomechanical (skeletal muscles), the physical behavior of a wide range of adaptive materials, thermo- and photo-mechanical, electro-mechanical, magneto-mechanical and meta-materials will be thoroughly discussed and analyzed. Up-to-date results on their performance and their implementation in mechanical structures will be detailed and studied in laboratory sessions. Analytical tools and energy based considerations will provide the students with effective instruments for understanding adaptive materials and assess their performance when integrated in structures or when arranged in particular fashions.

Basic concepts: Power conjugated variables, dissipative effects, geometry- and materials-based energy conversion


Thermo-mechanical coupling: Shape memory alloys / polymers

Electromechanical coupling(1): DEA, EBL, electrorheological fluids

Shape control / morphing: Use, requirements, challenges

Morphing applications of variable stiffness structures: Lab work

Electromechanical coupling (2): Piezoelectric, electrostrictive effect

Vibration Reduction: Measurement, passive, semi-active (active) damping methods

Vibration reduction applications of piezoelectric materials: Lab work

Metamaterials: Definition of metamaterials - electromagnetic, acoustical and other metamaterials

Energy harvesting and sensing: Energy harvesting with EAP and piezoelectric materials, transducers as sensors: Piezo, resistive,...

Lecture notes
Lecture notes (manuscript and handouts) will be provided

Literature
All material is provided online via Moodle.

151-8015-00L Moisture Transport in Porous Media W 3 credits 2G J. Carmeliet, A. Kubilay, A. Rubin, D. A. Strebel

Abstract
Moisture transport and related degradation processes in porous materials Theory of moisture transport in porous materials

Experimental determination of moisture transport properties

Exercises on moisture transport properties determination:

Selected topics

Liquid transport in cracked porous media, Drying of porous media, microclimate in urban street canyons.

Objective
- Basic knowledge of moisture transport and related degradation processes in porous materials
- Knowledge of experimental determination of moisture transport properties
- Application of knowledge to moisture transport in cracked materials, drying of porous materials and microclimate in urban street canyons

Content
1. Introduction

Moisture damage: problem statement, durability

Applications: building materials, soil science, geoscience

2. Moisture transport: theory and application

Description of moisture transport

Determination of moisture transport properties

Exercises on moisture transport properties

3. Special topics

Liquid transport in cracked materials, Drying of porous materials, Microclimate in urban street canyons

Lecture notes
Handouts, supporting material and exercises are provided online via Moodle.

Literature
All material is provided online via Moodle.
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

227-0377-10L  Physics of Failure and Reliability of Electronic Devices and Systems

W  3 credits  2V  I. Shorubalko, M. Held

Abstract
Understanding the physics of failures and failure mechanisms enables reliability analysis and serves as a practical guide for electronic devices design, integration, systems development and manufacturing. The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.

Objective
Provide an understanding of the physics of failure and reliability. Introduce the degradation and failure mechanisms, basics of failure analysis, methods and tools of reliability testing.

Content
Summary of reliability and failure analysis terminology; physics of failure: materials properties, physical processes and failure mechanisms; failure analysis; basics and properties of instruments; quality assurance of technical systems (introduction); introduction to stochastic processes; reliability analysis; component selection and qualification; maintainability analysis (introduction); design rules for reliability, maintainability, reliability tests (introduction).

237-2103-00L  Composites and Hybrids: From Design to Application

W  5 credits  3V+1U  F. J. Clemens, B. Weisse, A. Winistörfer

Abstract
Composites/hybrids are heterogeneous materials consisting of two or more bonded components, and it is possible to tailor material properties for certain applications. Typically, The components retain their structure and properties, but the properties of the composite are a combination of the properties of its components.

Objective
In this course you will get an inside to lightweight material with high strength, materials that are resistant against abrasion, ceramics with damage tolerance behavior, composites with bioactive, bioreabsorbable, piezoresistive and -electric properties. Enables materials scientists to design composite/hybrid materials for different applications. The course will comprise a balance of lectures, exercises and laboratory classes.

Content
Introduction and basic concepts on biomedical composites and smart composites/hybrids with sensing and actuation properties; production and properties of composites reinforced with particles, whiskers, short or long fibers; selection criteria, case studies and applications, future perspectives.

1. Structural composites (polymer-, metal- and ceramic matrix composites)
   1.1. Introduction and historical background
   1.2. Components: Matrix and reinforcement materials
   1.3. Types of composites and mechanisms of reinforcement
   1.4. Production processes
   1.5. Physical and chemical properties
   1.6. Applications

2. Biomedical Composites
   2.1. Introduction and historical background
   2.2. Components: metals&alloys, natural/synthetic polymers, bioceramics
   2.3. Types of biocomposites
   2.4. Production processes
   2.5. Properties
   2.6. Applications

3. Functional Composites (Sensors and Actuators)
   3.1. Introduction and historical background
   3.2. Components: Matrix and functional filler material
   3.3. Types of composites
   3.4. Production processes
   3.5. Properties
   3.6. Applications

Lecture notes
We will work with handouts

Literature
- Biomedical composites, J. Paulo Davim (Ed.), De Gruyter (2014)
- Biocomposites, J. Paulo Davim (Ed.), De Gruyter (2014)
- Bioresorbable polymers for biomedical applications – from fundamentals to translational medicine, G. Perale, J. Hilborn (Eds), Woodhead Publishing (2017)
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

376-0021-00L Materials and Mechanics in Medicine

Abstract
Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Objective
Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Content
Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

Lecture notes
course website on Moodle

Literature

Sustainable & Bioinspired Materials (MaP Doctoral School)

Number Title Type ECTS Hours Lecturers
101-0527-10L Materials and Constructions W 4 credits 2G G. Habert, M. Posani

Abstract
Building materials with a special focus on regenerative materials: earth, bio-based and reuse. Looking at material sourcing, properties and performance, as well as how they are integrated in the buildings (building envelope and detailing).

Objective
Choice of material is done out of sustainability concern.

Special focus on regenerative materials: earth, bio-based and reuse

The students will acquire knowledge in the following fields:
- Fundamentals of material performance
- Introduction to durability problems of building facades
- Materials for the building envelope:
  - Overview of structural materials and systems: concrete, steel, stone, earth, wood and bamboo
  - Insulating materials (bio-based vs conventional)
- Assessment of materials and components behaviour and performance
- Degradation risks connected to insulation and post-insulation
- Aspects of sustainability and durability

Content
Introduction
- Sustainable cement and concrete
- Earth construction
- Stone
- Steel
- Bamboo
- Timber construction
- Building physic and conventional insulation
- Bio-based insulation and degradation risks with insulation
- Hygrothermal properties of building materials and dynamic numerical simulations
- Efficiency and sustainability of modern window glazing

Course will have general lectures
- hands on lab @home experiments
- group project for implementation of regenerative materials.
Wood Structure and Function

Abstract

The course Wood structure and function conveys basic knowledge on the microstructure of softwoods and hardwoods as well as general and species-specific relationships between growth processes, wood properties and wood function in the living tree.

Objective

Learning target is a basic understanding of the anatomy of wood and the related impact of endogenous and exogenous factors. The students can learn how to distinguish common central European wood species at the macroscopic and microscopic level. A deeper insight will be given by wood identification exercises for softwood species. Further, the students will gain insight into the relationships between tree growth and wood properties with a specific focus on the wood function in the living tree.

Content

In an introduction to wood anatomy, the general structural features of softwoods and hardwoods will be explained and factors of diversity and variability will be discussed. A specific focus is laid on common central European tree species with relevance in the wood sector, which will be studied in macro- and microstructural investigations. In the following, relationships between wood structure, properties and function in the living tree will be the focus of the lectures. Topics covered are water transport, trends in wood anatomy within trees, environmental impact on wood anatomy, wood defects and their causes, tools to study wood properties over time, secondary changes in wood, and tree biomechanics.

Advanced Environmental Assessments

Abstract

This course deepens students' knowledge of the environmental assessment methodologies and their various applications.

Objective

This course has the aim of deepening students' knowledge of the environmental assessment methodologies and their various applications. In particular, students completing the course should have the

- Ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and models, and the adequacy of life cycle impact assessment models and factors
- Knowledge about the current state of the scientific discussion and new research developments
- Ability to properly plan, conduct and interpret environmental assessment studies
- Knowledge of how to use LCA as a decision support tool for companies, public authorities, and consumers

Content

- Inventory developments, transparency, data quality, data completeness, and data exchange formats
- Allocation (multitoutput processes and recycling)
- Hybrid LCA methods.
- Consequential and marginal analysis
- Recent development in impact assessment
- Spatial differentiation in Life Cycle Assessment
- Workplace and indoor exposure in Risk and Life Cycle Assessment
- Uncertainty analysis
- Subjectivity in environmental assessments
- Multicriteria analysis
- Case Studies

Lecture notes

No script. Lecture slides and literature will be made available on Moodle.

Literature

Literature will be made available on Moodle.

Prerequisites / notice

Basic knowledge of environmental assessment tools is a prerequisite for this class. Students that have not done classwork in this topic before are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. 2016: Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5.2)).

Acoustics in Fluid Media: From Robotics to Additive Manufacturing

Abstract

The course will provide you with the fundamentals of the new and exciting field of ultrasound-based microrobots to treat various diseases. Furthermore, we will explore how ultrasound can be used in additive manufacturing for tissue constructs and robotics.

Objective

The course is designed to equip students with skills in the design and development of ultrasound-based manipulation devices and microrobots for applications in medicine and additive manufacturing.

Content

Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices

Lecture notes

Competencies

Subject-specific Competencies
- Concepts and Theories (assessed)
- Techniques and Technologies (assessed)

Method-specific Competencies
- Analytical Competencies (assessed)
- Decision-making (fostered)
- Media and Digital Technologies (fostered)
- Problem-solving (assessed)
- Project Management (fostered)

Social Competencies
- Communication (assessed)
- Cooperation and Teamwork (assessed)
- Customer Orientation (fostered)
- Leadership and Responsibility (fostered)
- Self-presentation and Social Influence (assessed)
- Sensitivity to Diversity (fostered)
- Negotiation (fostered)

Personal Competencies
- Critical Thinking (assessed)
- Integrity and Work Ethics (assessed)
- Self-direction and Self-management (assessed)

Competencies

Continuum Mechanics I

Abstract
The lecture deals with constitutive models that are relevant for the design and analysis of components and structures. These include anisotropic linear elasticity, linear viscoelasticity, plasticity and viscoplasticity. The basic concepts of homogenization and laminate theory are introduced. Theoretical models are complemented by examples of engineering applications and experiments.

Objective
After successful completion of the course students are able to
- explain basic theories for solving continuum mechanics problems
- proficiently apply these theories by solving application-related academic examples
- relate the theories and examples to real engineering applications and challenges
- distinguish between different mechanical behaviors of materials
- systematically select appropriate constitutive theories suitable to analyze and model these materials

Content
Anisotropic Elasticity, Linear Elastic and Linear Viscous Material Behavior, Viscoelasticity, Micro-Macro Modelling, Laminate Theory, Plasticity, Viscoplasticity, Examples of Engineering Applications, Comparison with Experiments

Lecture notes
Yes

Bioelectronics and Biosensors

Abstract
The course introduces bioelectricity and the sensing concepts that enable obtaining information about neurons and their networks. The sources of electrical fields and currents in the context of biological systems are discussed. The fundamental concepts and challenges of measuring bioelectronic signals and the basic concepts to record optogenetically modified organisms are introduced.

Objective
During this course the students will:
- learn the basic concepts in bioelectronics including the sources of bioelectronic signals and the methods to measure them
- be able to solve typical problems in bioelectronics
- learn about the remaining challenges in this field

Content
Lecture topics:
1. Introduction
2. Membrane and Transport
3-4. Action potential and Hodgkin-Huxley

Measuring bioelectronic signals
5. Detection and Noise
6. Measuring currents in solutions, nanopore sensing and patch clamp pipettes
7. Measuring potentials in solution and core conductance model
8. Measuring electronic signals with wearable electronics, ECG, EEG
9. Measuring mechanical signals with bioelectronics

In vivo stimulation and recording
10. Functional electric stimulation
11. In vivo electrophysiology

Optical recording and control of neurons (optogenetics)
12. Measuring neurons optically, fundamentals of optical microscopy
13. Fluorescent probes and scanning microscopy, optogenetics, in vivo microscopy

14. Measuring biochemical signals

Lecture notes
A detailed script is provided to each lecture including the exercises and their solutions.

Literature
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites / notice
The course requires an open attitude to the interdisciplinary approach of bioelectronics. In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).
This course is divided into two main blocks. The first block focuses on the primary molecular adaptations of living organisms, while the second block covers the fundamental microstructural design principles present in biological materials.

The course addresses undergraduate and graduate students interested in getting introduced into the basic concepts of biomineralization. The course aims to introduce the basic concepts of biomineralization and the underlying principles, such as supersaturation, nucleation and growth of minerals, the interaction of biomolecules with mineral surfaces, and cell biology of inorganic materials creation. An important part of this class is the independent study and the presentation of original literature from the field.

Copies of the slides will be made available for download before each lecture.

This course explores the mechanisms that govern the adaptive functions of out-of-equilibrium systems in living organisms at the molecular scale and the microstructural design principles of biological materials at larger length scales. Throughout the course, we will also explore how these design principles can be incorporated into synthetic systems to improve targeted functions.

By the end of this course, students will be able to explain how natural selection optimizes biological materials at the molecular and microstructural levels and how this optimization process has resulted in the emergence of biological design principles that fulfill essential functions for species’ survival. Students will gain the ability to analyze and integrate bio-inspired adaptive functions into synthetic material systems, as well as interpret the correlation between function, microstructure, and performance of biological and bio-inspired materials. Through engaging activities, students will also develop strategies to create bio-inspired solutions for typical engineering problems and predict the performance of bio-inspired materials.

This course is divided into two main blocks. The first block focuses on the primary molecular adaptations of living organisms, while the second block covers the fundamental microstructural design principles present in biological materials.

Block I: Molecular Adaptations of Living Organisms and Creation of Adaptive Bio-inspired Materials

- Temporal regulation in biological and bio-inspired molecular systems;
- Autonomous molecular structures and out-of-equilibrium systems;
- Molecular motion and work generation mechanisms in biological and bio-inspired systems;
- Sensing, adaptation, and communication in biological and bio-inspired material systems;

Block II: Principles of Microstructural Design in Biological Materials and Their Synthetically Engineered Counterparts

- Fundamentals of engineering in biological and bio-inspired materials;
- Replicating biological design principles in synthetic materials (structural, optical, surface properties, etc.);
- Bio-inspired design and systems (mechanical actuation and bio-inspiration in the built environment).

Literature

3) P. M. Dove, J. J. DeYoreo, S. Weiner (Eds.) Biomineralization, Reviews in Mineralogy & Geochemistry Vol. 54, 2003
5) S. Weiner, Biomineralization, Oxford University Press, 2000

Prerequisites / notice

No special requirements are needed for attending. Basic knowledge in chemistry and cell biology is expected.

Competencies

<table>
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<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
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327-1101-00L Biomineralization W 2 credits 2V K.-H. Ernst

Abstract

The course addresses undergraduate and graduate students interested in getting introduced into the basic concepts of biomineralization. Biomineralization is a multidisciplinary field. Topics dealing with biology, molecular and cell biology, solid state physics, mineralogy, crystallography, organic and physical chemistry, biochemistry, dentistry, oceanography, geology, etc. are addressed. The course covers definition and general concepts of biomineralization (BM) / types of biominerals and their function / crystal nucleation and growth / biological induction of BM / control of crystal morphology, habit, shape and orientation by organisms / strategies of compartmentalization / the interface between biomolecules (peptides, polysaccharides) and the mineral phase / modern experimental methods for studying BM phenomena / inter-, intra, extra- and epicellular BM / organic templates and matrices for BM / structure of bone, teeth (vertebrates and invertebrates) and mollusk shells / calcification / silification in diatoms, radiolaria and plants / calcium and iron storage / impact of BM on lithosphere and atmosphere / evolution / taxonomy of organisms.

1. Introduction and overview
2. Biominerals and their functions
3. Chemical control of biomineralization
4. Control of morphology: Organic templates and additives
5. Modern methods of investigation of BM
6. BM in matrices: bone and nacre
7. Vertebrate teeth
8. Invertebrate teeth
9. BM within vesicles: calcite of coccoliths
10. Silica
11. Iron storage and mineralization

Lecture notes Script with more than 600 pages with many illustrations will be distributed free of charge.


Abstract

This course explores the mechanisms that govern the adaptive functions of out-of-equilibrium systems in living organisms at the molecular scale and the microstructural design principles of biological materials at larger length scales. Throughout the course, we will also explore how these design principles can be incorporated into synthetic systems to improve targeted functions.

Objective

By the end of this course, students will be able to explain how natural selection optimizes biological materials at the molecular and microstructural levels and how this optimization process has resulted in the emergence of biological design principles that fulfill essential functions for species’ survival. Students will gain the ability to analyze and integrate bio-inspired adaptive functions into synthetic material systems, as well as interpret the correlation between function, microstructure, and performance of biological and bio-inspired materials. Through engaging activities, students will also develop strategies to create bio-inspired solutions for typical engineering problems and predict the performance of bio-inspired materials.

Content

This course is divided into two main blocks. The first block focuses on the primary molecular adaptations of living organisms, while the second block covers the fundamental microstructural design principles present in biological materials.

Block I: Molecular Adaptations of Living Organisms and Creation of Adaptive Bio-inspired Materials

- Temporal regulation in biological and bio-inspired molecular systems;
- Autonomous molecular structures and out-of-equilibrium systems;
- Molecular motion and work generation mechanisms in biological and bio-inspired systems;
- Sensing, adaptation, and communication in biological and bio-inspired material systems;

Block II: Principles of Microstructural Design in Biological Materials and Their Synthetically Engineered Counterparts

- Fundamentals of engineering in biological and bio-inspired materials;
- Replicating biological design principles in synthetic materials (structural, optical, surface properties, etc.);
- Bio-inspired design and systems (mechanical actuation and bio-inspiration in the built environment).

Lecture notes Copies of the slides will be made available for download before each lecture.
The course is mainly based on the references listed below. Additional references will be provided during the lectures.


### Literature

**376-0021-00L**

**Materials and Mechanics in Medicine**

W 4 credits 3G M. Zenobi-Wong, J. G. Snedeker

**Abstract**

Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

**Objective**

Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

**Content**

Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

**Lecture notes**

Course website on Moodle

**Literature**


Academic Press

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**376-0121-00L**

**Multiscale Bone Biomechanics**

W 6 credits 3S R. Müller, X.-H. Qin

The seminar provides state-of-the-art insight to the biomechanical function of bone from molecules, to cells, tissue and up to the organ. Multiscale imaging and simulation allow linking different levels of hierarchy, where systems biology helps understanding the mechanobiological response of bone to loading and injury in scenarios relevant for personalized health and translational medicine.

**Abstract**

The learning objectives include

1. advanced knowledge of the state-of-the-are in multiscale bone biomechanics;
2. basic understanding of the biological principles governing bone in health, disease and treatment from molecules, to cells, tissue and up to the organ;
3. good understanding of the prevalent biomechanical testing and imaging techniques on the various levels of bone hierarchy;
4. practical implementation of state-of-the-art multiscale simulation techniques;
5. improved programing skills through the use of python;
6. hands on experience in designing solutions for clinical and industrial problems;
7. encouragement of critical thinking and creating an environment for independent and self-directed studying.

**Objective**

Bone is one of the most investigated biological materials due to its primary function of providing skeletal stability. Bone is susceptible to different local stimuli including mechanical forces and has great capabilities in adapting its mechanical properties to the changes in its environment. Nevertheless, aging or hormonal changes can make bone lose its ability to remodel appropriately, with loss of strength and increased fracture risk as a result, leading to devastating diseases such as osteoporosis. To better understand the biomechanical function of bone, one has to understand the hierarchical organization of this fascinating material down from the molecules, to the cells, tissue and up to the organ. Multiscale imaging and simulation allow to link these different levels of hierarchy. Incorporating systems biology approaches, not only biomechanical strength of the material can be assessed but also the mechanobiological response of the bone triggered by loading and injury in scenarios relevant for personalized health. Watching cells working together to build and repair bone in a coordinated fashion is a spectacle, which will need dynamic image content and deep discussions in the lecture room to probe the imagination of the individual student interested in the topic. Lastly, state-of-the-art developments in tissue engineering and regeneration, 3D bioprinting and bio-manufacturing and organoid technology will be highlighted towards personalized health.

For the seminar, concepts of video lectures will be used in a flipped classroom setup, where students can study the basic biology, engineering, and mathematical concepts in video tutorials online (TORQUES). All videos and animations will be incorporated in Moodle and PolyBook allowing studying and interactive course participation online. It is anticipated that the students need to prepare 2-45 minutes for the study of the actual lecture material. The course is structured as a seminar in three parts of 45 minutes with video lectures and a flipped classroom setup. In the first part (TORQUES: Tiny, Open-with-Restrictions courses focused on QUality and Effectiveness), students study the basic concepts in short, interactive video lectures on the online learning platform Moodle. Students are able to post questions at the end of each video lecture in the Moodle forum that will be addressed in the second part of the lectures using a flipped classroom concept. For the flipped classroom, the lecturers may prepare additional teaching material to answer the posted questions (Q&A).

Following the Q&A, the students will have to form small groups to try to solve such problems and to present their solutions for advanced multiscale investigation of bone ranging from basic science to clinical application. Towards the end of the semester, students will have to present self-selected publications associated with the different topics of the lecture identified through PubMed or the Web of Science.

**Lecture notes**

Material will be provided on Moodle and eColab.

**Prerequisites / notice**

Prior experience with the programming language python is beneficial but not mandatory. ETH offers courses for practical programming with python.
The main objective of the course is to introduce micro/nanotechnology and microfluidics to students having any technical background. The course fosters mostly formal lectures (2 × 45 min), with few specific guest lectures on topics of particular relevance. For example, an introduction to the (infamous) history of Theranos, as well as some discussions on diagnostics for COVID, R0, and (im)precision of diagnostic devices and why it matters.

The course should familiarize the students with the techniques used in micro/nanotechnology, cleanroom microfabrication, and show them how micro/nanotechnology pervades throughout life sciences. Microfluidics will be emphasized due to their increasing importance in research and for medical applications.

The second objective is to have life sciences students less intimidated by micro/nanotechnology and make them able to link instruments and techniques to specific problems that they might have in their projects/studies. This will also help students getting access to the ETHZ/IBM Nanotech Center infrastructure if needed.

In terms of technical content, the lectures will cover:
- an overview of the microelectronic industry, Moore’s law, field-effect transistors, next-generation DNA sequencing
- liquid crystal displays, organic light emitting diodes, electrophoretic displays, micromirrors and beamers, photopatterning of proteins and cells, optogenetics, and flexible displays and electronics
- hard disk drives and the giant magnetoresistance effect, magnetic nanoparticles, photonics, magnetic sensing and optical biosensing
- cleanroom techniques and instruments, from design to microfabrication of simple devices and microfluidics, examples of DNA microarrays
- the principles of microfluidics, microfluidic functions and fabrication, from microfluidics for research to point-of-care diagnostics, and the history of Theranos, as well as some discussions on diagnostics for COVID, R0, and (im)precision of diagnostic devices and why it matters.
- 2 × 45 min will be covered by Yuksel Temiz, a master of Arduino programming and do-it-yourself electronics, who will present how to make 20$ electronic components that are synergistic to microfluidic devices and that can be controlled using a smartphone

The course is multi-disciplinary and covers a broad range of techniques. For each lecture, a brief historical perspective is given to illustrate by whom and how the techniques were invented.

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Practical exercises on topics including sterile cell culture, light microscopy and histology, and biomaterials are covered. Practical work, the course will teach skills in data acquisition/analysis.

The course should cover the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.
### Content
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the material surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

### Lecture notes
Handouts are deposited online (moodle).

### Literature

(available online via ETH library)

Handouts and references therin.

### Literature
- B. Helgason, B. de Wildt, S. J. Ferguson, J. Kimenai
- W. R. Taylor, M. Zenobi-Wong
- A. de Mello

### Objective
Getting insight into actual areas and problems of biomechanics.

### Abstract
Current topics in biomechanics presented by speakers from academia and industry.

### Content

### Objective
To understand the current state of research in polymerization reactors and bioreactors to produce polymers and proteins with the specific product qualities that are required for different applications in chemical, pharmaceutical and food industry. This activity includes the post-treatment of polymer latexes, the downstream processing of proteins and the analysis of their colloidal behavior.

### Abstract

### Lecture notes
Scripts are available on the web page of the Arosio-group: http://www.arosiogroup.ethz.ch/education.html
Additional handout of slides will be provided during the lectures.

### Literature
- Biocompatible Polymers in Medicine, R. Amici, M. Zenobi-Wong, 2002

### Literature
- W. R. Taylor, M. Zenobi-Wong
- A. de Mello

### Objective
A central component of this course is a research project. This will allow students to develop a practical understanding of the benefits of miniaturization in chemical and biological experimentation. Projects will be performed in groups of between four and six students and will include both experimental and simulation aspects. Each group, under the guidance of a mentor, will plan and execute a novel research project. The results of this activity will be disseminated through an "academic-style" research article and a "conference-style" oral presentation. Course grades will be evaluated through both a written exam and the project grade.
Specific topics covered in the course include, but are not limited to:

1. Theoretical Concepts
   - Scaling laws, features of thermal/mass transport, diffusion, basic description of fluid flow in small volumes, microfluidic mixing strategies.

2. Microfluidic Device Manufacture
   - Basic principles of conventional lithography of rigid materials, 'soft' lithography, polymer machining (injection molding, hot embossing, and 3D-printing).

3. Electrokinetics
   - Principles of electrophoresis, electroosmosis, high performance capillary electrophoresis, electrokinetic scaling laws, chip-based electrophoresis and isoelectric focusing.

4. Mass Transfer Phenomena
   - Key features of mass transport in microfluidic systems, diffusive transport, diffusion-convection, Péclet number, Taylor-Aris diffusion, chaotic mixing and Damköhler numbers.

5. Heat Transfer Phenomena
   - Key features of thermal transport in microfluidic systems, conduction, convection, heat transfer by convection in internal flows, heat transfer processes in microfluidic devices.

6. Microfluidic Systems for Materials Synthesis
   - Microfluidic reactors for the controlled synthesis of colloidal nanomaterials, advanced automation for bespoke materials discovery & characterization.

7. Point-of-Care Diagnostics
   - Microscale tools for diagnostics, challenges associated with point-of-care (PoC) diagnostic testing, requirements for PoC devices, common PoC device formats, applications of PoC diagnostics in the developing world.

8. Microscale DNA Amplification
   - Amplification and analysis of nucleic acids using batch, continuous flow and droplet-based microfluidic reactors.

9. Small volume Molecular Detection
   - Spectroscopic approaches for analyte detection in small volumes with a particular focus on single molecule detection.

10. Droplets and Segmented Flows
    - Formation, manipulation and use of liquid/liquid segmented flows in chemical and biological experimentation.

Lecture notes
- Handout will be given to students at lecture.

There is no set text for the course. All relevant literature will be provided electronically through the course Moodle site.

### Competencies

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#### Abstract

Students will be imparted knowledge in basic and advanced biophysical methods applied to problems in molecular biotechnology. The course is fundamental to applying the methods in their daily and advanced research routines. The students will learn the physical basis of the methods as well as their limitations and possibilities to address existing and future topics in molecular biotechnology.

#### Objective

Gain of interdisciplinary competence in experimental and theoretical research, which qualifies for academic scientific work (master's or doctoral thesis) as well as for research in a biotechnology or a pharmaceutical company. The module is of general use in courses focused on modern biomolecular technologies, systems biology and systems engineering.

#### Content

The students will learn basic and advanced knowledge in applying biophysical methods to address problems and overcome challenges in biotechnology, cell biology and life sciences in general. The biological and physical possibilities and limitations of the methods will be discussed and critically evaluated. By the end of the course the students will have assimilated knowledge on a portfolio of biophysical tools widening their research capabilities and aptitude.

The biophysical methods to be taught will include:

- Light microscopy: Resolution limit of light microscopy, fluorescence, GFP, fluorescence microscopy, DIC, phase contrast, difference between wide-field and confocal microscopy
  - Super resolution optical microscopy: STED, PALM, STORM, other variations
  - Electron microscopy: Scanning electron microscopy, transmission electron microscopy, electron tomography, cryo-electron microscopy, single particle analysis and averaging, tomography, sectioning, negative stain
  - X-ray, electron and neutron diffraction
  - MRI imaging
  - Scanning tunnelling microscopy and atomic force microscopy
  - Patch clamp technologies: Principles of patch clamp analysis and application. Various patch clamp approaches used in research and industry
  - Surface plasmon resonance-based biosensors
  - Molecular pore-based sensors and sequencing devices
  - Mechanical molecular and cellular assembly devices
  - Optical and magnetic tweezers
  - CD spectroscopy
  - Optogenetics
  - Molecular dynamics simulations
Ethics and Scientific Integrity for Doctoral Students

Objective

The objective of this course is to highlight the link between human physiology, product sensory, nutritional functions, and engineering approaches to facilitate the design of food matrices reflecting the requirements for the beforementioned properties. To identify and manipulate these properties, the pathways that control the interaction of food structures and their physiological action will be introduced. Students are introduced to a skill set that will encompass basic digestion, sensory physiology knowledge, and food structures. Students will be exposed to the interplay along the gastrointestinal tract including taste, aroma, and texture perception, swallowing mechanics, and gastrointestinal digestion with an engineering or physical sciences angle.

Content

Chapter 1: Introduction - The need for physiology guided structure and process design in the context of personalized nutrition (Peter Fischer)
Chapter 2: Food Oral Processing: the impact of food oral breakdown on sensory perception (Marine Devezeaux de Lavergne)
Chapter 3: Chewing and swallowing across the lifespan, from infants to elderly (Marine Devezeaux de Lavergne)
Chapter 4: Perception physiology in humans and other species (Benoit von der Weid)
Chapter 5: Biophysics of food digestion & how it can be exploited in the development of strategies for delivery (Timothy J. Wooster)
Chapter 6: Numerical and experimental modelling of the intestinal system (Peter Fischer)

Lecture notes

Lecture notes are available at Moodle

Competencies

Subject-specific Competencies: Concepts and Theories, assessed
Techniques and Technologies, assessed
Method-specific Competencies: Analytical Competencies, fostered
Decision-making, fostered
Media and Digital Technologies, fostered
Problem-solving, assessed
Project Management, fostered
Social Competencies: Communication, fostered
Personal Competencies: Creative Thinking, fostered
Critical Thinking, fostered
Integrity and Work Ethics, fostered

Transferable Skills

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<td>Ethics and Scientific Integrity for Doctoral Students (MaP Doctoral School)</td>
<td>W</td>
<td>1 credit</td>
<td>2U</td>
<td>M. Trassin, K. M. Berg, A. Lauria, S. Stepianow</td>
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Abstract

This course sensitises doctoral students to ethical issues that may occur during their doctorate. After an introduction to ethics and good scientific practice, students are familiarised with resources that can assist them with ethical decision-making. Students get the chance to apply their knowledge in a discipline specific context.

Objective

Doctoral students learn how to identify, analyse and address ethical issues in their own scientific research. In addition, they will reflect on their professional role as scientific researchers.

Content

Part I

The self-paced e-learning course consists of 5 modules:
(1) Ethics: Introduction to moral theory (with emphasis on practical guidance regarding decision making)
(2) Ethics in Scientific Research: Introduction to ethical issues that occur within research (i.e. regarding authorship, cooperation, data use and sharing, and other aspects that are subject to scientific integrity and good scientific practice).
(3) Collecting Resources: A variety of tools and resources that help identify ethical issues are presented and explained
(4) Setting up a Strategy: Example examination of a case regarding its ethical scope (students develop their own strategy to examine situations for their ethical implications).
(5) Making Decisions: Different ways of addressing ethical issues are presented and explained (i.e. how to make hard choices, or solve ethical dilemmas. But also where to seek advice if needed).

Part II

The second, face-to-face part of this course focuses on discipline-specific aspects of Materials, Processes and Manufacturing Technologies. It provides an interactive learning environment. Participants get to apply their knowledge, and they are encouraged to reflect on ethical problems and critically discuss them with fellow doctoral students.

Prerequisites / notice

For doctoral students only

900-0100-DRL | Transferable Skills Course I (1-3 days) | W | 1 credit | 2S | Lecturers |

Only for doctoral students.

Abstract

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

900-0101-DRL | Transferable Skills Course II (1-3 days) | W | 1 credit | 2S | Lecturers |

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer
Abstract Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

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| 900-0103-DRL  | Transferable Skills Course I (1-3 days, with Poster or Talk) | W | 2       | 4S| Lecturers |
|               | Only for doctoral students.                          |   |         |   |           |
|               | Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate. |   |         |   |           |
| Abstract      | Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. |   |         |   |           |
| Objective     | Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion. |   |         |   |           |

| 900-0104-DRL  | Transferable Skills Course II (1-3 days, with Poster or Talk) | W | 2       | 4S| Lecturers |
|               | Only for doctoral students.                          |   |         |   |           |
|               | Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate. |   |         |   |           |
| Abstract      | Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. |   |         |   |           |
| Objective     | Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion. |   |         |   |           |

| 900-0105-DRL  | Transferable Skills Course III (1-3 days, with Poster or Talk) | W | 2       | 4S| Lecturers |
|               | Only for doctoral students.                          |   |         |   |           |
|               | Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate. |   |         |   |           |
| Abstract      | Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. |   |         |   |           |
| Objective     | Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion. |   |         |   |           |

| 900-0106-DRL  | Transferable Skills Course I (1 week)               | W | 2       | 4S| Lecturers |
|               | Only for doctoral students.                          |   |         |   |           |
|               | Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate. |   |         |   |           |
| Abstract      | Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. |   |         |   |           |
| Objective     | Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. |   |         |   |           |

| 900-0107-DRL  | Transferable Skills Course II (1 week)             | W | 2       | 4S| Lecturers |
|               | Only for doctoral students.                          |   |         |   |           |
|               | Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate. |   |         |   |           |
| Abstract      | Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. |   |         |   |           |
| Objective     | Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. |   |         |   |           |

| 900-0108-DRL  | Transferable Skills Course III (1 week)            | W | 2       | 4S| Lecturers |
|               | Only for doctoral students.                          |   |         |   |           |
|               | Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate. |   |         |   |           |
| Abstract      | Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. |   |         |   |           |
| Objective     | Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. |   |         |   |           |
Objective: Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

900-0109-DRL Transferable Skills Course I (1 week, with Poster or Talk) Only for doctoral students.

Abstract: Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Objective: Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

900-0110-DRL Transferable Skills Course II (1 week, with Poster or Talk) Only for doctoral students.

Abstract: Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Objective: Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

900-0111-DRL Transferable Skills Course III (1 week, with Poster or Talk) Only for doctoral students.

Abstract: Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Objective: Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

900-0112-DRL Participation in Commission I (min 1 year) Only for doctoral students.

Abstract: Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Objective: Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

900-0113-DRL Participation in Commission II (min 1 year) Only for doctoral students.

Abstract: Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Objective: Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

900-0114-DRL Member of Executive Board (min 1 year) Only for doctoral students.

Abstract: Active participation in the presidium or executive board of a university group for at least 1 year. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Objective: Active participation in the presidium or executive board of a university group for at least 1 year.

Integration into Scientific Community

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<td>900-0150-DRL</td>
<td>Summer School I (1-3 days) Only for doctoral students.</td>
<td>W</td>
<td>1 credit</td>
<td>2K</td>
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Abstract: Participation in summer or winter schools with a maximum duration of 3 days. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Objective: Participation in summer or winter schools with a maximum duration of 3 days.

900-0151-DRL | Summer School II (1-3 days) Only for doctoral students. | W | 1 credit | 2K | Lecturers |

Abstract: Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Duration</th>
<th>Credits</th>
<th>Lecturers</th>
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<td>900-0152-DRL</td>
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<td>1</td>
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<td>900-0154-DRL</td>
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<td>900-0160-DRL</td>
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Abstract: Participation in summer or winter schools with a maximum duration of 3 days.
Objective: Participation in summer or winter schools with a maximum duration of 3 days.
**Doctorate Materials Science - Key for Type**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>E-</th>
<th>Z</th>
<th>Dr</th>
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<tr>
<td>O</td>
<td>Compulsory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Key for Hours**

| V    | lecture                                        | P  | practical/laboratory course |
| G    | lecture with exercise                          | A  | independent project         |
| U    | exercise                                       | D  | diploma thesis              |
| S    | seminar                                       | R  | revision course / private study |
| K    | colloquium                                     |    |                              |

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.

---

**Certificate.**

Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**Objective**

Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

### 900-0161-DRL Summer School III (1 week, with Poster or Talk)

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

<table>
<thead>
<tr>
<th>W</th>
<th>3 credits</th>
<th>6K Lecturers</th>
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**Abstract**

Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

**Objective**

Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

### 900-0162-DRL External Conference I (incl. Poster or Talk)

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

<table>
<thead>
<tr>
<th>W</th>
<th>1 credit</th>
<th>2K Lecturers</th>
</tr>
</thead>
</table>

**Abstract**

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

**Objective**

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

### 900-0163-DRL External Conference II (incl. Poster or Talk)

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

<table>
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<tr>
<th>W</th>
<th>1 credit</th>
<th>2K Lecturers</th>
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</thead>
</table>

**Abstract**

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

**Objective**

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

### 900-0164-DRL External Conference III (incl. Poster or Talk)

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

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</table>

**Abstract**

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

**Objective**

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.
### Subject Specialisation

The list of courses (together with the allocated credit points) eligible for doctoral students is published each semester in the newsletter of the ZGSM. [More Information](https://zgsm.math.uzh.ch/index.php?id=861&keySemId=47&key1=0)

### Graduate School

Official website of the Zurich Graduate School in Mathematics: [http://www.zgsm.ch](http://www.zgsm.ch)

#### Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
401-5741-DRL | Floer Homology of Three-Manifolds and Applications to Low Dimensional Topology | W | 2 credits | 2V | not available |

**Abstract**

Doctoral students of I-Math (UZH) need to send an email to Jessica Bolsinger (info@zgsm.ch) with the course number. The email should have the subject „Graduate course registration (ETH)“.

401-5743-DRL | Dispersive Equations and Wave Turbulence Theory | W | 2 credits | 2V | not available |

**Abstract**

Doctoral students of I-Math (UZH) need to send an email to Jessica Bolsinger (info@zgsm.ch) with the course number. The email should have the subject „Graduate course registration (ETH)“.

#### Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
401-5001-DRL | Foundations of D-MATH Doctoral Studies I

**Prerequisites / notice**

Foundations of D-MATH Doctoral Studies II

#### Colloquia

#### Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
401-5000-00L | Zurich Colloquium in Mathematics | E- | 0 credits | | University lecturers, further speakers |

**Abstract**

The Graduate Colloquium is an informal seminar aimed at graduate students and postdocs whose purpose is to provide a forum for communicating one's interests and thoughts in mathematics.

401-5110-00L | Number Theory Seminar | E- | 0 credits | 1K | R. Pandharipande |

**Abstract**

Research colloquium

401-5140-11L | Algebraic Geometry and Moduli Seminar | E- | 0 credits | 2K | M. Burger |

**Abstract**

Research colloquium

401-5350-00L | Analysis Seminar | E- | 0 credits | 1K | F. Da Lio, N. Hungerbühler, T. Ilmanen, L. Kobel-Keller, S. Mayboroda, J. Serra, University lecturers |

**Abstract**

Research colloquium

401-5530-00L | Geometry Seminar | E- | 0 credits | 1K | R. Alaifari, H. Ammari, R. Hiptmair, S. Mishra, C. Schwab |

**Abstract**

Research colloquium

401-5620-00L | Seminar on Stochastic Processes | E- | 0 credits | 1K | A. Nikeghbali |

**Abstract**

Research colloquium


**Abstract**

Research colloquium

401-5370-00L | Ergodic Theory and Dynamical Systems | E- | 0 credits | 1K | M. Akka Ginosar, M. Einsiedler, University lecturers |

**Abstract**

Research colloquium

401-5580-00L | Symplectic Geometry Seminar | E- | 0 credits | 1K | P. Biran, A. Cannas da Silva |

**Abstract**

Research colloquium

401-5650-00L | Zurich Colloquium in Applied and Computational Mathematics | E- | 0 credits | 1K | R. Alaifari, H. Ammari, R. Hiptmair, S. Mishra, C. Schwab |

**Abstract**

Research colloquium

401-5330-00L | Talks in Mathematical Physics | E- | 0 credits | 1K | M. Gaberdiel, G. M. Graf, P. Hintz, T. H. Willwacher |

**Abstract**

Research colloquium

401-5600-00L | Seminar on Applied Statistics | E- | 0 credits | 1K | A. Nikeghbali |

**Abstract**

Research colloquium

---

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 889 of 2653
About 3 talks on applied statistics.

See how statistical methods are applied in practice.

There will be about 3 talks on how statistical methods are applied in practice.

This is no lecture. There is no exam and no credit points will be awarded. The current program can be found on the web:
http://stat.ethz.ch/events/zukost

Course language is English or German and may depend on the speaker.

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Decision-making
- Problem-solving

Personal Competencies
- Critical Thinking
- Creative Thinking

This is no lecture. There is no exam and no credit points will be awarded. The current program can be found on the web:
http://stat.ethz.ch/events/zukost

Course language is English or German and may depend on the speaker.

E- 0 credits
A. Bandeira, H. Bölcskei, J. Peters, F. Yang

Research colloquium

E- 0 credits
A. Bandeira, R. Weismantel, R. Zenklusen

Research colloquium

E- 0 credits
B. Acciaio, P. Cheridito, D. Possamaï, J. Teichmann

Research colloquium

Regular research talks on various topics in mathematical finance and actuarial mathematics

Presentation of recent publications in theoretical computer science, including results by diploma, masters and doctoral candidates.

The goal is to introduce students to current research, and to enable them to read, understand, and present scientific papers. This seminar takes place as part of the joint research seminar of several theory groups. Intended participation is for students with excellent performance only. Formal restriction is: prior successful participation in a master level seminar in theoretical computer science.

Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

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Transferable Skills Course I (1-3 days)

Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

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<td>900-0106-DRL</td>
<td>Transferable Skills Course I (1 week)</td>
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<td>Autumn 2024</td>
<td>Lecturers</td>
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<tr>
<td>900-0107-DRL</td>
<td>Transferable Skills Course II (1 week)</td>
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<td>Lecturers</td>
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<td>900-0108-DRL</td>
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<td>900-0109-DRL</td>
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Abstract: Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

Objective: Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days. Participants need to present either a poster or a talk at this occasion.

W: 2 credits
W: 3 credits
W: 3 credits

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.
900-0112-DRL  Participation in Commission I (min 1 year)  
Only for doctoral students.

Abstract  
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

Objective  
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

900-0113-DRL  Participation in Commission II (min 1 year)  
Only for doctoral students.

Abstract  
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

Objective  
Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.

900-0114-DRL  Member of Executive Board (min 1 year)  
Only for doctoral students.

Abstract  
Active participation in the presidium or executive board of a university group for at least 1 year.

Objective  
Active participation in the presidium or executive board of a university group for at least 1 year.

401-5010-00L  Ethics and Scientific Integrity for Doctoral Students at D-MATH  
W 1 credit  
1R E. Kowalski, not available

Abstract  
This course sensitises doctoral students to ethical issues that may occur during their doctorate. After an introduction to ethics and good scientific practice, students are familiarised with resources that can assist them with ethical decision-making. Students get the chance to apply and deepen their knowledge in an interactive face-to-face workshop.

Objective  
Doctoral students learn how to identify, analyse and address ethical issues in their own scientific research. In addition, they will reflect on their professional role as scientific researchers.

Content  
Part I on Moodle  
The self-paced e-learning course on Moodle consists of 5 modules:

Module 1: Ethics  
- Introduction to moral theory (with emphasis on practical guidance regarding decision making)

Module 2: Ethics in scientific research  
- Introduction to ethical issues that occur within scientific research (i.e. regarding authorship, cooperation, data use and sharing, and other aspects that are subject to scientific integrity and good scientific practice).

Module 3: Collecting resources  
- A variety of tools and resources that help identify ethical issues are presented and explained

Module 4: Setting up a strategy  
- Example examination of a case regarding its ethical scope (students develop their own strategy to examine situations for their ethical implications).

Module 5: Making decisions  
- Different ways of addressing ethical issues are presented and explained (i.e. how to make hard choices, or solve ethical dilemmas. But also where to seek advice if needed).

Part II  
The second, face-to-face part (group sessions) of this course provides an interactive learning environment (workshop). Students get to apply their knowledge, and they are encouraged to reflect on ethical problems and to critically discuss them with fellow doctoral students.

Prerequisites / notice  
For doctoral students only.

The first part on Moodle (part I) must be successfully completed before the face-to-face workshop (part II).

Hence, when you choose a group make sure you have enough time to finish the first part on Moodle before the workshop starts (appr. 20 hours).

Competencies  
Subject-specific Competencies  
- Concepts and Theories  
- Decision-making  
- Problem-solving

Method-specific Competencies  
- Critical Thinking

Personal Competencies  
- Integrity and Work Ethics

Educational Science for Teaching Diploma and TC  
Language Courses ETH/UZH: see Science in Perspective

Integration into Scientific Community

<table>
<thead>
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<th>Number</th>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 892 of 2653
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<td>1</td>
<td>2K</td>
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</table>
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

### Abstract
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

### Objective
Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

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**Doctorate Mathematics - Key for Type**

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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<td>Z</td>
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<td>O</td>
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**Key for Hours**

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<td>U</td>
<td>exercise</td>
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<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

**ECTS**

- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
# Subject Specialisation

Please note that this is an INCOMPLETE list of courses.

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<tr>
<th>Number</th>
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<td>402-0317-00L</td>
<td>Semiconductor Materials: Fundamentals and Fabrication</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>S. Schön, W. Wegscheider</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>This course gives an introduction into the fundamentals of semiconductor materials. The main focus is on state-of-the-art fabrication and characterization methods. The course will be continued in the spring term with a focus on applications.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Basic knowledge of semiconductor physics and technology. Application of this knowledge for state-of-the-art semiconductor device processing</td>
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| **Content** | 1. Fundamentals of Solid State Physics  
1.1 Semiconductor materials  
1.2 Band structures  
1.3 Carrier statistics in intrinsic and doped semiconductors  
1.4 p-n junctions  
1.5 Low-dimensional structures  
2. Bulk Material growth of Semiconductors  
2.1 Czochalski method  
2.2 Floating zone method  
2.3 High pressure synthesis  
3. Semiconductor Epitaxy  
3.1 Fundamentals of Epitaxy  
3.2 Molecular Beam Epitaxy (MBE)  
3.3 Metal-Organic Chemical Vapor Deposition (MOCVD)  
3.4 Liquid Phase Epitaxy (LPE)  
4. In situ characterization  
4.1 Pressure and temperature  
4.2 Reflectometry  
4.3 Ellipsometry and RAS  
4.4 LEED, AES, XPS  
4.5 STM, AFM  
5. The invention of the transistor - Christmas lecture |
| **Lecture notes** | https://moodle-app2.let.ethz.ch/course/view.php?id=20749 |
| **Prerequisites / notice** | The "compulsory performance element" of this lecture is a short presentation of a research paper complementing the lecture topics. Several topics and corresponding papers will be offered on the moodle page of this lecture. |
| **Competencies** | Subject-specific Competencies: Concepts and Theories  
Techniques and Technologies  
Method-specific Competencies: Analytical Competencies  
Social Competencies: Communication  
Self-presentation and Social Influence |

| 402-0442-00L | Quantum Optics | W | 10 | 3V+2U | A. Imamoglu   |
| **Abstract** | This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics covered include the quantum nature of light, semi-classical and quantum mechanical description of light-matter interaction, laser manipulation of atoms and ions, optomechanics and quantum computation. |
| **Objective** | The course aims to provide the knowledge necessary for pursuing research in the field of Quantum Optics. Fundamental concepts and techniques of Quantum Optics will be linked to modern experimental research. During the course the students should acquire the capability to understand currently published research in the field. |
| **Content** | - coherence properties of light  
- quantum nature of light: statistics and non-classical states of light  
- light matter interaction: density matrix formalism and Bloch equations  
- quantum description of light matter interaction: the Jaynes-Cummings model, photon blockade  
- laser manipulation of atoms and ions: laser cooling and trapping, atom interferometry, further topics: Rydberg atoms, optomechanics, quantum computing, complex quantum systems. |
| **Lecture notes** | Selected book chapters will be distributed. |
| **Literature** | Text-books:  
G. Grynberg, A. Aspect and C. Fabre, Introduction to Quantum Optics  
R. Loudon, The Quantum Theory of Light  
Atomic Physics, Christopher J. Foot  
Advances in Atomic Physics, Claude Cohen-Tannoudji and David Guéry-Odelin  
C. Cohen-Tannoudji et al., Atom-Photon-Interactions  
M. Scully and M.S. Zubairy, Quantum Optics  
Y. Yamamoto and A. Imamoglu, Mesoscopic Quantum Optics |
| **Competencies** | Subject-specific Competencies: Concepts and Theories  
Techniques and Technologies  
Method-specific Competencies: Analytical Competencies  
Media and Digital Technologies  
Problem-solving  
Social Competencies: Communication  
Cooperation and Teamwork  
Personal Competencies: Creative Thinking  
Critical Thinking |

| 402-0442-05L | Advanced Topics in Quantum Optics | W | 4 | 2G | T. Esslinger   |
| **Abstract** | This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics that are covered include: |
| **Lecture notes** | |
| **Literature** | |
| **Competencies** | Subject-specific Competencies: Concepts and Theories  
Techniques and Technologies  
Method-specific Competencies: Analytical Competencies  
Media and Digital Technologies  
Problem-solving  
Social Competencies: Communication  
Cooperation and Teamwork  
Personal Competencies: Creative Thinking  
Critical Thinking |

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Autumn Semester 2024  
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Abstract
The lecture will cover current topics and papers in the wider field of quantum optics in an interactive format. Several papers will be presented by the students in the style of a journal club. Selected papers will be contrasted and their strengths and weaknesses discussed by the students in panel discussions. Recent papers on arXiv.org will be discussed and referee reports referee reports.

Objective
The aim of the lecture is to deepen and broaden the knowledge about current research in the field of quantum optics. In addition, it will also be discussed and critically examined how research results are communicated via publications and lectures and which techniques are used in the process.

Content
We will select topical fields in quantum optics and quantum science and discuss recently published work.

Topics:
- Atoms or ions-based quantum computing
- Quantum simulation
- Opto-mechanics
- Driven and dissipative quantum systems
- Cavity based atom-light interaction
- Topological photonics

The interactive part of the lecture will include presentations of recent papers, panel discussions of recent papers and the writing of a critical assessment of an arXiv paper in the style of a referee report.

Competencies

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402-0448-01L Quantum Information Processing I: Concepts
This theory part QIP I together with the experimental part 402-0448-02L QIP II (both offered in the autumn semester) combine to the core course in experimental physics "Quantum Information Processing" (totally 10 ECTS credits). This applies to the Master's degree programme in Physics.

Abstract
The course covers the key concepts and formalism of quantum information processing. Topics include quantum algorithms, quantum error correction, quantum cryptography, and quantum metrology, with an emphasis on the power of quantum information processing beyond that of classical information processing. The formalism of quantum states, measurements, and channels is developed in detail.

Objective
By the end of the course students are able to explain the basic mathematical formalism of quantum mechanics and apply it to quantum information processing problems. They are able to adapt and apply these concepts and methods to analyze and discuss quantum algorithms and other quantum information-processing protocols.

Content
The topics covered in the course will include quantum circuits, gate decomposition and universal sets of gates, efficiency of quantum circuits, quantum algorithms (Shor, Grover, Deutsch-Jozsa,...), stabilizer-based quantum error correction, fault-tolerant designs, the BB84 quantum key distribution protocol, and simple methods of quantum metrology.

Lecture notes
Will be provided.

Literature
Quantum Computation and Quantum Information
Michael Nielsen and Isaac Chuang
Cambridge University Press

Prerequisites / notice
A good understanding of finite dimensional linear algebra is recommended.

Competencies

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402-0448-02L Quantum Information Processing II: Implementations
This experimental part QIP II together with the theory part 402-0448-01L QIP I (both offered in the autumn semester) combine to the core course in experimental physics "Quantum Information Processing" (totally 10 ECTS credits). This applies to the Master's degree programme in Physics.

Abstract

Objective
Throughout the past 20 years the realm of quantum physics has entered the domain of information technology in more and more prominent ways. Enormous progress in the physical sciences and in engineering and technology has allowed us to build novel types of information processors based on the concepts of quantum physics. In these processors information is stored in the quantum state of physical systems forming quantum bits (qubits). The interaction between qubits is controlled and the resulting states are read out on the level of single quanta in order to process information. Realizing such challenging tasks is believed to allow constructing an information processor much more powerful than a classical computer. This task is taken on by academic labs, startups and major industry. The aim of this class is to give a thorough introduction to physical implementations pursued in current research for realizing quantum information processors. The field of quantum information science is one of the fastest growing and most active domains of research in modern physics.
The aim of this course is to equip students of different backgrounds with a solid base to follow this rapidly developing and exciting multi-disciplinary field.

Intersubband Optoelectronics

The rich physics of the optical properties of semiconductors, as well as the advanced processing available on these materials, enabled recent years to witness incredible progress in the development of new quantum technologies driven by their application in quantum information, metrology, high precision spectroscopy and quantum sensing. This course will present how these emerging technologies are powerful tools to address open questions of the Standard Model in a complementary way to what is done at the high energy frontier.

The course presents fundamental aspects of light-matter interaction in semiconductor materials, from basic research topics to opto-electronic devices. The main part of the course will introduce the following (quantum) technologies and systems, and how they can be used for probing New Physics.

- Quantum technologies for searches of New Physics
  - Quantum technologies for searches of New Physics
  - Quantum Computation and Quantum Information
  - Jerome Faist, published by Oxford University Press

5 credits

More information on this class can be found on the web site www.qudev.ethz.ch

### Course Material
- Lecture notes: Course material be made available at www.qudev.ethz.ch and on the Moodle platform for the course. More details to follow.
- Literature: Quantum Computation and Quantum Information
- Michael Nielsen and Isaac Chuang
- Cambridge University Press

### Prerequisites / Notice
- The class will be taught in English language.
- Basic knowledge of concepts of quantum physics and quantum systems, e.g from courses such as Physics III, Quantum Mechanics I and II or courses on topics such as atomic physics, solid state physics, quantum electronics are considered helpful.
- More information on this web site www.qudev.ethz.ch

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<td>2V+1U</td>
<td>P. Crivelli</td>
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<td>6 credits</td>
<td>2V+1U</td>
<td>G. Scalari, J. Faist</td>
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### Lecture Notes
- The reference book for the lecture is "Quantum Cascade Lasers" by Jerome Faist, published by Oxford University Press.
- Mostly the original articles, other useful reading can be found in:
  - E. Rosencher and B. Vinter, Optoelectronics, Cambridge Univ. Press
  - G. Bastard, Wave mechanics applied to semiconductor heterostructures, Halsted press

### Prerequisites / Notice
- The preceding attendance of introductory particle physics, quantum mechanics and quantum electronics courses at the bachelor level is recommended.
- Requirements: A basic knowledge of solid-state physics and of quantum electronics.
### Competencies

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<td>Assessed</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>Assessed</td>
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### 402-0468-15L Nanomaterials for Photonic Devices

**W 6 credits 2V+1U**  
R. Grange, E. Bailly, R. Chapman, V. Falcone, A. Morandi

**Abstract**  
The lecture describes various nanomaterials (semiconductor, metal, dielectric, carbon-based...) for photonic applications (optoelectronics, plasmonics, photonic integrated circuits, ordered and disordered structures...). It starts with concepts of light-matter interactions, fabrication and characterization, the description of the properties and the state-of-the-art applications and devices.

**Objective**  
The students will acquire theoretical and experimental knowledge about the different types of nanomaterials (semiconductors, metals, dielectric, carbon-based,...) and their uses as building blocks for advanced applications in photonics (optoelectronics, plasmonics, photonic crystal,...). Together with the exercises, the students will learn (1) to read, summarize and discuss scientific articles related to the lecture, (2) to estimate order of magnitudes with calculations using the theory seen during the lecture, (3) to prepare a short oral presentation and report about one topic related to the lecture, and (4) to imagine an original photonic device.

**Content**

1. Introduction to nanophotonics
2. Wave physics for nanophotonics
3. Characterization of nanomaterials
4. Semiconductors
5. Nonlinear crystals
6. Photonic integrated circuits
7. Optical quantum devices
8. Plasmonics
9. Metasurfaces
10. Graphene & 2D Materials
11. Nanocomposites

**Lecture notes**  
Slides and book chapter will be available for downloading

**Literature**  
References will be given during the lecture

**Prerequisites / notice**  
Basics of solid-state physics (i.e. energy bands) can help

### 402-0475-00L Terahertz Science and Applications

**W 5 credits 2V+1U**  
E. Abreu

**Abstract**  
The Terahertz (THz) range (0.1 – 10 THz), lies between the infrared and microwave spectral regions and has become accessible in the past few years. This new capability has had great impact in scientific research, and has led to technological advances and to the development of a variety of applications and devices. This course provides an introduction to THz science, technology and applications.

**Objective**  
The goal of this course is to enable students to determine whether a THz solution can be applied to a particular scientific or technological problem. Armed with the fundamentals of THz science and of current THz technologies, covered in this introductory course, students will be able to weigh the capabilities, advantages and limitations of THz tools to address topics ranging from phonons in solid state systems and molecular vibrations in solutions to medical imaging and wireless communications.

**Lecture notes**  
Will be distributed via moodle.

**Literature**  
Yun-Shik Lee, Principles of Terahertz Science and Technology, Springer 2009  
Additional references distributed via moodle.

**Prerequisites / notice**  
Basic knowledge in physics, especially in electromagnetism, is required. No formal prerequisites.

### 402-0492-00L Experimental Techniques in Quantum and Electro-

**W 6 credits 2V+1U**  
Autumn Semester 2024

**Competencies**

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Assessed</th>
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<td>Social Competencies</td>
<td>Decision-making</td>
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<td>Personal Competencies</td>
<td>Communication</td>
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</table>

**Additional competencies**

| Competencies     | Adaptable and Flexibility     | Assessed       |
|------------------| Creative Thinking             | Assessed       |
|                  | Critical Thinking             | Assessed       |
|                  | Integrity and Work Ethics     | Assessed       |
|                  | Self-awareness and Self-reflection | Assessed       |
|                  | Self-direction and Self-management | Assessed       |
Ultrafast Processes in Solids

Abstract
Ultrafast processes in solids are of fundamental interest as well as relevant for modern technological applications. The dynamics of the lattice, the electron gas as well as the spin system of a solid are discussed. The focus is on time resolved experiments which provide insight into pico- and femtosecond dynamics.

Objective
By the end of this course, students will develop the ability to utilize quantum mechanics concepts to estimate the strength of atomic magnetic moments and understand their reciprocal interactions. They will gain proficiency in interpreting experimental measurements on model systems in terms of material composition and an appropriate, phenomenological spin Hamiltonian. For instance, students will be able to recognize whether the magnetic hysteresis observed in some samples arises from slow dynamics or from a phase transition. Lastly, they will be capable of interpreting the occurrence of abrupt transitions or the emergence of characteristic length scales as resulting from the interplay between competing interactions. Altogether, students will acquire the basic knowledge needed to develop a research project in the field of magnetism or to attend effectively more advanced courses on this topic.

Content
1. Experimental techniques, an overview
   - Dynamics of the electron gas
   - First experiments on electron dynamics and lattice heating
2. Dynamics of the spin system
   - Laser induced ultrafast demagnetization
   - Ultrafast spin currents generated by lasers
3. Dynamics of the lattice
   - Phonons
   - Non-thermal melting
4. Correlated materials
   - Laser induced switching
   - Landau-Lifschitz-Dynamics
   - Laser induced switching
5. Correlated materials
   - Spin precession and relaxation (Larmor precession, resonance phenomena, quantum tunneling, Bloch equation, superparamagnetism)
   - Magnetic order at finite temperatures (Ising, XY, and Heisenberg models, low-dimensional magnetism)
   - Magnetism in solids (mechanisms producing inter-atomic exchange interaction in solids, crystal field)
   - Magnetic order at finite temperatures (Ising, XY, and Heisenberg models, low-dimensional magnetism)
   - Spin precession and relaxation (Larmor precession, resonance phenomena, quantum tunneling, Bloch equation, superparamagnetism)

Literature
The lecture “Introduction to Magnetism” aims at letting students familiarize themselves with the basic principles of quantum and statistical physics that determine the behavior of real magnets. Understanding why only a few materials are magnetic at finite temperature will be the leitmotiv of the course. We will see that defining in a formal way what “being magnetic” means is essential to address this question properly. Theoretical concepts will be applied to a few selected nano-sized magnets, which will serve as clean reference systems.

Topics:
- Magnetism in atoms (quantum-mechanical origin of atomic magnetic moments, intra-atomic exchange interaction)
- Magnetism in solids (mechanisms producing inter-atomic exchange interaction in solids, crystal field)
- Magnetic order at finite temperatures (Ising, XY, and Heisenberg models, low-dimensional magnetism)
- Spin precession and relaxation (Larmor precession, resonance phenomena, quantum tunneling, Bloch equation, superparamagnetism)

Learning material will be made available through Moodle and through the ETH JupyterHub.

Prerequisites
Students are assumed to possess a basic background knowledge in quantum mechanics, solid-state and statistical physics as well as classical electromagnetism.

Examples from a modern quantum information laboratory will be discussed and illustrated through active devices in the lecture.
Semiconductor Nanostructures

W 6 credits 2V+1U T. M. Ihn

Objective
At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:
1. The integer quantum Hall effect
2. Conductance quantization in quantum point contacts
3. the Aharonov-Bohm effect
4. Coulomb blockade in quantum dots

Content
1. Introduction and overview
2. Semiconductor crystals: Fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k.p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

Lecture notes

Literature
In addition to the lecture notes, the following supplementary books can be recommended:

Prerequisites / notice
The lecture is suitable for all physics students, students of Quantum Engineering, and students of Micro- and Nanosystems beyond the bachelor of science degree. Basic knowledge of solid state physics is a prerequisite. Very ambitious students in the third year of Physics may be able to follow. The lecture can be chosen as part of the PhD-program. The course is taught in English.

Current Topics in Accelerator Mass Spectrometry and Its Applications

E- 0 credits 2S M. Christl, S. Willett

Abstract
The seminar is aimed at all students who, during their studies, are confronted with age determination methods based on long-living radionuclides found in nature. Basic methodology, the latest developments, and special examples from a wide range of applications will be discussed.

Objective
The seminar provides the participants an overview about newest trends and developments of accelerator mass spectrometry (AMS) and related applications. In their talks and subsequent discussions the participants learn intensively about the newest trends in the field of AMS thus attaining a broad knowledge on both, the physical principles and the applications of AMS, which goes far beyond the horizon of their own studies.

Introduction to Accelerator Mass Spectrometry

W 6 credits 2V+1U C. Vockenhuber, M. Christl, A. Müller, L. Wacker

Abstract
This course gives an introduction into Accelerator Mass Spectrometry (AMS), the most sensitive method for measuring long-lived radionuclides in natural samples.

Objective
Students learn the basic concepts of Accelerator Mass Spectrometry. Based on the underlying physics of ion matter interaction they learn the measurement methods and interpretation of the results for most of the important AMS radionuclides, e.g. radiocarbon (14C), the cosmogenic radionuclides 10Be, 26Al, 36Cl, and anthropogenic nuclides 129I, 236U and other actinides.
Content

Introduction into the physics of ion matter interaction: ion stopping, ion scattering and charge exchange.

Ion optics and ion acceleration.

Mass separation, molecular destruction and isobar separation.

Ion detection and identification.

The measurement methods for all the important radionuclides and the interpretation of their results are discussed on a few examples from the application:

- 14C – radiocarbon dating and environmental studies
- 10Be, 26Al, 36Cl – cosmogenic dating and ice core research
- 129I, 236U, actinides – anthropogenic tracers in the environment
- 14C, 41Ca – biomedical studies
- 60Fe, 244Pu – astrophysics

Alternative methods: ICP-MS, RIMS, ATTA

A visit to the Tandem accelerator and AMS facilities at ETH Hönggerberg is organized as part of lectures and exercises.

Lecture notes

Lecture notes will be distributed in pdf

402-0715-00L Low Energy Particle Physics W 6 credits 2V+1U A. S. Antognini, D. Ries

Abstract

Low energy particle physics provides complementary information to high energy physics with colliders. In this lecture, we will concentrate on flagship experiments which have significantly improved our understanding of particle physics today, concentrating mainly on precision experiments with neutrons, muons and exotic atoms.

Objective

You will be able to present and discuss:
- the principle of the experiments
- the underlying technique and methods
- the context and the impact of these experiments on particle physics

Content

Low energy particle physics provides complementary information to high energy physics with colliders. At the Large Hadron Collider one directly searches for new particles at energies up to the TeV range. In a complementary way, low energy particle physics indirectly probes the existence of such particles and provides constraints for "new physics", making use of high precision and high intensities.

Besides the sensitivity to effects related with new physics (e.g. lepton flavor violation, symmetry violations, CPT tests, search for electric dipole moments, new low mass exchange bosons etc.), low energy physics provides the best test of QED (electron g-2), the best tests of bound-state QED (atomic physics and exotic atoms), precise determinations of fundamental constants, information about the CKM matrix, precise information on the weak and strong force even in the non-perturbative regime etc.

Starting from a general introduction on high intensity/high precision particle physics and the main characteristics of muons and neutrons and their production, we will then focus on the discussion of fundamental problems and ground-breaking experiments:

- search for rare decays and charged lepton flavor violation
- electric dipole moments and CP violation
- spectroscopy of exotic atoms and symmetries of the standard model
- what atomic physics can do for particle physics and vice versa
- neutron decay and primordial nucleosynthesis
- atomic clock
- Penning traps
- Ramsey spectroscopy
- Spin manipulation
- neutron-matter interaction
- ultra-cold neutron production
- various techniques: detectors, cryogenics, particle beams, laser cooling....

Literature

Golub, Richardson & Lamoreaux: "Ultra-Cold Neutrons"
Rauch & Werner: "Neutron Interferometry"
Carlile & Willis: "Experimental Neutron Scattering"
Byrne: "Neutrons. Nuclei and Matter"
Klapdor-Kleingrothaus: "Non Accelerator Particle Physics"

Prerequisites / notice

Einführung in die Kern- und Teilchenphysik / Introduction to Nuclear- and Particle-Physics

402-0738-10L Bayesian Statistical Methods and Data Analysis 6 credits 3G T. Tröster

Abstract

The course covers various data analysis methods using Bayesian statistics, with a focus on practical problem solving. We will go over a brief introduction to probability theory, Bayesian reasoning, and how to build a statistical model and compare it to data. The course builds towards analysing data from real astrophysical problems, using both classical statistical methods and machine learning.

Objective

The goal of this course is to introduce students to Bayesian statistics and prepare them to solve statistical inference problems in contemporary (astrophysics) research. After introducing Bayesian statistics and general methodology, the course focusses on building up a structured approach to analyse increasingly complex data and models. The methods are general and applicable beyond (astro)physics, however.
Topics covered include:
- Review of probability theory:
  - Independence, joint and conditional probabilities
  - Univariate and multivariate probability distributions
  - Change of variables
- Bayesian statistics:
  - Bayes' theorem
  - Priors
  - Bayesian reasoning
  - Posterior distributions, model checking, and model comparison
- Tools for statistical inference:
  - Various sampling methods, such as Markov chain Monte Carlo (Metropolis Hastings, slice sampling, Hamiltonian Monte Carlo) and resampled sampling
  - Simulation-based inference
  - PCA, bootstrap
  - Gaussian processes and Gaussian random fields
  - Machine learning and probabilistic programming

The lectures are accompanied with code examples, both to illustrate the covered topics and to demonstrate how the theoretical concepts can be implemented in practical computational inference problems.

The students complete a project on a statistical analysis, using the tools covered in the course.

Prerequisites / notice
Prior knowledge of probability theory and statistics would be useful but not required. Since most of the course makes use of computational methods, some knowledge of scientific computing with Python (e.g. numpy, scipy) will be assumed.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Project Management</td>
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<td>Social Competencies</td>
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<td></td>
<td>Cooperation and Teamwork</td>
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<td>Leadership and Responsibility</td>
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<td>Personal Competencies</td>
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<td>Self-direction and Self-management</td>
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</table>

Abstract
Theoretical basis and selected experiments to determine the properties of neutrinos and their interactions (mass, spin, helicity, chirality, oscillations, charge-parity violation, interactions with leptons and quarks) and implications on physics beyond the Standard Model of elementary particles as well as on Cosmology.

Objective
Critically analyze and elaborate the neutrino production and detection techniques. Derive the theory of neutrino scattering and analyze its implications in neutrino experiments. Analyze the phenomenology of neutrino oscillations and its implication on the physics Beyond the Standard Model of particles. Derive the main concepts of the theory of neutrino masses within and beyond the Standard Model of particles and analyze the experimental techniques related to the measurement of the neutrino masses. Describe the role of neutrinos in Cosmology and make connections with current and future neutrino experiments. Review the experimental configurations and analyze the challenges in searches for leptonic Charge-Parity symmetry violation and the measurement of the neutrino mass hierarchy.

Content
1. Introduction to Neutrinos and Neutrino Sources;
2. Neutrino Detectors
3. Neutrino Interactions
4. Neutrino Oscillations
5. Nature of Neutrino masses
6. Neutrinos in Cosmology
7. Search for leptonic Charge Parity violation and precision measurement of the neutrino oscillation probability

Literature
A. Rubbia, “Phenomenology of Particle Physics”, Cambridge University Press
D.O. Caldwell, Current Aspects of Neutrino Physics, Springer.
K.Zuber, “Neutrino Physics” CRC Press 2020

Competencies

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Literature
A. Rubbia, “Phenomenology of Particle Physics”, Cambridge University Press
D.O. Caldwell, Current Aspects of Neutrino Physics, Springer.
K.Zuber, “Neutrino Physics” CRC Press 2020

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH.
UZH Module Code: PHYS29

Mind the enrolment deadlines at UZH:
Abstract

The aim of this lecture is to discuss some advanced topics in general relativity, which are useful to understand the present research activities in the field. A list of possible topics is given below. A basic knowledge of general relativity is required (ideally having followed the lecture on General Relativity). The course is particularly suited for master and PhD students.

Objectives

Is to be able to read and understand the original literature and the presently published papers in the field of the discussed advanced topics. This might also be useful in view of doing afterwards a master thesis in the field of general relativity.

Content

Possible content:
- General relativistic stellar structure equations (Neutron stars)
- Tetrad formalism
- Spinors in GR
- Klein-Gordon & Dirac eqs. in GR
- Thermodynamics of black holes and Hawking radiation
- Topics in gravitational waves: GW generation by PN sources, GW from elliptic, hyperbolic binaries
- Tests of the equivalence principle

Competencies

Subject-specific Competencies

Concepts and Theories assessed

402-0836-16L Quantum Simulations of Gauge Theories

W 6 credits 2V+1U M. Krstic Marinkovic

Abstract

Divided into three parts, the course introduces various aspects of lattice quantum field theory (QFT), gauge symmetries, quantum simulations, and implementation schemes. Other than highlighting the strengths and weaknesses of the lattice formulation of QFTs suitable for Monte Carlo simulations, the course discusses practical realization of quantum simulators for gauge theories.

Objective

After acquiring the foundations on lattice formulation of gauge theories, and challenges of conventional Monte Carlo simulation approaches, the students will learn about different strategies for quantum simulation of gauge theories and their implementation on digital and analog quantum devices.

Content

1. Background and Motivation
   1.1 From Quantum Field Theories to Lattice field theories;
   1.2 Lattice Gauge Theories - Lagrangian formulation, gauge symmetries, observables;
   1.3 Monte Carlo simulations, sign problems, and complex actions.
2. Road-map for Quantum Simulation of Gauge Theories
   2.1 Hamiltonian formulation, Wilson's formulation, and the infinite Hilbert spaces;
   2.2 Finite Hilbert spaces: Z(N) gauge theories. Dualizing the Ising model and relation with the toric code;
   2.3 Finite Hilbert spaces: Quantum link models for Abelian gauge theories;
   2.4 Finite Hilbert spaces: Quantum link models for non-Abelian gauge theories;
   2.5 Exploring the physics of gauge theories - phases, dynamics, and thermalization;
   2.6 Exploring methods for gauge theories - exact diagonalization, tensor networks, Monte Carlo.
3. Quantum Simulation Approaches and Platforms
   3.1 Digital vs. analog quantum simulations;
   3.2 Proposals for simulations of gauge theories, realization, and perspectives.

Literature

Quantum chromodynamics on the lattice (Christof Gattringer, Christian B. Lang. Series Title: Lecture Notes in Physics. DOI: https://doi.org/10.1007/978-3-642-01850-3)


402-0845-61L Effective Field Theories for Particle Physics

W 6 credits 2V+1U A. Signer

Abstract

The focus of the course is on Effective Field Theories (EFTs) and their interplay with dispersion theory. These topics will be discussed both in general terms and with specific phenomenological applications in the context of physics beyond the Standard Model, effective description of the weak interaction, as well as the description of non-perturbative strong interaction at low energies.

Objective

This course covers the basic concepts of effective field theories (EFTs) and dispersion theory. We will start by introducing the core concept of constructing EFTs and apply them to the low-energy description of the weak interaction and the effective description of heavy physics beyond the Standard Model.

In the next part of the course, we will discuss Chiral Perturbation Theory (ChPT), the low-energy effective theory of Quantum Chromodynamics (QCD). We will briefly discuss the application of this concept to describe a class of theories beyond the SM in which the SM Higgs arises as a composite state of a new confining sector.

The second focus of the course is on dispersion theory and its interplay with EFTs. We will discuss how to make use of the constraints from unitarity of the S-matrix and analyticity of scattering amplitudes, in order to extend the range of validity of the theoretical description compared to pure EFT methods. We will also discuss how to obtain constraints on EFT parameters from unitarity and analyticity. We will discuss the application of these methods both in the context of low-energy strong interaction and physics beyond the Standard Model.

Content

- Introduction to Effective Field Theories
- Decoupling and matching
- Renormalization group resummation
- The Standard Model Effective Field Theory (SMEFT)
- Chiral Lagrangians
- Unitarity of the S-matrix
- Analyticity and dispersion relations

Prerequisites / notice

QFT-I (mandatory) and QFT-II (highly recommended)

402-0897-00L Introduction to String Theory

W 6 credits 2V+1U J. Brödel

Abstract

String theory is an attempt to quantise gravity and unite it with the other fundamental forces of nature. It is related to numerous interesting topics and questions in quantum field theory. In this course, an introduction to the basics of string theory is provided.

Objective

Within this course, a basic understanding and overview of the concepts and notions employed in string theory shall be given. More advanced topics will be touched upon towards the end of the course briefly in order to foster further research.

Content

- mechanics of point particles and extended objects
- string modes and their quantisation; higher dimensions, supersymmetry
- critical dimension and no-ghost theorem
- D-branes, T-duality
- two-dimensional conformal field theories

Literature

M.B. Green, J.H. Schwarz, E. Witten, Superstring Theory I, CUP (1987).
<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
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<tr>
<td>402-0010-00L Basics of Computing Environments for Scientists</td>
<td>Subject-specific Competencies</td>
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<td>Enrollment is only possible under <a href="https://www.lehrbetrieb.ethz.ch/laborpraktika">https://www.lehrbetrieb.ethz.ch/laborpraktika</a></td>
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<td>No registration required via myStudies.</td>
<td>C. D. Herzog, C. Becker, S. Müller</td>
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<tr>
<td>Abstract</td>
<td>Introduce IT services at D-PHYS and offer modules covering IT-related topics for scientists.</td>
<td>Objective</td>
<td>The &quot;IT at D-PHYS&quot; introduction provides a good understanding of how IT works at D-PHYS and presents an overview of the IT services and their providers. It is recommended for everyone joining the department.</td>
<td>The &quot;IT and Information Security&quot; crash course will address the most common threats you'll encounter when using the internet and teach you how to fend them off.</td>
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<td>The remainder is structured into individual modules which can be attended separately. They give practical insights into everyday research-related IT challenges.</td>
<td>Use the dedicated web page <a href="https://www.lehrbetrieb.ethz.ch/laborpraktika">https://www.lehrbetrieb.ethz.ch/laborpraktika</a> to register. Enrolled students are eligible for an attestation of attendance after visiting at least 3 out of the 5 modules. Refer to <a href="https://compenv.phys.ethz.ch">https://compenv.phys.ethz.ch</a> for the detailed contents.</td>
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<tr>
<td>Content</td>
<td>Introduction: IT at D-PHYS (IT service providers and IT services at D-PHYS) IT and Information Security</td>
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<td>Modules:</td>
<td>Linux Basics I (system components, basic shell usage) Python Ecosystem I (interpreters, packages, virtual environments) Python Ecosystem II (development environments, formatter and linter, string formatting, regexp) Python Ecosystem III (external data files, config parameters and automation) System Aspects (how the hardware affects your scientific code and vice versa)</td>
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<td>Competencies</td>
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<tr>
<td>402-0883-63L Symmetries in Physics</td>
<td>Subject-specific Competencies</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
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<td>Recommended: Quantum Field Theory I (in parallel)</td>
<td>Method-specific Competencies</td>
<td>G. M. Graf</td>
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<tr>
<td>Abstract</td>
<td>The course gives an introduction to symmetry groups in physics. It explains the relevant mathematical background (finite groups, Lie groups and algebras as well as their representations), and illustrates their important role across modern physics.</td>
<td>Objective</td>
<td>The aim of the course is to give a self-contained introduction into finite group theory as well as Lie theory from a physicists point of view. Abstract mathematical constructions will be illustrated with examples from physics.</td>
<td>Finite group theory, including representation theory and character methods; applications to crystallography and solid state physics. The symmetric group and the structure of its representations; applications to identical particles. Clifford algebras; application to relativistic wave equations equations. Simple Lie algebras and their finite-dimensional representations. Description of representations of SU(N) in terms of Young diagrams; applications in particle physics.</td>
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<td>Techniques and Technologies</td>
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<td>Problem-solving</td>
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<tr>
<td>376-1791-00L Introductory Course in Neuroscience I (University of Zurich)</td>
<td>Subject-specific Competencies</td>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: SPV0Y005</td>
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<td>W. Knecht, University lecturers</td>
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<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadline">https://www.uzh.ch/cmsssl/en/studies/application/deadline</a> s.html</td>
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The course gives an introduction to human and comparative neuroanatomy, molecular, cellular and systems neuroscience.

Objective
The course gives an introduction to the development and anatomical structure of nervous systems. Furthermore, it discusses the basics of cellular neurophysiology and neuropharmacology. Finally, the nervous system is described on a system level.

Content
1) Human Neuroanatomy I&II
2) Comparative Neuroanatomy
3) Building a central nervous system I&II
4) Synapses I&II
5) Glia and more
6) Excitability
7) Circuits underlying Emotion
8) Visual System
9) Auditory & Vestibular System
10) Somatosensory and Motor Systems
11) Learning in artificial and biological neural networks

Prerequisites / notice
For doctoral students of the Neuroscience Center Zurich (ZNZ).

227-0671-00L Nanodevices and Circuits for the Beyond-Moore Era W 3 credits 2V M. Csontos, I. Shorubalko

Abstract
Big Data, AI and the Internet of Things demand new hardware which overcomes the limitations of von Neumann architectures. The lecture gives an insight how the fundamental physics and the resulting complex functionalities of nanodevices and circuits offer viable alternatives. Their increased computational power and energy efficiency are demonstrated through neuromorphic computing applications.

Objective
The students will gain a firm understanding in the theory and pioneering experiments of electronic and heat transport at atomic- to nanometer length-scales. Advanced device functionalities enabled by recently discovered material systems will be covered. The students will learn how to exploit such phenomena for designing nanodevices and circuits to energy-efficiently implement neuromorphic algorithms for a sustainable future of information technologies.

Lecture notes
The presentation slides and further material will be provided every week.

Prerequisites / notice
Basic knowledge of solid state physics and semiconductors.

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Method-specific Competencies
| Analytical Competencies | fostered |
| Problem-solving | fostered |

Social Competencies
| Communication | fostered |

Personal Competencies
| Critical Thinking | fostered |

227-0654-00L Carbon-based Nanoelectronics W 6 credits 2V+1U+1A M. Perrin

Abstract
This course explores the exciting realm of carbon-based nanoelectronics, where the remarkable quantum properties of materials like graphene, carbon nanotubes, graphene nanoribbons, and single molecules are used for building electronic devices.

Objective
The objective of this course is to understand how the electronic properties of carbon-based materials can be exploited for fabricating quantum devices. We will delve into both the theoretical and experimental aspects, discussing how these materials’ unique properties can be translated into device functionality.

Content
The course will cover the following carbon-based materials:
- Single-molecule
- Graphene (single layer, bilayer, twisted bilayer)
- Graphene nanoribbons
- Carbon nanotubes

For each material, we will discuss:
- Electronic structure and charge transport properties
- Material synthesis and characterization
- Device integration and characterization

The course also includes a presentation by each student in which a related scientific publication is discussed. This presentation is compulsory and accounts for 50% of the grade.

Lecture notes
Lecture notes are distributed every week. In addition, relevant scientific articles and book chapters will be provided for self-study.

Prerequisites / notice
A basic knowledge of solid-state physics and quantum mechanics is required. The course is taught in English.

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Method-specific Competencies
| Analytical Competencies | assessed |
| Media and Digital Technologies | assessed |
| Problem-solving | assessed |

Social Competencies
| Communication | assessed |
| Cooperation and Teamwork | assessed |
| Self-presentation and Social Influence | fostered |

Personal Competencies
| Creative Thinking | assessed |
| Critical Thinking | assessed |
| Self-awareness and Self-reflection | fostered |
| Self-direction and Self-management | fostered |

Transferable Skills

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<th>Number</th>
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<th>Hours</th>
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**Abstract**

Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week.

**Objective**

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<td>Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.</td>
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<td></td>
<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>Active participation in commissions or university bodies, like associations of scientific staff, the university assembly or similar for at least 1 year.</td>
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</table>

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>900-0114-DRL</td>
<td>Member of Executive Board (min 1 year)</td>
<td>W 2 credits</td>
<td>4P Lecturers</td>
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<tr>
<td></td>
<td>Only for doctoral students.</td>
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<td></td>
<td>Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>Active participation in the presidium or executive board of a university group for at least 1 year.</td>
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<tr>
<td></td>
<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>Active participation in the presidium or executive board of a university group for at least 1 year.</td>
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<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0180-00L</td>
<td>Ethics and Scientific Integrity for Doctoral Students in Physics</td>
<td>W 1 credit</td>
<td>2G N. Beisert, V. Bondar, M. Christl</td>
</tr>
</tbody>
</table>
Abstract
This course sensitises doctoral students to ethical issues that may occur during their doctorate. After an introduction to ethics and good scientific practice, students are familiarised with resources that can assist them with ethical decision-making. Students get the chance to apply their knowledge in a context specific to research in physics.

Objective
Doctoral students learn how to identify, analyse and address ethical issues in their own scientific research. In addition, they will reflect on their professional role as scientific researchers.

Content
Part I: A self-paced e-learning course in Moodle consisting of several modules on the foundations of ethics in research:
- introduction to moral theory
- introduction to ethical issues that occur within scientific research (authorship, cooperation, data use and sharing as well as other aspects that are subject to scientific integrity and good scientific practice).
- collecting resources; presentation of a variety of tools and resources that help identify ethical issues
- setting up a strategy: example examination of a case regarding its ethical scope
- making decisions: presentation of different ways of addressing ethical issues by making hard choices, solving ethical dilemmas and seeking advice.

Part II: Two face-to-face workshops focus on applications and physics-specific aspects providing an interactive learning environment. Participants get to apply their knowledge, and they are encouraged to reflect on ethical problems and to critically discuss them with fellow doctoral students. The workshops consist of several modules on:
- ethics introduction
- dilemma discussions
- case analyses
- group work and discussions
- role plays
- sustainability aspects
- dialogues with supervisor

Prerequisites / notice
For doctoral students of D-PHYS only.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>fostered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Problem-solving</td>
<td>fostered</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
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<td></td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<td></td>
<td>Leadership and Responsibility</td>
<td>fostered</td>
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<td></td>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
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<td></td>
<td>Negotiation</td>
<td>fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>fostered</td>
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</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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</tbody>
</table>

851-0373-00L Learning to Teach

This programme is designed for ETH Doctoral Teaching Assistants with current teaching responsibilities.

Abstract
This course imparts a variety of teaching skills which will help Doctoral Teaching Assistants with their teaching tasks.

Objective
In this course Doctoral Teaching Assistants will...
- discuss learning science and teaching techniques with peers.
- design the introduction of their course/lecture/exercise class.
- develop learning activities according to learning objectives.
- practice classroom assessment techniques in order to measure student learning.
- engage in peer feedback in order to improve own teaching.

Content
We will meet for the mandatory kick-off meeting online in October. You will get detailed information together with the invitation email in the first week of the semester. The online phase, where you work through 6 modules in the Moodle course page will end in November. We will meet also face-to-face for the Consolidation workshop. You will find more information on the course page in Moodle.

Prerequisites / notice
This programme is designed for ETH Doctoral Teaching Assistants with current teaching responsibilities (exercises, excursions, supervision of practicals, lectures, etc.) or those who will assume teaching tasks in the semester following the programme. No previous teacher training is required.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>fostered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Media and Digital Technologies</td>
<td>fostered</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td></td>
<td>Critical Thinking</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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</tbody>
</table>

Integration into Scientific Community

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>900-0150-DRL</td>
<td>Summer School I (1-3 days)</td>
<td>W</td>
<td>1</td>
<td>2K</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

Abstract
Participation in summer or winter schools with a maximum duration of 3 days.

Objective
Participation in summer or winter schools with a maximum duration of 3 days.
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>W</th>
<th>Credits</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>900-0152-DRL</td>
<td>Summer School III (1-3 days)</td>
<td>W</td>
<td>1 credit</td>
<td>2K</td>
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<tr>
<td>900-0153-DRL</td>
<td>Summer School I (1-3 days)</td>
<td>W</td>
<td>2 credits</td>
<td>4K</td>
</tr>
<tr>
<td>900-0154-DRL</td>
<td>Summer School II (1-3 days, with Poster or Talk)</td>
<td>W</td>
<td>2 credits</td>
<td>4K</td>
</tr>
<tr>
<td>900-0155-DRL</td>
<td>Summer School III (1-3 days, with Poster or Talk)</td>
<td>W</td>
<td>2 credits</td>
<td>4K</td>
</tr>
<tr>
<td>900-0156-DRL</td>
<td>Summer School I (1 week)</td>
<td>W</td>
<td>2 credits</td>
<td>4K</td>
</tr>
<tr>
<td>900-0157-DRL</td>
<td>Summer School II (1 week)</td>
<td>W</td>
<td>2 credits</td>
<td>4K</td>
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<tr>
<td>900-0158-DRL</td>
<td>Summer School III (1 week)</td>
<td>W</td>
<td>2 credits</td>
<td>4K</td>
</tr>
<tr>
<td>900-0159-DRL</td>
<td>Summer School I (1 week, with Poster or Talk)</td>
<td>W</td>
<td>3 credits</td>
<td>6K</td>
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</table>

Abstract
Participation in summer or winter schools with a maximum duration of 3 days.

Objective
Participation in summer or winter schools with a maximum duration of 3 days.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Lecturers</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>900-0160-DRL</td>
<td>Summer School II (1 week, with Poster or Talk)</td>
<td>3</td>
<td>6K</td>
<td>Only for doctoral students. Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
</tr>
<tr>
<td>900-0161-DRL</td>
<td>Summer School III (1 week, with Poster or Talk)</td>
<td>3</td>
<td>6K</td>
<td>Only for doctoral students. Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
</tr>
<tr>
<td>900-0162-DRL</td>
<td>External Conference I (incl. Poster or Talk)</td>
<td>1</td>
<td>2K</td>
<td>Only for doctoral students. Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
</tr>
<tr>
<td>900-0163-DRL</td>
<td>External Conference II (incl. Poster or Talk)</td>
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<td>2K</td>
<td>Only for doctoral students. Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion. Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.</td>
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<td>900-0164-DRL</td>
<td>External Conference III (incl. Poster or Talk)</td>
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</table>

**Doctorate Physics - Key for Type**

<table>
<thead>
<tr>
<th>W+</th>
<th>Eligible for credits and recommended</th>
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</thead>
<tbody>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<td>O</td>
<td>Compulsory</td>
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**Key for Hours**

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**

- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Doctorate Environmental Systems Sciences

Subject Specialisation
Agricultural Sciences
Further courses: Subject Specialisation

Plant Sciences
Agriculture Economics

Graduate Programme in Plant Sciences

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-4003-01L</td>
<td>Current Topics in Grassland Sciences (autumn)</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>N. Buchmann</td>
</tr>
<tr>
<td>Abstract</td>
<td>Research results in agro- and forest ecosystem sciences will be presented by experienced researchers as well as by doctoral and graduate students. Citation classics as well as recent research results will be discussed. Topics will range from plant ecophysiology, biodiversity and biogeochemistry to management aspects in agro- and forest ecosystems.</td>
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<tr>
<td>Objective</td>
<td>Students will be able to understand and evaluate experimental design and data interpretation of on-going studies, be able to critically analyze published research results, practice to present and discuss results in the public, and gain a broad knowledge of recent research and current topics in agro- and forest ecosystem sciences.</td>
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<tr>
<td>Content</td>
<td>Research results in agro- and forest ecosystem sciences will be presented by experienced researchers as well as by doctoral and graduate students. Citation classics as well as recent research results will be discussed. Topics will range from plant ecophysiology, biodiversity and biogeochemistry to management aspects in agro- and forest ecosystems.</td>
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<tr>
<td>Lecture notes</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Basic knowledge of plant ecophysiology, terrestrial ecology and management of agro- and forest ecosystems. Course will be taught in English.</td>
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<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
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<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td>assessed</td>
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<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td>Self-direction and Self-management</td>
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<tbody>
<tr>
<td>551-0205-00L</td>
<td>Challenges in Plant Sciences</td>
<td>W</td>
<td>2</td>
<td>2K</td>
<td>M. Paschke, K. Bombilies, S. Dötterl, J. Hille Ris Lambers, J. Jacobi, J. Six, S. C. Zeeman, further lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>The colloquium “Challenges in Plant Sciences” is a core class of the Zurich-Basel Plant Science Center’s PhD program. The colloquium introduces participants to the broad spectrum of plant sciences within the network. The course offers the opportunity to approach interdisciplinary topics in the field of plant sciences.</td>
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<tr>
<td>Objective</td>
<td>Objectives of the colloquium are:</td>
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<tr>
<td>Content</td>
<td>Introduction to recent research in all fields of plant sciences.</td>
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<td>Working in interdisciplinary teams on the topics</td>
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<td>Developing presentation and discussion skills.</td>
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<td>Competencies</td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
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<td>Method-specific Competencies</td>
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<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>551-0209-00L</td>
<td>Sustainable Plant Systems (Seminar)</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>M. Paschke, S. F. Bender, G. S. Bhullar, F. Liebisch, further lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Agriculture, food and waste management should use less resources to accept the planetary boundaries. The focus of the seminar is:</td>
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<tr>
<td></td>
<td>(1) Agroecological systems. Can we transform the impact of agricultural in Switzerland and beyond?</td>
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<tr>
<td></td>
<td>(2) Food system transformation. How can local sustainable food systems be built and scaled through policy strategies, food environments and consumer habits.</td>
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<tr>
<td>Objective</td>
<td>Participants will be able to:</td>
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<td></td>
<td>(1) Review issues of sustainability in the context of plant science research and literature on sustainable agriculture and the food system.</td>
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<td>(2) Analyze and interact on several case studies on agro-ecology and the food system.</td>
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<tr>
<td>Content</td>
<td>Future society has to feed nine billion people, therefore agriculture and food, waste and resource management have to go hand in hand toward the use of less resources and acceptance of the limits of Planetary Boundaries. The focus of the seminar will be:</td>
<td></td>
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<tr>
<td></td>
<td>(1) Research in agroecological systems. Can we transform the impact of agricultural in Switzerland and beyond?</td>
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<tr>
<td></td>
<td>(2) Food system transformation. How can local sustainable food systems be built and scaled through policy strategies, food environments and consumer habits.</td>
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<tr>
<td>Case studies (CS)</td>
<td>will include:</td>
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<tr>
<td>CS 1: How can Swiss farmers move to zero environmental impact?</td>
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<tr>
<td>CS 2: What influence do the consumers in developed (importing) countries have on sustainability of (mainly) small-holder farming in the developing (sourcing) countries?</td>
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<tr>
<td>CS 3: Sensor based fertilization techniques at the filed for sustainability?</td>
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<tr>
<td>CS 4: The blessing and curse of nitrogen – transferring knowledge from Science to Society to create more awareness.</td>
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<tr>
<td>CS 5: The transformation of the (urban) food systems and changing consumer food habits.</td>
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</tbody>
</table>
Compositional Data Analysis (CODA)

Participants of PhD Program in Plant Sciences have priority - open to other PhD students if places are available.

Please register additionally to the registration in ETHZ course catalogue here: https://ethz.ch/staffnet/en/service/courses-continuing-education.html (select Plant Sciences)

Abstract

Compositional data analysis is a methodology used to describe the parts/compounds of a whole, conveying relative information. Typical examples in different fields are: geology (geochemical elements), medicine (body composition: fat, bone, lean), food industry (food composition: fat, sugar, etc), chemistry (chemical composition), ecology (abundance of different species), agriculture (nutrient balance).

Objective

Students will be able to:
- describe what their problems are and what challenges are associated with them, and to decide which method to choose for their research task
- critically evaluate the model results of a compositional data approach in the context of plant science.

Content

The objective of this course is to introduce students with a basic programming background to compositional data analysis. We will discuss topics like the geometric properties of compositional data in plant science including the representation of data in so-called log-ratio coordinates, exploratory data analysis and visualization, location and covariance measures, application to multivariate analysis (e.g. cluster analysis), linear models and we give an outline on problems for high-dimensional data. In addition, problems with missing values, zeros and outliers are discussed. The course will consist of 50% lectures and 30% hands-on programming in R, where students will directly apply methods in software to help solving problems in plant sciences, and 20% is spent on a given task.

Literature


Prerequisites / notice

Participants should bring their laptops to the exercises with the R software environment and a suitable editor (e.g. RStudio) installed. It is assumed that students enrolling in this course have successfully completed a fundamentals of data science or statistics course and are familiar with programming (preferably in R).


Genetic Diversity: Techniques

This course provides laboratory training for advanced students (master, doctoral or post-doctoral level). Various DNA/RNA extraction protocols, quality control measurements, SNP genotyping and gene expression techniques will be addressed. This is a course for practitioners.

Objective

To learn and improve on standard and modern methods of genetic data collection. With a focus on: Use of different DNA/RNA extractions protocols, techniques for DNA/RNA quality control measurements, gene expression and SNP genotyping techniques.

Content

After an introduction (one afternoon), students have 3 weeks to work independently in groups of two on different protocols. At the end of this practical part, the whole class meets for another afternoon to present the techniques/results and to discuss the advantages and disadvantages of the different techniques.

Techniques addressed are: RNA/DNA extractions and quality control, SNP genotyping and real-time qPCR.

Lecture notes

Material will be handed out in the course.

Literature

Material will be handed out in the course.

Prerequisites / notice

There will be two afternoons in class. The lab work in between the afternoons is done by the students according to their own schedule but with the support of the teacher and must be completed after 3 weeks. The workload is approximately 1-2 full days per week, depending on the student's ability. Student must know how to pipette.

Introduction to Light Microscopy and Image Processing

This 3-day course gives a basic introduction into light microscopy. The course offers a combination of theoretical introduction with hands-on sessions teaching the fundamentals of light microscopy including transmission with phase contrast and DIC, wide-field fluorescence, deconvolution and 3D microscopy methods such as confocal imaging, including laser scanning point confocal microscopy and spinning disk, and how to operate the different acquisition modes to acquire multichannel and 3D/4D (time-lapse) image stacks.
Aerosols I: Physical and Chemical Principles

Abstract
Aerosols I deals with basic physical and chemical properties of aerosol particles. The importance of aerosols in the atmosphere and in other fields is discussed.

Objective
Physical and chemical principles:
The students...
- know the processes and physical laws of aerosol dynamics.
- understand the thermodynamics of phase equilibria and chemical equilibria.
- know the photo-chemical formation of particulate matter from inorganic and organic precursor gases.

Experimental methods:
The students...
- know the most important chemical and physical measurement instruments.
- understand the underlying chemistry and physics.

Environmental impacts:
The students...
- know the major sources of atmospheric aerosols, their chemical composition and key physical properties.
- know the most important climate impacts of atmospheric aerosols.
are aware of the health impacts of atmospheric aerosols.

Literature

Cloud Microphysics

Abstract
Clouds are a fascinating atmospheric phenomenon central to the hydrological cycle and the Earth’s climate. Interactions between cloud particles can result in precipitation, glaciation or evaporation of the cloud depending on its microstructure and microphysical processes.

Objective
The learning objective of this course is that students understand the formation of clouds and precipitation and can apply learned principles to interpret atmospheric observations of clouds and precipitation.

Content
see: http://www.iac.ethz.ch/edu/courses/master/modules/cloud-microphysics.html
and: https://moodle-app2.let.ethz.ch/course/view.php?id=15424
In this seminar, the process of writing a scientific proposal will be introduced. The essential elements of a proposal, including the peer review process, will be outlined and class exercises will train scientific writing skills. Knowledge exchange between class participants is promoted through the preparation of a master thesis proposal and evaluation of each other's work.

**Abstract**
Training scientific writing skills.

**Objective**
In this seminar, the process of writing a scientific proposal will be introduced. The essential elements of a proposal, including the peer review process, will be outlined and class exercises will train scientific writing skills. Knowledge exchange between class participants is promoted through the preparation of a master thesis proposal and evaluation of each other's work.

**Prerequisites / notice**
Attendance is mandatory.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Methods-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Critical Thinking</td>
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<tr>
<td>fostered</td>
<td>assessed</td>
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**Literature**
Lamb and Verlinde: PHYSICS AND CHEMISTRY OF CLOUDS, Cambridge University Press, 2011

**Prerequisites / notice**
The colloquium is a series of scientific talks by prominent invited speakers assembling interested students and researchers from around Zürich. Students take part of the scientific discussions.

**Objective**
The students are exposed to different atmospheric science topics and learn how to take part in scientific discussions.
### Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
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<th>Concepts and Theories</th>
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</thead>
<tbody>
<tr>
<td>701-1253-00L</td>
<td>Analysis of Climate and Weather Data</td>
<td>W</td>
<td>3 credits</td>
</tr>
</tbody>
</table>

### Abstract

An introduction to methods of statistical data analysis in meteorology and climatology. Applications of hypothesis testing, extreme value analysis, evaluation of predictions, principal component analysis. Course goals: Participants understand the theoretical concepts and purpose of methods, can apply them independently, and know how to interpret results professionally.

### Objective

Students understand the theoretical foundations and probabilistic concepts of advanced analysis tools in meteorology and climatology. They can conduct such analyses independently, and they develop an attitude of scrutiny and an awareness of uncertainty when interpreting results. Participants improve skills in understanding technical literature that uses modern statistical data analyses.

### Content

The course introduces several advanced methods of statistical data analysis frequently used in meteorology and climatology. It introduces the theoretical background of the methods, illustrates their application with example datasets, and discusses complications from assumptions and uncertainties. Generally, the course shall empower students to conduct data analysis thoughtfully and to interpret results critically.

Topics covered: exploratory methods, hypothesis testing, analysis of climate trends, measuring the skill of deterministic and probabilistic predictions, analysis of extremes, principal component analysis and maximum covariance analysis, detection and attribution.

The course is divided into lectures and computer workshops. Hands-on experimentation with example data shall encourage students in the practical application of methods and train professional interpretation of results.

R (a free software environment for statistical computing) will be used during the workshop. A short introduction into R will be provided during the course.

### Lecture notes

- Documentation and supporting material:
  - slides used during the lecture
  - exercise sets and solutions
  - R-packages with software and example datasets for workshop sessions

All material is made available via the lecture web-page.

### Literature

For complementary reading:

### Prerequisites / notice

- Prerequisites: Basics in exploratory data analysis, probability calculus and statistics (incl linear regression) (e.g. Mathematik IV: Statistik (401-0624-00L) and Mathematik VI: Angewandte Statistik für Umweltnaturwissenschaften (701-0105-00L)). Some experience in programming (ideally in R). Some elementary background in atmospheric physics and climatology.

### Competencies

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<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Analytical Competencies</td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Communication</td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<tr>
<td>Adaptability and Flexibility</td>
<td>Critical Thinking</td>
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### Number

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-1313-00L</td>
<td>Isotopes and Biomarkers in Biogeochemistry</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>C. Schubert, N. Casacuberta Arola, R. Kipfer</td>
</tr>
</tbody>
</table>

### Abstract

The course introduces the scientific concepts and typical applications of tracers in biogeochemical processes. The course covers stable and radioactive isotopes, geochemical tracers and biomarkers and their application in biogeochemical processes as well as regional and global cycles.

### Objective

The course aims at understanding the fractionation of stable isotopes in biogeochemical processes. Students learn to know the origin and decay modes of relevant radiogenic isotopes. They discover the spectrum of possible geochemical tracers and biomarkers, their potential and limitations and get familiar with important applications

### Content

- Geogenic and cosmogenic radionuclides (sources, decay chains);
- Stable isotopes in biogeochemistry (natural abundance, fractionation);
- Geochemical tracers for processes such as erosion, productivity, redox fronts; biomarkers for specific microbial processes.

### Lecture notes

A list of relevant books and papers will be provided

### Literature

Students should have a basic knowledge of biogeochemical processes (BSc course on Biogeochemical processes in aquatic systems or equivalent)

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<tr>
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<tbody>
<tr>
<td>701-1315-00L</td>
<td>Biogeochemistry of Trace Elements</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>A. Voegelin, D. Janssen, L. Winkel</td>
</tr>
</tbody>
</table>

### Abstract

The course addresses the biogeochemical classification and behavior of trace elements, including key processes driving the cycling of important trace elements in aquatic and terrestrial environments and the coupling of abiotic and biotic transformation processes of trace elements. Examples of the role of trace elements in natural or engineered systems will be presented and discussed in the course.

### Objective

The students are familiar with the chemical characteristics, the environmental behavior and fate, and the biogeochemical reactivity of different groups of trace elements. They are able to apply their knowledge on the interaction of trace elements with geosphere components and on abiotic and biotic transformation processes of trace elements to discuss and evaluate the behavior and impact of trace elements in aquatic and terrestrial systems.

### Content

(i) Definition, importance and biogeochemical classification of trace elements. (ii) Key biogeochemical processes controlling the cycling of different trace elements (base metals, redox-sensitive and chalcophile elements, volatile trace elements) in natural and engineered environments. (iii) Abiotic and biotic processes that determine the environmental fate and impact of selected trace elements.

### Lecture notes

Selected handouts (lecture notes, literature, exercises) will be distributed during the course.

### Prerequisites / notice

Students are expected to be familiar with the basic concepts of aquatic and soil chemistry covered in the respective classes at the bachelor level (soil mineralogy, soil organic matter, acid-base and redox reactions, complexation and sorption reactions, precipitation/dissolution reactions, thermodynamics, kinetics, carbonate buffer system).

The lecture 701-1315-00L Biogeochemistry of Trace Elements is a prerequisite for attending the laboratory course 701-1331-00L Trace Elements Laboratory, or students must be concurrently enrolled in 701-1315-00L Biogeochemistry of Trace Elements in the same semester.
Climate Change Mitigation: Carbon Dioxide Removal

**Objective**
The goal of this course is to investigate, as a group, a particular set of carbon mitigation/sequestration options and to evaluate their potential, their cost, and their consequences.

**Content**
From the large number of carbon sequestration/mitigation options, a few options will be selected and then investigated in detail by the students. The results of this research will then be presented to the other students, the involved faculty, and discussed in detail by the whole group.

**Literature**
None

**Prerequisites / notice**
Exam: No final exam. Pass/No-Pass is assigned based on the quality of the presentation and ensuing discussion.

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**Ecology and Evolution**

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0263-01L</td>
<td>Seminar in Evolutionary Ecology of Infectious Diseases</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>R. R. Regös, S. Bonhoeffer</td>
</tr>
</tbody>
</table>

**Abstract**
Students of this course will discuss current topics from the field of infectious disease biology. From a list of publications, each student chooses some themes that he/she is going to explain and discuss with all other participants and under supervision. The actual topics will change from year to year corresponding to the progress and new results occurring in the field.

**Objective**
This is an advanced course that will require significant student participation. Students will learn how to evaluate and present scientific literature and trace the development of ideas related to understanding the ecology and evolutionary biology of infectious diseases.

**Content**
A core set of ~10 classic publications encompassing unifying themes in infectious disease ecology and evolution, such as virulence, resistance, metapopulations, networks, and competition will be presented and discussed. Pathogens will include bacteria, viruses and fungi. Hosts will include animals, plants and humans.

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**Ecological Assessment and Evaluation**

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<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1453-00L</td>
<td>Ecological Assessment and Evaluation</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td>F. Knaus</td>
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</tbody>
</table>

**Abstract**
The course provides methods and tools for ecological evaluations dealing with nature conservation or landscape planning. It covers census methods, ecological criteria, indicators, indices and critically appraises objectivity and accuracy of the available methods, tools and procedures. Birds and plants are used as main example guiding through different case studies.

**Objective**
Students will be able to:
1) critically consider biological data books and local, regional, and national inventories;
2) evaluate the validity of ecological criteria used in decision making processes;
3) critically appraise the handling of ecological data and criteria used in the process of evaluation
4) perform an ecological evaluation project from the field survey up to the decision making and planning.

**Literature**
Basic literature and references are listed on the webpage.

**Prerequisites / notice**
The course structure changes between lecture parts, seminars and discussions. The didactic atmosphere is intended as working group.

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Suggested prerequisites for attending this course are skills and knowledge equivalent to those taught in the following ETH courses:
- Pflanzen- und Vegetationsökologie
- Systematische Botanik
- Raum- und Regionalentwicklung
- Naturschutz und Naturschutzbiologie
In this seminar, we will critically discuss recent publications on current topics in Ecological Genetics. We aim to foster learning and improvement of standard and modern methods of genetic data collection. The seminar places a focus on:

- Use of different DNA/RNA extraction protocols,
- Analytical Competencies
- Techniques for DNA/RNA quality control measurements, gene expression and SNP genotyping techniques.

After an introduction, students have 3 weeks to work independently in groups of two on different protocols. At the end of this practical part, the whole class meets for another afternoon to present the techniques/results and discuss the advantages and disadvantages of the different techniques.

This five-day winter school aims at teaching advanced Master students, PhD students and postdoctoral researchers on aspects of the genomics of environmental adaptation. It provides both theoretical background and hands-on exercises on major topics of contemporary environmental genomics such as signatures of selection, outlier analysis, genotype-environment associations, and GWAS. The winter school focuses on current methods and hands-on exercises, emphasizing an understanding of the underlying concepts and a discussion of benefits, limitations and pitfalls of environmental genomics. It is specifically aimed at the needs of advanced Master students, PhD students and early postdoctoral researchers.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Problem-solving: assessed
  - Project Management: fostered

- **Social Competencies**
  - Communication: fostered
  - Cooperation and Teamwork: assessed
  - Negotiation: fostered

- **Personal Competencies**
  - Adaptability and Flexibility: fostered
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Self-direction and Self-management: fostered

**Prerequisites / notice**

- Active and regular participation in the discussions, together with the presentation of a scientific paper are required to successfully pass this course.
- It is strongly recommended that participants have in advance successfully participated in the course Evolutionary Genetics (701-2413-00) or Ecological Genetics (701-1413-01).

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**701-1425-01L Genetic Diversity: Techniques**

- **Prerequisites:**
  - Some experience in using GIS and R is required.

- **Abstract**
  - This course provides laboratory training for advanced students (master, doctoral or post-doctoral level). Various DNA/RNA extraction protocols, quality control measurements, SNP genotyping and gene expression techniques will be addressed. This is a course for practitioners.

- **Objective**
  - To learn and improve on standard and modern methods of genetic data collection. With a focus on: Use of different DNA/RNA extraction protocols, techniques for DNA/RNA quality control measurements, gene expression and SNP genotyping techniques.

- **Content**
  - After an introduction, students have 3 weeks to work independently in groups of two on different protocols. At the end of this practical part, the whole class meets for another afternoon to present the techniques/results and to discuss the advantages and disadvantages of the different techniques.

- **Lecture notes**
  - Material will be handed out in the course.

- **Literature**
  - Material will be handed out in the course.

- **Prerequisites / notice**
  - There will be two afternoons in class. The lab work in between the afternoons is done by the students according to their own schedule but with the support of the teacher and must be completed after 3 weeks. The workload is approximately 1-2 full days per week, depending on the student's ability. Student must know how to pipette.

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**701-1676-01L Genomics of Environmental Adaptation**

- **Abstract**
  - The genomics of environmental adaptation is an evolving scientific field of both basic and applied interest. Researchers make increasing use of diverse methodological approaches built on concepts from ecology, evolutionary biology and population genomics. This five-day winter school introduces students to some major concepts and methods of environmental genomics, i.e., (i) how the environment and adaptive genetic variation are related and (ii) how signatures of genomic adaptation can be detected in natural populations. The winter school focuses on current methods and hands-on exercises, emphasizing an understanding of the underlying concepts and a discussion of benefits, limitations and pitfalls of environmental genomics. It is specifically aimed at the needs of advanced Master students, PhD students and early postdoctoral researchers.

- **Objective**
  - The topics include:
    1. Molecular markers and next generation sequencing techniques; neutral and adaptive genetic variation, genetic drift and genetic population structure.
    2. Outlier analysis: concept, methodology and types of outlier analyses.
    3. Environmental data: which environmental data are available and used to identify signatures of adaptation; data limitations; collinearity.
    5. Genotypes and phenotypes: GWAS; follow-up analyses.

- **Lecture notes**
  - Hand-outs will be distributed.

- **Literature**
  - The course requires 4 hours of preparatory reading of selected papers on the genomics of environmental adaptation. The papers will be distributed by e-mail.

- **Prerequisites / notice**
  - Grading will be according to a written report (8-10 pages), in which students will have to design a complete study in environmental genomics, and according to student contributions during the course.
  - Prerequisites: students must have good knowledge in population genetics and evolutionary biology and some experience with R.
Environmental Governance

**Abstract**
The course addresses environmental policies, focusing on new steering approaches, which are generally summarized as environmental governance. The course also provides students with tools to analyze environmental policy processes and assesses the key features of environmental governance by examining various practical environmental policy examples.

**Objective**
To understand how an environmental problem may (not) become a policy and explain political processes, using basic concepts and techniques from political science.

To analyze the evolution as well as the key elements of environmental governance.

To be able to identify the main challenges and opportunities for environmental governance and to critically discuss them with reference to various practical policy examples.

Key questions that this course seeks to answer: What are the core characteristics of environmental challenges from a policy perspective? What are key elements of 'environmental governance' and how legitimate and effective are these approaches in addressing persistent environmental challenges?

Furthermore, we encourage the development of soft skills by engaging students in activities such as moderating discussions in class, presenting own proposals, giving regular peer feedback, as well as critically reflecting on various relevant publications in the environmental governance domain.

**Content**
Improvements in environmental quality and sustainable management of natural resources cannot be achieved through technical solutions alone. The quality of the environment and the achievement of sustainable development strongly depend on human behavior and specifically the human uses of nature. To influence human behavior, we rely on public policies and other societal rules, which aim to steer the way humans use natural resources and their effects on the environment. Such steering can take place through government intervention alone. However, this often also involves governance, which includes the interplay between governmental and non-governmental actors, the use of diverse tools such as emission standards or financial incentives to steer actors' behavior and can occur at the local, regional, national or international level.

In this course, we will address both the practical aspects of as well as the scientific debate on environmental governance. The course gives future environmental experts a strong basis to position themselves in the governance debate, which does not preclude government but rather involves a spectrum from government to governance.

We recommend that students have (a) three-years BSc education of a (technical) university; (b) successfully completed Bachelor introductory course to environmental policy (Entwicklungen nationaler Umweltpolitik (or equivalent)) and (c) familiarity with key issues in environmental policy and some fundamental knowledge of one social science or humanities discipline (political science, economics, sociology, history, psychology, philosophy).

**Lecture notes**
Lecture slides, a script and additional course material will be provided on Moodle.

**Prerequisites / notice**
A detailed course schedule will be made available at the beginning of the semester.

During the lecture we will work with Moodle. We ask that all students register themselves on this platform before the lecture.

For information, location and details: https://pe.ethz.ch/education/zis.html
This course introduces the broad variety of conflicts that arise in projects focusing on sustainable management of natural resources. It explores case studies of ecosystem management approaches and considers their practicability, their achievements and possible barriers to their uptake.

Students should be able to
a) propose appropriate and realistic solutions to ecosystem management problems that integrate ecological, economic and social dimensions across relevant temporal and spatial scales.
b) identify important stakeholders, their needs and interests, and the main conflicts that exist among them in the context of land and resource management.

Traditional management systems focus on extraction of natural resources, and their manipulation and governance. However, traditional management has frequently resulted in catastrophic failures such as, for example, the collapse of fish stocks and biodiversity loss. These failures have stimulated the development of alternative ecosystem management approaches that emphasise the functionality of human-dominated systems. Inherent to such approaches are system-wide perspectives and a focus on ecological processes and services, multiple spatial and temporal scales, as well as the need to incorporate diverse stakeholder interests in decision making. Thus, ecosystem management is the science and practice of managing natural resources, biodiversity and ecological processes, to meet multiple demands of society. It can be local, regional or global in scope, and addresses critical issues in developed and developing countries relating to economic and environmental security and sustainability.

This course provides an introduction to ecosystem management, and in particular the importance of integrating ecology into management systems to meet multiple societal demands. The course explores the extent to which human-managed terrestrial systems depend on underlying ecological processes, and the consequences of degradation of these processes for human welfare and environmental well-being. Building upon a theoretical foundation, the course will tackle issues in resource ecology and management, notably forests, agriculture and wild resources within the broader context of sustainability, biodiversity conservation and poverty alleviation or economic development. Case studies from tropical and temperate regions will be used to explore these issues. Dealing with ecological and economic uncertainty, and how this affects decision making, will be discussed. Strategies for conservation and management of terrestrial ecosystems will give consideration to landscape ecology, protected area systems, and community management, paying particular attention to alternative livelihood options and marketing strategies of common pool resources.
Improvements in environmental quality and sustainable management of natural resources cannot be achieved through technical solutions alone. The quality of the environment and the achievement of sustainable development strongly depend on human behavior and specifically the human uses of nature. To influence human behavior, we rely on public policies and other societal rules, which aim to steer the way humans use natural resources and their effects on the environment. Such steering can take place through government intervention alone. However, this often also involves governance, which includes the interplay between governmental and non-governmental actors, the use of diverse tools such as emission standards or financial incentives to steer actors' behavior and can occur at the local, regional, national or international level.

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Key questions that this course seeks to answer: What are the core characteristics of environmental challenges from a policy perspective? What are key elements of 'environmental governance' and how legitimate and effective are these approaches in addressing persistent environmental challenges?

Furthermore, we encourage the development of soft skills by engaging students in activities such as moderating discussions in class, presenting own proposals, giving regular peer feedback, as well as critically reflecting on various relevant publications in the environmental governance domain.

During the lecture we will work with Moodle. We ask that all students register themselves on this platform before the lecture.

We recommend that students have (a) three-years BSc education of a technical university; (b) successfully completed Bachelor introductory course to environmental policy (Entwicklungen nationaler Umweltpolitik (or equivalent)) and (c) familiarity with key issues in environmental policy and some fundamental knowledge of one social science or humanities discipline (political science, economics, sociology, history, psychology, philosophy)
The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for bio/geophysical environmental parameter estimation.

Students should know at the end of the course:
1. Basics of measurement principle
2. Fundamentals of image acquisition
3. Basics of the sensor-specific geometries
4. Sensor-specific determination of environmental parameters

The course communicates the basics of the Python programming language and provides a general introduction to the ArcGIS Pro Python scripting framework. It also introduces several Python libraries (pandas, numpy, scipy, statsmodels, geopandas, rasterio) that greatly extend the capabilities of spatial data analysis and modelling.

Students will learn the basics of geographic data processing using the Python programming language and ArcGIS Pro (arcpy). They will be able to implement their own geoprocessing scripts for spatial data analysis and modelling. Students will be able to integrate open source libraries into their Python scripts and know how to apply the libraries to geospatial datasets.

The course covers basic Python language concepts such as data types, control structures and functions. These concepts are then used to gain a deeper understanding of ArcGIS Pro’s geoprocessing framework (arcpy). This includes vector data processing functions as well as geoprocessing functions for raster data analysis. It also introduces the use of key Python libraries in conjunction with geospatial datasets.

Lecture notes, exercises and worked-out solutions will be provided.

Geographic Data Processing with Python and ArcGIS

Abstract
The course dendroecology offers theoretical and practical aspects of dendrochronology. The impact of different environmental influences on tree-ring characteristics will be shown. The students learn various methods to date tree rings and they understand how ecological and environmental processes and patterns can be reconstructed using tree rings.

Objective
- understand, how wood is configured and how tree-ring structures are formed.
- are able to identify and describe different tree-ring structures.
- understand the theoretical and practical aspects of the dating of tree rings.
- know the effects of different abiotic and biotic environmental influences (climate, site, competition, insects, fire, physical-mechanical influences) on trees and tree rings.
- discover a tool for understanding and reconstructing global change processes.
- learn software to date, standardize and analyze tree rings.
- get hands-on experience based on the demonstration of wood (increment cores, stem discs, wedges), sampling in the field, and measuring and dating of tree rings in the tree-ring lab.
- solve R-based exercises (R tutorial will be provided) and answer questions in Moodle.
- work out an independent research question related to a dendroecological topic and write a short literature review based on scientific papers.

Content
- Overview and history of dendrochronology
- Principles of dendrochronology
- Formation and structure of wood and tree rings
- Wood anatomy and intra-seasonal tree-ring growth
- Continuous and discontinuous tree-ring characteristics
- Sampling and measuring of tree rings
- Crossdating methods (visual, skeleton plots, quantitative)
- Detrending and standardization of tree-ring series
- Development of tree-ring chronologies
- Water transport in trees
- Stable isotopes in tree rings
- Climate influences, climate-growth relationships, climate reconstructions
- Reconstruction of forest dynamics (regeneration, growth, competition, mortality)
- Disturbance ecology (fire, insects, blowdown)
- Application of tree-ring research in practice and in interdisciplinary research projects
- Field and lab day (date will be searched together with the students in the beginning of the semester); discussion of different dendroecological questions in the forest; sampling of trees; insight into different tree-ring projects in the lab (Swiss Federal Institute for Forest, Snow and Landscape Research WSL)
The lecture notes and further documents (papers, software) can be downloaded from Moodle (https://moodle-app2.let.ethz.ch) following registration for the course.

The class language is English, by mutual request only German.

Requirements:
Basics of biology, ecology and forest ecology

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Problem-solving
Project Management

ECTS
Type
Transdisciplinary Research: Challenges of inter- and transdisciplinary research

Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can

Analytical Competencies

This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and

Soil Science Seminar

Invited external speakers present their research on current issues in the field of soil science and discuss their results with the participants.

Master and PhD students are introduced to current areas of research in soil sciences and get first-hand experience in scientific discussion.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Problem-solving
Project Management

Social Competencies
Communication

Personal Competencies
Critical Thinking

Inter- and Transdisciplinary Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0015-00L</td>
<td>Transdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement</td>
<td>W</td>
<td>2 credits</td>
<td>1S</td>
<td>B. Vienni Baptista, C. E. Pohl, M. Stauffacher</td>
</tr>
</tbody>
</table>

The following open access article builds a core element of the course:

available at (open access): http://www.ingentaconnect.com/content/oekom/gaia/2017/00000026/00000001/art00011

Further, this collection of tools will be used:

https://www.shapeidtoolkit.eu

Prerequisites / notice
Participation in the course requires participants to be working on their own research project.
Students will:
- Be informed about the ethical considerations associated with the use and development of new and emerging technologies in different settings of our society.
- Learn how ethical reflection and value statements can provide guidance for future research and design decisions.
- Apply a value-based design process to emerging technologies and applications in their research.
- Get to know the value-based design approach.

**Objective**

**Content**

Block 1 (8 hours)

Day 1 (face-to-face): An introduction to the notions of ethics and values in the context of technological innovation. An introduction to the value-sensitive design framework (VSD) will conclude the first session.

Day 2 (face-to-face): An introduction to the value-based design approach (VBD).

In between:

- Self-study session (20 hours): Self-guided in the OLAT environment: webinars and online course material on key knowledge points.
- Group work (20 hours): Participants will apply the value-based design approach to a technology application or an innovation project of their choice in a small group.

Final Half-Day (4 hours)

Day 3: Individual presentation of own project, using the tools and approaches introduced and exercised during the course in a pitch to a jury.

**Prerequisites / notice**

Good English Skills are necessary.

### Basic and Scientific Skills

<table>
<thead>
<tr>
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<th>Type</th>
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<tr>
<td>701-0019-00L</td>
<td>Readings in Environmental Thinking</td>
<td>W</td>
<td>3</td>
<td>2S</td>
<td>J. Ghazoul</td>
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</table>

**Abstract**

This course introduces students to foundational texts that led to the emergence of the environment as a subject of scientific importance, and shaped its relevance to society. Above all, the course seeks to give confidence and raise enthusiasm among students to read more widely around the broad subject of environmental sciences and management both during the course and beyond.

**Objective**

The course will provide students with opportunities to read, discuss, evaluate and interpret key texts that have shaped the environmental movement and, more specifically, the environmental sciences. Students will gain familiarity with the foundational texts, but also understand the historical context within which their academic and future professional work is based. More directly, the course will encourage debate and discussion of each text that is studied, from both the original context as well as the modern context. In so doing students will be forced to consider and justify the current societal relevance of their work.

**Content**

The course will be run as a book reading club. The first session will provide a short introduction as to how to explore a particular text (that is not a scientific paper) to identify the key points for discussion.

Thereafter, in each week a text (typically a chapter from a book or a paper) considered to be seminal or foundational will be assigned by a course lecturer. The lecturer will introduce the selected text with a brief background of the historical and cultural context in which it was written, with some additional biographical information about the author. He/she will also briefly explain the justification for selecting the particular text.

The students will read the text, with two to four students (depending on class size) being assigned to present it at the next session. Presentation of the text requires the students to prepare by, for example:
- identifying the key points made within the text
- identifying issues of particular personal interest and resonance
- considering the impact of the text at the time of publication, and its importance now
- evaluating the text from the perspective of our current societal and environmental position

Such preparation would be supported by a mid-week tutorial discussion (about 1 hour) with the assigning lecturer.

These students will then present the text (for about 15 minutes) to the rest of the class during the scheduled class session, with the lecturer facilitating the subsequent class discussion (about 45 minutes). Towards the end of the session the presenting students will summarise the emerging points (5 minutes) and the lecturer will finish with a brief discussion of how valuable and interesting the text was (10 minutes). In the remaining 15 minutes the next text will be presented by the assigning lecturer for the following week.

**Literature**

The specific texts selected for discussion will vary, but examples include:
- Leopold (1949) A Sand County Almanach
- Carson (1962) Silent Spring
- Jared Diamond (2005) Collapse

**Competencies**

Discussions might also encompass films or other forms of media and communication about nature.

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<thead>
<tr>
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<th>Concepts and Theories</th>
<th>Media and Digital Technologies</th>
<th>Communication</th>
<th>Cooperation and Teamwork</th>
<th>Self-presentation and Social Influence</th>
<th>Sensitivity to Diversity</th>
<th>Negotiation</th>
<th>Adaptability and Flexibility</th>
<th>Creative Thinking</th>
<th>Critical Thinking</th>
<th>Integrity and Work Ethics</th>
<th>Self-awareness and Self-reflection</th>
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**701-3001-00L Environmental Systems Data Science: Data Processing**

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 923 of 2653
Abstract
Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

Objective
The students are able to
● frame a data science problem and build a hypothesis
● describe the steps of a typical data science project workflow
● conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
● critically think about the limits and implications of a method
● visualise data and results throughout the workflow
● access online resources to keep up with the latest data science methodology and deepen their understanding

Content
● The data science workflow
● Access and handle (large) datasets
● Prepare and clean data
● Analysis: data exploratory steps
● Analysis: machine learning and computational methods
● Evaluate results and analyse uncertainty
● Visualisation and communication

Prerequisites / notice
252-0640-02L Anwendungsnahes Programmieren mit Python
401-0624-00L Mathematik IV: Statistik
401-6215-00L Using R for Data Analysis and Graphics (Part I)
401-6217-00L Using R for Data Analysis and Graphics (Part II)
701-0105-00L Mathematik VI: Angewandte Statistik für Umweltnaturwissenschaften

Transferable Skills

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>701-5001-00L</td>
<td>Ethics and Scientific Integrity for Doctoral Students</td>
<td>W</td>
<td>1 credit</td>
<td>1S</td>
<td>N. Gruber, E. Lieberherr, A. Widmer</td>
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</table>

Abstract
This course sensitises doctoral students to ethical issues that may arise during their doctorate. After an introduction to ethics and good scientific practice, students are familiarised with resources that can assist them with ethical decision-making. Students are given the opportunity to apply their knowledge and train their newly acquired skills in an interactive, discipline-specific context.

Objective
Doctoral students learn how to identify, analyse and address ethical issues in their own scientific research. Furthermore, they are encouraged to reflect on their professional role as scientific researchers.

Content
Part I
The self-paced e-learning course consists of 5 modules:

Module 1: Ethics
Introduction to moral theory (with emphasis on practical guidance regarding decision making)

Module 2: Ethics in scientific research
Introduction to ethical issues that occur within scientific research (i.e. regarding authorship, cooperation, data use and sharing, and other aspects that are subject to scientific integrity and good scientific practice).

Module 3: Collecting resources
A variety of tools and resources that help identify ethical issues are presented and explained

Module 4: Setting up a strategy
Example examination of a case regarding its ethical scope (students develop their own strategy to examine situations for their ethical implications).

Module 5: Making decisions
Different ways of addressing ethical issues are presented and explained (i.e. how to make hard choices or solve ethical dilemmas).

Part II
The second, face-to-face part of this course focuses on discipline-specific aspects in the general area of Environmental Sciences. It provides an interactive learning environment. Students get to apply their knowledge, and they are encouraged to reflect on ethical problems and to critically discuss them with fellow doctoral students.

Pre-requisites / notice
For doctoral students only

Competencies
Subject-specific Competencies: Concepts and Theories assessed
Method-specific Competencies: Decision-making assessed
Personal Competencies: Critical Thinking assessed
Integrity and Work Ethics assessed

900-0100-DRL Transferable Skills Course I (1-3 days)  W 1 credit 2S Lecturers
Only for doctoral students.

Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of short courses or workshops with a maximum duration of 3 days.

900-0101-DRL Transferable Skills Course II (1-3 days)  W 1 credit 2S Lecturers
Only for doctoral students.

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
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<th>Credits</th>
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<td>900-0109-DRL</td>
<td>Transferable Skills Course I (1 week, with Poster or Talk)</td>
<td>1 week</td>
<td>3</td>
<td>Only for doctoral students.</td>
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</table>
Abstract
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

Objective
Acquisition of transferable skills and cross-disciplinary competences in the range of courses or workshops with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

<table>
<thead>
<tr>
<th>Number</th>
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<td>900-0114-DRL</td>
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Integration into Scientific Community

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<td>900-0152-DRL</td>
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<td>2K</td>
<td>Lecturers</td>
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</table>
Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

### Abstract
Participation in summer or winter schools with a maximum duration of 3 days.

### Objective
Participation in summer or winter schools with a maximum duration of 3 days.

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Description</th>
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### Summer School III (1 week, with Poster or Talk)

- **900-0161-DRL**
- **Type:** W
- **Credits:** 3
- **ECTS:** 6K
- **Lecturers**

**Abstract**

Please select your doctoral thesis supervisor as a lecturer and prove your participation with the appropriate certificate.

**Objective**

Participation in summer or winter schools with a minimum duration of 1 week. Participants need to present either a poster or a talk at this occasion.

---

### External Conference I (incl. Poster or Talk)

- **900-0162-DRL**
- **Type:** W
- **Credits:** 1
- **ECTS:** 2K
- **Lecturers**

**Abstract**

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

**Objective**

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

---

### External Conference II (incl. Poster or Talk)

- **900-0163-DRL**
- **Type:** W
- **Credits:** 1
- **ECTS:** 2K
- **Lecturers**

**Abstract**

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

**Objective**

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

---

### External Conference III (incl. Poster or Talk)

- **900-0164-DRL**
- **Type:** W
- **Credits:** 1
- **ECTS:** 2K
- **Lecturers**

**Abstract**

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

**Objective**

Participation in conferences outside ETH to foster scientific exchange. Participants need to present either a poster or a talk at this occasion.

---

**Doctorate Environmental Systems Sciences - Key for Type**

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<td>Z                   Courses outside the curriculum</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr                  Suitable for doctorate</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
<td>O                   Compulsory</td>
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**Key for Hours**

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<td>exercise</td>
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<td>seminar</td>
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<td>colloquium</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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**ECTS**

European Credit Transfer and Accumulation System

- **Special students and auditors need special permission from the lecturers.**
Electrical Engineering and Information Technology Bachelor

1st Semester

First Year Examinations

First Year Examination Block A

<table>
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<td>O</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>M. Luisier</td>
</tr>
<tr>
<td>Abstract</td>
<td>Digital and analogue signals and their representation, logic gates, transistors, combinational and sequential circuits and systems, boolean algebra, Karnaugh-maps, finite state machines, memory and computing building blocks in CMOS technology.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Provide basic knowledge and methods to understand and to design digital circuits and systems.</td>
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</tr>
<tr>
<td>Content</td>
<td>Digital and analogue signals and their representation. Boolean Algebra, circuit analysis and synthesis, the MOS transistor, CMOS logic, static and dynamic behaviour, Karnaugh-Maps, hazards, binary number systems, coding. Combinational and sequential circuits and systems (boolean algebra, K-maps, etc.). Memory building blocks and memory structures, programmable logic circuits. Finite state machines, architecture of microprocessors.</td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Lecture notes for all lessons, assignments and solutions.</td>
<td></td>
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</tr>
<tr>
<td>Literature</td>
<td>Literature will be announced during the lessons.</td>
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</tbody>
</table>

| 401-0151-00L | Linear Algebra                      | O    | 5 credits | 3V+2U | V. C. Gradinaru |
| Abstract      | Contents: Linear systems - the Gaussian algorithm, matrices - LU decomposition, determinants, vector spaces, least squares - QR decomposition, linear maps, eigenvalue problem, normal forms - singular value decomposition; numerical aspects. |
| Objective     | Einführung in die Lineare Algebra für Ingenieure unter Berücksichtigung numerischer Aspekte |
| Lecture notes | eigenes Aufschrieb und K. Nipp / D. Stoffer, Lineare Algebra, vdf Hochschulverlag, 5. Auflage 2002 |
| Literature    | K. Nipp / D. Stoffer, Lineare Algebra, vdf Hochschulverlag, 5. Auflage 2002 |

| 227-0001-00L  | Networks and Circuits I             | O    | 4 credits | 2V+2U | C. Franck |
| Abstract      | This course introduces the students into the basics of electric circuits, the underlying physical phenomena and required mathematical methods. |
| Objective     | Voltage, current and properties of basic elements of electric circuits, i.e. capacitors, resistors and inductors should be understood in relation to electric and magnetic fields. Furthermore, the students should be able to mathematically describe, analyze and finally design technical realizations of circuit elements. Students should also be familiar with the calculation of voltage and current distributions of DC circuits. The effect and the mathematical formulation of magnetic induction should be known for technical applications. |
| Content       | Electrostatic field; Stationary electric current flow; Basic electric circuits; current conduction mechanisms; time variant electromagnetic field. |
| Lecture notes | Manfred Albach, Elekrotechnik ISBN 978-3-88894-398-6 (2020) and lecture notes |
| Literature    | Manfred Albach, Elekrotechnik 978-3-88894-398-6 (2020) |
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving fostered

Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Abstract
Introduction to engineering mechanics: kinematics, statics and dynamics of rigid bodies and systems of rigid bodies.

Objective
Students can solve problems of elementary engineering mechanics.

Content
Basic notions: position and velocity of particles, rigid bodies, planar motion, kinematics of rigid body, force, couple, power.
Statics: static equivalence, force-couple system, center of forces, centroid, principle of virtual power, equilibrium, constraints, statics, friction.
Dynamics: acceleration, inertial forces, d'Alembert's Principle, Newton's Second Law, principles of linear and angular momentum, equations of planar motion of rigid bodies.

First Year Examination Block B

Number Title Type ECTS Hours Lecturers
151-0223-10L Engineering Mechanics O 4 credits 2V+2U+1K P. Tiso
Abstract
Objective
Content
Lecture notes
Literature

First Year Compulsory Laboratory Courses

Number Title Type ECTS Hours Lecturers
227-0005-10L Digital Circuits Laboratory O 1 credit 1P A. Emboras, M. Luisier
Abstract
Objective
Content
Lecture notes
Prerequisites / notice

Autumn Semester 2024
Abstract
The course provides an elementary introduction to programming with C++. Prior programming experience is not required.

Objective
Establish an understanding of basic concepts of imperative programming and how to systematically approach programming problems. Students are able to read and write simple C++ programs.

Content
This course introduces you to the basics of programming with C++. Programming means instructing a computer to execute a series of commands that ultimately solve a particular problem.

The course comprises the following:
- General introduction to computer science: development, goals, fundamental concepts
- Interactive self-study tutorial that provides an introduction to C++ and covers the following topics: variables, data types, conditional statements and loops
- Introduction to stepwise refinement as an approach to systematically solving programming problems
- Two small programming projects, to practically apply the studied fundamentals

Lecture notes
All teaching material is available online; an online development environment is used for the programming projects.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Conceptual and Theoretical Knowledge assessed</th>
<th>Method-specific Competencies</th>
<th>Analytical Competencies assessed</th>
<th>Technological and Practical Skills assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Competencies</td>
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<tr>
<td>Personal Competencies</td>
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</table>
The goal of the Physics II class is an introduction to quantum mechanics. To work effectively in many areas of modern engineering, such as renewable energy and nanotechnology, students must possess a basic understanding of quantum mechanics. The aim of this course is to provide this knowledge while making connections to applications of relevance to engineers. After completing this course, students will understand the basic postulates of quantum mechanics and be able to apply mathematical methods for solving various problems including atoms, molecules, and solids. Additional examples from engineering disciplines will also be integrated.

Abstract: The goal of the Physics II class is an introduction to quantum mechanics. To work effectively in many areas of modern engineering, such as renewable energy and nanotechnology, students must possess a basic understanding of quantum mechanics. The aim of this course is to provide this knowledge while making connections to applications of relevance to engineers. After completing this course, students will understand the basic postulates of quantum mechanics and be able to apply mathematical methods for solving various problems including atoms, molecules, and solids. Additional examples from engineering disciplines will also be integrated.

**Literature**


**Prerequisites / notice**

Prerequisites: Physics I.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniken und Technologien</td>
<td></td>
<td></td>
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<tr>
<td>Analytical Competencies</td>
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<tr>
<td>Decision-making</td>
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<tr>
<td>Media and Digital Technologies</td>
<td></td>
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<tr>
<td>Problem-solving</td>
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<tr>
<td>Communication</td>
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<tr>
<td>Cooperation and Teamwork</td>
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<tr>
<td>Creative Thinking</td>
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<tr>
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**Method-specific Competencies**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave mechanics</td>
<td>the old quantum theory</td>
</tr>
<tr>
<td>Postulates and formalism of Quantum Mechanics</td>
<td></td>
</tr>
<tr>
<td>First application: the quantum well and the harmonic Oscillator</td>
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<tr>
<td>QM in three dimension: the Hydrogen atom</td>
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<tr>
<td>Identical particles: Pauli's principle</td>
<td></td>
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<tr>
<td>Crystalline Systems and band structures</td>
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<tr>
<td>Quantum statistics</td>
<td></td>
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<tr>
<td>Approximation Methods</td>
<td></td>
</tr>
<tr>
<td>Applications in Engineering</td>
<td></td>
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<tr>
<td>Entanglement and superposition</td>
<td></td>
</tr>
</tbody>
</table>

**Lecture notes**

Lecture notes (hand-written) will be distributed via the Moodle interface.

**Prerequisites / notice**

Prerequisites: Physics I.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
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<td></td>
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<tr>
<td>Analytical Competencies</td>
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<tr>
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<td></td>
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<tr>
<td>Critical Thinking</td>
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<td></td>
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</tbody>
</table>

**Literature**


B. Stroustrup, A Tour of C++, 3rd Edition, Addison-Wesley, 2022

**Prerequisites / notice**

Prerequisite: Computer Science I

**Competencies**

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</table>

**Method-specific Competencies**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asymptotic runtime (algorithmic complexity)</td>
<td></td>
</tr>
<tr>
<td>Fundamental algorithmic problems, e.g. searching, sorting, shortest paths, spanning trees</td>
<td></td>
</tr>
<tr>
<td>Classical data structures, e.g. search trees, balanced trees, heaps, hash tables</td>
<td></td>
</tr>
<tr>
<td>Graph theory and graph problems</td>
<td></td>
</tr>
<tr>
<td>Problem solving strategies as design patterns for algorithms, e.g. induction, divide and conquer, backtracking, dynamic programming</td>
<td></td>
</tr>
<tr>
<td>Generic programming; C++ templates higher-order functions, lambdas, closures</td>
<td></td>
</tr>
<tr>
<td>Parallel programming; (in)dependence of computations, parallelism and concurrency, shared memory, races, mutual exclusion, communication and synchronisation</td>
<td></td>
</tr>
</tbody>
</table>

**Lecture notes**

Lecture notes, problem set with solutions.

**Prerequisites / notice**

Prerequisite: Computer Science I

**Competencies**

<table>
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<td></td>
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<tr>
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</tbody>
</table>

**Method-specific Competencies**

<table>
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<tr>
<th>Concept</th>
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<tr>
<td>Parallel programming; (in)dependence of computations, parallelism and concurrency, shared memory, races, mutual exclusion, communication and synchronisation</td>
<td></td>
</tr>
</tbody>
</table>

**Lecture notes**

Lecture notes, problem set with solutions.

**Prerequisites / notice**

Prerequisite: Computer Science I
Modern, transistor-based electronics has transformed our lives and plays a crucial role in our economy since the second half of the last century. The main objective of this course in electronic circuits is to introduce the concept of the active device, including operational amplifiers, and their use in amplification, signal conditioning, switching and filtering to students. In addition to gaining experience with typical electronic circuits that are found in common applications, including their own Gruppenarbeit and Fachpraktikum projects, students sharpen their understanding of linear circuits based on nonlinear devices, imperfections of electronic circuits and the concept of design (as opposed to analysis). The course is a prerequisite for higher semester subjects such as analog integrated circuits, RF circuits for wireless communications, A/D and D/A converters and optoelectronics.

### Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0077-10L</td>
<td>Electronic Circuits</td>
<td>O</td>
<td>4</td>
<td>2V+2U</td>
<td>H. Wang</td>
</tr>
</tbody>
</table>

**Abstract**

Introduction to electronic circuits. Transistor fundamentals, analysis and design of transistor based electronic circuits such as amplifiers and filters; operational amplifiers and circuits based thereon.

**Objective**

- You can apply set theory and its axioms as the foundation of mathematics.
- You can solve counting problems using elementary counting methods and principles from combinatorics.
- You can explain fundamental graph types and their properties.
- You can determine the solution of classical graph problems (e.g. flows in networks).
- You can use elementary number theory for applications in information theory.
- You can describe the basic algebraic structures and use them to implement error correction methods.

**Content**

- Algebra: elementary number theory (divisibility, congruence, ...), introduction to cryptography, groups, fields, and rings.
- Graph theory: properties, types (networks, trees, ...), colouring, flows & cuts, and matchings
- Combinatorics: elementary counting methods, counting principles, and special counting problems
- Set theory
- Combinatorics: elementary counting methods, counting principles, and special counting problems
- Graph theory: properties, types (networks, trees, ...), colouring, flows & cuts, and matchings
- Algebra: elementary number theory (divisibility, congruence, ...), introduction to cryptography, groups, fields, and rings

**Literature**


### 3rd Semester: Second Year Compulsory Laboratory Course

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>227-0079-10L</td>
<td>Electronic Circuits Laboratory</td>
<td>O</td>
<td>1</td>
<td>1P</td>
<td>H. Wang</td>
</tr>
</tbody>
</table>

**Abstract**

Lab with principal electronic circuit experiments on the transistor and operational amplifier basis.

**Objective**

Modern, transistor-based electronics has transformed our lives and plays a crucial role in our economy since the second half of the last century. The main objective of this course in electronic circuits is to introduce the concept of active device, including operational amplifiers, and their use in amplification, signal conditioning, switching and filtering to students. In addition to gaining experience with typical electronic circuits that are found in common applications, including their own Gruppenarbeit and Fachpraktikum projects, students sharpen their understanding of linear circuits based on nonlinear devices, imperfections of electronic circuits and the concept of design (as opposed to analysis). The course is a prerequisite for higher semester subjects such as analog integrated circuits, RF circuits for wireless communications, A/D and D/A converters and optoelectronics.

**Content**

- You can describe the basic algebraic structures and use them to implement error correction methods.
- You can determine the solution of classical graph problems (e.g. flows in networks).
- You can use elementary number theory for applications in information theory.
- You can describe the basic algebraic structures and use them to implement error correction methods.

**Literature**

### General Laboratory

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0095-10L</td>
<td>General Laboratory I</td>
<td>W</td>
<td>2 credits</td>
<td>2P</td>
<td>Professors</td>
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<tr>
<td></td>
<td>Enrollment via Online-Tool (EE-Website: Studies -&gt; Bachelor Program -&gt; Third Year -&gt; Laboratory Courses)</td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>The Laboratory courses in the 5th and 6th semesters enable the students to put the contents of the courses from the first four semesters to the test and to consolidate the acquired knowledge. Furthermore students have the possibility to gain specific knowledge in certain software packages as MATLAB.</td>
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<tr>
<td>Objective</td>
<td>Implementing the knowledge acquired during the basic studies.</td>
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</table>

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0096-10L</td>
<td>General Laboratory II</td>
<td>W</td>
<td>4 credits</td>
<td>4P</td>
<td>Professors</td>
</tr>
<tr>
<td></td>
<td>Enrollment via Online-Tool (EE-Website: Studies -&gt; Bachelor Program -&gt; Third Year -&gt; Laboratory Courses)</td>
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<td>Abstract</td>
<td>The Laboratory courses in the 5th and 6th semesters enable the students to put the contents of the courses from the first four semesters to the test and to consolidate the acquired knowledge. Furthermore students have the possibility to gain specific knowledge in certain software packages as MATLAB.</td>
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</tr>
<tr>
<td>Objective</td>
<td>Implementing the knowledge acquired during the basic studies.</td>
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</tbody>
</table>

### Projects & Seminars

**Enrollment is only possible for students in the BSc Electrical Engineering and Information Technology from Friday before the start of the semester. Places are allocated using the P&S application tool (https://psapp.ee.ethz.ch/). Please only enroll for P&S for which you apply via the tool.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0085-01L</td>
<td>P&amp;S: Amateur Radio Course ■ ■ ■</td>
<td>W</td>
<td>1.5 credits</td>
<td>1P</td>
<td>J. Leuthold</td>
</tr>
<tr>
<td></td>
<td>Does not take place this semester. The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>The category of &quot;Laboratory Courses, Projects, Seminars&quot; includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.</td>
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<tr>
<td>Objective</td>
<td>Der Amateurfunk ermöglicht es, drahtlos über weite Distanzen zu kommunizieren. Doch darf eine Amateurfunk-Station nicht ohne Weiteres betrieben werden.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Voraussetzung ist das Ablegen der Amateurfunkprüfung HB3 oder HB9 beim BAKOM.</td>
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<tr>
<td></td>
<td>In diesem Kurs werden wir einen Überblick über die wichtigsten Themengebiete des Amateurfunks bieten.</td>
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<tr>
<td></td>
<td>Im praktischen Teil werdet ihr unter anderem die Gelegenheit haben, das Funkgerät selbst in die Hand zu nehmen.</td>
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<td></td>
<td>Nach dem Kurs habt ihr die Möglichkeit, die HB9-Prüfung abzulegen.</td>
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<tr>
<td></td>
<td>Eine erfolgreiche Funkverbindung zu einer anderen Station ist ebenfalls Teil der Testabteilung.</td>
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<tr>
<td></td>
<td>Das Lernmaterial wird in der ersten Kursstunde ausgegeben.</td>
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<table>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0085-03L</td>
<td>P&amp;S: COMSOL Design Tool -- Design of Optical Components ■ ■ ■</td>
<td>W</td>
<td>3 credits</td>
<td>3P</td>
<td>J. Leuthold</td>
</tr>
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</tr>
<tr>
<td>Objective</td>
<td>Simulation tools are becoming an essential accessory for scientists and engineers for the development of new devices and study of physical phenomena. More and more disciplines rely on accurate simulation tools to get insight and also to accurately design novel devices.</td>
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<tr>
<td></td>
<td>COMSOL is a powerful multiphysics simulation tool. It is used for a wide range of fields, including electromagnetics, semiconductors, thermodynamics and mechanics. In this P&amp;S we will focus on the rapidly growing field of integrated photonics.</td>
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<tr>
<td></td>
<td>During hands-on exercises, you will learn how to accurately model and simulate various optical devices, which enables high-speed optical communication. At the end of the course, students will gain practical experience in simulating photonic components by picking a small project in which certain photonic devices will be optimized to achieve required specifications. These simulated devices find applications in Photonic Integrated Circuits (PICs) on chip-scale.</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Course website: <a href="https://blogs.ethz.ch/ps_comsol">https://blogs.ethz.ch/ps_comsol</a></td>
<td></td>
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<tr>
<td></td>
<td>No previous knowledge of simulation tools is required. A basic understanding of electromagnetics is helpful but not mandatory. The course will be taught in English.</td>
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</tbody>
</table>

*Data: 15.06.2024 12:39  Autumn Semester 2024  Page 934 of 2653*
Objective

Ultra Low Power Microcontroller (MCU) – Firmware Programming and Sensors Interfacing using Arm Cortex-M (STM32) Microcontrollers

Microprocessors are used to execute extensive and generic applications. In contrast to that, microcontrollers (MCUs) are low-cost and low-power embedded chips with program memory and data memory built into the device. They are widely used to execute simple tasks within one specific application domain (i.e., sensor devices, wearable systems, and IoT devices). Microcontrollers demand precise and resource-saving programming. Therefore, it is necessary to know the processor architecture, relevant hardware peripherals (clocks, timers, interrupts, ADC, serial interfaces, etc.), and their implementation in the targeted device.

The STM32 family from STMicroelectronics has gained popularity in the industry due to its large product portfolio, solid documentation, and ease of use. This course aims to develop a basic understanding of hard and software concepts for embedded systems and their application in real-world problems. A combination of theory (20%) and practical implementation (80%) should enable students to conduct high-level firmware programming for microcontrollers. Besides programming the MCU, this includes the interaction with analog and digital sensors, data management, on-device processing, and wireless data exchange. More advanced topics, such as hardware-accelerated digital signal processing (DSP), machine learning, and real-time operating systems, will be discussed as part of individual projects if needed. The main programming language will be C.

The course will be taught in English.

227-0085-05L  P&S: FPGA in Quantum Computing with Superconducting Qubits

Objectives:
The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract:
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective:
FPGAs are used in a wide range of applications including video processing, machine learning, cryptography and radar signal processing, thanks to their flexibility and massive parallel processing power. Recently, FPGAs have become increasingly important in quantum signal processing when high amount of data should be analyzed in a short time to use quantum state detection and feedback generation, which have to be performed in the scale of hundreds of nanoseconds. The goal of this course is to understand the FPGA based signal processing for superconducting circuits based quantum experiments. The course participants will learn the implementation techniques of the modules for fast quantum signal acquisition and processing, the electronics supporting quantum experiments, and FPGA programming. You will implement quantum signal processing and quantum state detection modules using Xilinx FPGA, Verilog HDL, and high speed ADC. The course will be taught in English. No prior knowledge in quantum physics or FPGA is required, still a good knowledge in any coding language (for example C or Java) is required.

The course will be taught in English.

227-0085-06L  P&S: Neural Network on Low Power FPGA: A Practical W

Approach:
The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract:
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective:
Artificial Intelligence and in particular neural networks are inspired by biological systems, such as the human brain. Through the combination of powerful computing resources and novel architectures for neurons, neural networks have achieved state-of-the-art results in many domains such as computer vision. FPGAs are one of the most powerful platforms to implement neural networks as they can handle different algorithms in computing, logic, and memory resources in the same device. Faster performance comparing to competitive implementations as the user can hardcore operations into the hardware. This course will give to the student the basis of Machine Learning to understand how they work and how they can be trained and giving hand-on experiences with the training tools such as Keras. Moreover the course will focus in deploy algorithms in low power FPGA such as the Lattice sensAI platform to have energy efficient running algorithms. The course will provide to the students the tools and know-how to implement neural network on an FPGA, and the student will challenge themselves in a 5 weeks practical project that they will present at the end of the course. Experience in FPGA programming is desirable but not mandatory.

The course will be taught in English.

227-0085-08L  P&S: Bluetooth Low Energy Programming for IoT W

Sensing System:
The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract:
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective:
Bluetooth Low Energy System on Chip – Firmware Programming and sensors interfacing using an Arm Cortex-M (Nordic nrf52838) Microcontroller

With the introduction of the BLE 5.0 standard, Bluetooth has achieved high data bandwidth with low power consumption. This makes the technology an ideal match for many applications, i.e., IoT sensor application or audio streaming, by addressing two of the greatest bottlenecks of these devices. This course offers the chance for participants to do hands-on programming of microcontrollers. In particular, the focus will be laid on interfacing with sensors, acquisition of data, on-board event-driven data processing with ARM-Cortex-M4 processors and BLE or other wireless transmissions. The programming will be performed in C. Today’s microcontrollers offer a low power, efficient and cost-effective solution of tackling a nearly infinite number of task-specific applications. Ranging from IoT devices, wearable systems, sensor (mesh) devices, all the way to be integrated as submodules for the most complex system such as cars, planes, and rockets. Microcontrollers derive their advantages from the efficient use of resources and as such require very efficient and resource-saving programming. Therefore, it is mandatory to understand hardware components such as processor cores, ADC, clocks, serial communication, wireless communication, timers, interrupts, etc. The P&S includes five weeks project where the student will setup an IoT sensor node to monitor electric power transmission and distribution system.

The course will be taught in English by the ITET center for project based learning.

227-0085-09L  P&S: Spiking Neural Network on Neuromorphic W

Processors:
The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Objective:
Spiking Neural Network on Neuromorphic Processors - This course will provide an in-depth understanding of spiking neural networks and their implementation on neuromorphic processors. Students will learn how to design, simulate, and implement spiking neural networks using hardware platforms such as SpiNNaker and Loihi. The course will cover topics such as neuron models, synapse models, and network architectures. Students will also gain hands-on experience with real-world applications such as computer vision and robotics.

The course will be taught in English by the ITET center for project based learning.
Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective

Compared to the "traditional" artificial neural network, the spiking neural network (SNN) can provide both latency and energy efficiency. Moreover, SNN has demonstrated in previous works a better performance in processing physiological information of small sample size, and the output layer of the spiking neural network needs to be trained, which results in a fast training rate. This course focuses on giving the basics of spiking neural networks and neuromorphic processors. Students will learn the tools to implement SNN algorithm in both academic processors and Intel Loihi using data from Event-based Vision camera and biomedical sensors (i.e. ECG and EEG). The course will end with a project where students can target a specific application scenario.

The course will be taught in English.

227-0085-12L P&S: Electronic Circuits & Signals Exploration Laboratory

Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective
The goal of this lab course is for the students to enhance their understanding on how basic analog electronic circuits work, or perhaps don't work, and provide enough practical experience for the students to feel at ease using transistors, resistors, capacitors, diodes, etc., to create working circuits.

For example, students create circuits that make physical quantities audible. Students are encouraged to realize their own circuit ideas.

227-0085-13L P&S: Assembling and Controlling a Tuning-Fork AFM

Abstract
Invented in the 1980s in Zurich and awarded with the Kavli prize in 2016, the atomic force microscope (AFM) has enabled us to visualize surfaces at the single atom level, and to measure single molecule and cell-cell interactions, deepening our understanding of material science and biology. This is achieved by controlling micromechanical piezo actuators with nanometer precision and processing noisy signals in order to achieve meaningful data.

In order to introduce you to the capabilities of modern AFMs in biomedical sensing, you will build your own setups in groups of two. You will be introduced to an AFM's functionality, control, and signal read-out using LabView. A signal of an oscillating tuning-fork will be used as feedback for the self-built AFM. In order to better understand the working principle of a tuning fork, you will also build your own frequency sweeper and analyze it with self-built low-pass filters.

After you have implemented your own setup, you will have the chance to characterize different biomedical samples on state-of-the-art setups. This data will then be analyzed using Python.

The focus of this P&S seminar is to enable you to transfer your theoretical knowledge into practice and at the same time get to know how electrical engineering can be used in biomedical research.

The course requires active participation during the practical sessions, a 10-15 min presentation and a short written report on the acquired results. The course will be given in English.

IMPORTANT: Laptops with WINDOWS are compulsory (because Labview runs NEITHER on Macs NOR on the Macs' Virtual machine).

Room: GLC F26

Competencies


Abstract

Objective
The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.
### Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

### Objective
More and more sustainable and renewable energy technologies are used for electricity generation to cope with climate change. These distributed resources transform the electric power grid and impose major challenges.

In this seminar, students have the opportunity to glance at cutting-edge research in the field of power systems. Possible research questions might be:

- How to integrate distributed energy generation like PV plants and wind turbines into the electricity grid?
- What challenges does the increasing share of electric vehicles and batteries impose on the power grid?
- How to cope for the uncertain generation capacity of renewables and how to forecast it?
- How does the electricity market work and how do the new sources of flexibility transform it?

Students will prepare a presentation and a report on their individual research question, which is based on an assigned paper. The main objectives are to practice literature review, scientific writing and presenting. Students will learn to independently understand specific research results – a crucial skill for academic research including semester and master projects.

The language of instruction is English. Registrations for the seminar are binding.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0085-15L</td>
<td>P&amp;S: Python for Engineers - Get Productive in the Classroom, in the Lab and at Home</td>
<td>W 3 credits 3P</td>
<td>J. Leuthold</td>
<td></td>
</tr>
<tr>
<td>227-0085-16L</td>
<td>P&amp;S: Machine Learning for Brain-Computer Interfaces</td>
<td>W 3 credits 3P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>227-0085-17L</td>
<td>P&amp;S: Building a Wireless Infrared Headphone</td>
<td>W 2 credits 2P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>227-0085-18L</td>
<td>P&amp;S: Bits on Air</td>
<td>W 2 credits 2P</td>
<td>M. Lerjen</td>
<td></td>
</tr>
</tbody>
</table>

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Techniques and Technologies

In the first half of the P&S, we will introduce the physical model for a quad-rotor and use this to apply the control and estimation techniques fostered by Prof. John Lygeros (IfA), Prof. Luc Van Gool (CVL) and Prof. Fisher Yu (CVL). The objective of this P&S is to make a real-world quad-rotor fly autonomously by applying the control and estimation theory taught in class. The course is taught in English and is open to 5th or higher-semester students. Prior exposure to control theory (e.g., by attending a Control Systems course) is desirable but not required. Students who are not familiar with control theory will need some extra study to understand some aspects of this P&S. The simulations will be coded in MATLAB, and the real-world implementation in C++.

**P&S: Quad-Rotors: Control and Estimation**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credits</th>
<th>Prerequisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0085-21L</td>
<td>2 credits</td>
<td>C++ is required. You are required to bring your own Laptop for the programming exercises. A basic knowledge of programming in MATLAB, Python, and C++ is required.</td>
</tr>
</tbody>
</table>

**Objectives**

- Subject-specific Competencies fostered
- Method-specific Competencies fostered
- Social Competencies fostered
- Personal Competencies fostered

**Content**

- In the first half of the P&S, we will introduce the physical model for a quad-rotor and use this to apply the control and estimation techniques that are taught in the 5th semester in the Control Systems 1 (CS1) class. The students will then create their own control functions for a quad-rotor and test these in simulation. The second half of the course will involve the students implementing the control and estimation algorithms they design in the real-world on our fleet of nano-quad-rotors. Once stable flight is achieved, the students will have the freedom to perform tasks with the quad-rotor. By implementing the control and estimation algorithms on a real quad-rotor, the students will gain experience in how decisions in the modelling and design stage affect real-world performance.

**Competencies**

- Subject-specific Competencies
- Method-specific Competencies
- Social Competencies
- Personal Competencies

**Prerequisites**

- A basic knowledge of programming in MATLAB, Python, and C++ is required.
- You are required to bring your own Laptop for the programming exercises.

**P&S: RoboCup: Learning and Control**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>227-0085-24L</td>
<td>3 credits</td>
</tr>
</tbody>
</table>

**Objectives**

- “RoboCup: Learning and Control” is jointly offered by Prof. John Lygeros (IfA), Prof. Luc Van Gool (CVL) and Prof. Fisher Yu (CVL).
- RoboCup is a tournament where teams of autonomous robots compete in soccer matches against each other. The ETH team NomadZ (https://robocup.ethz.ch) plays in the Standard Platform League with a team of humanoid NAO robots. The focus lies on developing robust and efficient algorithms for vision, control and behavior.

**Competencies**

- Subject-specific Competencies assessed
- Social Competencies fostered
- Personal Competencies fostered

**Prerequisites**

- A basic knowledge of programming in MATLAB, Python, and C++ is required.
- You are required to bring your own Laptop for the programming exercises.

**P&S: Magnetic Resonance: From Spectrum to Image**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credits</th>
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<tbody>
<tr>
<td>227-0085-25L</td>
<td>1 credit</td>
</tr>
</tbody>
</table>

**Objectives**

- The phenomenon of nuclear magnetic resonance (NMR) and its application for spectroscopy and imaging are introduced. The course starts with a general introduction to NMR, followed by measurements on a clinical MRI scanner. The NMR experiments will be developed and programmed by the students. Starting from a simple spectroscopic experiment, the basics of imaging will be acquired step-by-step. Finally, sectional images of test objects will be obtained.

**P&S: Biosignal Acquisition and Processing for IoT Wearable Devices**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credits</th>
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<tbody>
<tr>
<td>227-0085-26L</td>
<td>3 credits</td>
</tr>
</tbody>
</table>

**Objectives**

- The course will be conducted only if at least 2 participants show up. In case in-classroom teaching is not allowed, the course must be cancelled.

**P&S: RoboCup: Learning and Control**

The course is taught in English and is open to 5th or higher-semester students. Prior exposure to control theory (e.g., by attending a Control Systems course) is desirable but not required. Students who are not familiar with control theory will need some extra study to understand some aspects of this P&S course.

**Competencies**

- Subject-specific Competencies assessed
- Method-specific Competencies assessed

**Prerequisites**

- A basic knowledge of programming in MATLAB, Python, and C++ is required.
- You are required to bring your own Laptop for the programming exercises.

**P&S: Magnetic Resonance: From Spectrum to Image**

The course is taught in English and is open to 5th or higher-semester students. Prior exposure to control theory (e.g., by attending a Control Systems course) is desirable but not required. Students who are not familiar with control theory will need some extra study to understand some aspects of this P&S course.

**Competencies**

- Subject-specific Competencies assessed
- Social Competencies fostered
- Personal Competencies fostered

**Prerequisites**

- A basic knowledge of programming in MATLAB, Python, and C++ is required.
- You are required to bring your own Laptop for the programming exercises.

**P&S: Biosignal Acquisition and Processing for IoT Wearable Devices**

The course is taught in English and is open to 5th or higher-semester students. Prior exposure to control theory (e.g., by attending a Control Systems course) is desirable but not required. Students who are not familiar with control theory will need some extra study to understand some aspects of this P&S course.

**Competencies**

- Subject-specific Competencies assessed
- Method-specific Competencies assessed

**Prerequisites**

- A basic knowledge of programming in MATLAB, Python, and C++ is required.
The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

### Abstract

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

### Objective

- Biosignal acquisition and processing – Wearable sensor node design and analysis for bio-impedance sensor using an Arm Cortex-M (Nordic nrf52832) Microcontroller
- Wearable smart sensor electronics has the potential to revolutionize the medical field. Various body conformal flexible sensors have been used to monitor motion and physiological electrical signals such as electrocardiography (ECG), electroencephalography (EEG) and body composition analysis via body bio-impedance measurements. Smart sensor nodes not only provide accurate and continuous data in time but also automate the process of maintaining medical records, thereby lowering the workload off he health worker or clinician. This course offers an avenue for the students to understand the interdisciplinary principles that make it possible to interpret human physiology by utilizing discreet electronic components. Most importantly, participants will get a chance to do hands-on system design specific to electronically tracking a particular physiological phenomenon. In particular, the focus will be laid on programming of micro controllers, interfacing with sensors, acquisition of data and utilizing discreet analog elements for bio-signal processing. The programming will be performed in C.
- Field-programmable gate array (FPGA) is an integrated circuit designed to be configured by a customer or a designer after manufacturing, so they are also "field-programmable". The FPGA configuration is generally specified using a hardware description language (HDL), similar to that used for an application-specific integrated circuit (ASIC). However more and more nowadays producers and open source community are providing higher level tools to program them similiar than processors. On the other side still it is important know the hardware architectures. This course will give to the students the opportunity to program FPGA in a high level way and use them to connect with external peripherals such as display, sensors, etc. In particular, the course will use the iCEBreaker FPGA boards that is specifically designed for students and engineers. They work out of the box with the latest open source FPGA development tools and next-generation open CPU architectures. The course will also iCEBreaker can be expandable through its Pmod connectors, so the students can make use of a large selection of third-party modules. The course will include a project where the students will learn how to build a ful working system for the next generation of Internet of Things intelligent smart sensing.
- Although the App-Industry is dominated by the giant Apps right now, it is still crucial that one knows how those Apps function and how those Apps are communicating with their hardware. This course offers the opportunity for the participants to understand the development of application using Android Studio. Most importantly, participants will get a chance to do hands-on software design specific to Android smartphone and the data acquisition from sensors, GPS, google maps and other internal devices. The main goal of the course if providing the students with the basic principle and software programming for build up every android application. The course include 4-5 weeks project were the students alone or in group will build up a working demo of a target application. The course will conclude with the presentation of the students work. Previous experience in C/Java or other languages is preferable but not mandatory. The students will program their own Android Smartphone.
- Ultra Low Lattice FPGA – High Level Programming – Peripherals Interfacing using an Lattice FPGA
- The course will conclude with the presentation of the students work. Previous experience in C/Java or other languages is preferable but not mandatory. The students will program their own Android Smartphone.
- Bio-signal acquisition and processing – Wearable sensor node design and analysis for bio-impedance sensor using an Arm Cortex-M (Nordic nrf52832) Microcontroller
- Wearable smart sensor electronics has the potential to revolutionize the medical field. Various body conformal flexible sensors have been used to monitor motion and physiological electrical signals such as electrocardiography (ECG), electroencephalography (EEG) and body composition analysis via body bio-impedance measurements. Smart sensor nodes not only provide accurate and continuous data in time but also automate the process of maintaining medical records, thereby lowering the workload off he health worker or clinician. This course offers an avenue for the students to understand the interdisciplinary principles that make it possible to interpret human physiology by utilizing discreet electronic components. Most importantly, participants will get a chance to do hands-on system design specific to electronically tracking a particular physiological phenomenon. In particular, the focus will be laid on programming of micro controllers, interfacing with sensors, acquisition of data and utilizing discreet analog elements for bio-signal processing. The programming will be performed in C.
- Field-programmable gate array (FPGA) is an integrated circuit designed to be configured by a customer or a designer after manufacturing, so they are also "field-programmable". The FPGA configuration is generally specified using a hardware description language (HDL), similar to that used for an application-specific integrated circuit (ASIC). However more and more nowadays producers and open source community are providing higher level tools to program them similiar than processors. On the other side still it is important know the hardware architectures. This course will give to the students the opportunity to program FPGA in a high level way and use them to connect with external peripherals such as display, sensors, etc. In particular, the course will use the iCEBreaker FPGA boards that is specifically designed for students and engineers. They work out of the box with the latest open source FPGA development tools and next-generation open CPU architectures. The course will also iCEBreaker can be expandable through its Pmod connectors, so the students can make use of a large selection of third-party modules. The course will include a project where the students will learn how to build a ful working system for the next generation of Internet of Things intelligent smart sensing.
- Although the App-Industry is dominated by the giant Apps right now, it is still crucial that one knows how those Apps function and how those Apps are communicating with their hardware. This course offers the opportunity for the participants to understand the development of application using Android Studio. Most importantly, participants will get a chance to do hands-on software design specific to Android smartphone and the data acquisition from sensors, GPS, google maps and other internal devices. The main goal of the course if providing the students with the basic principle and software programming for build up every android application. The course include 4-5 weeks project were the students alone or in group will build up a working demo of a target application. The course will conclude with the presentation of the students work. Previous experience in C/Java or other languages is preferable but not mandatory. The students will program their own Android Smartphone.
- Ultra Low Lattice FPGA – High Level Programming – Peripherals Interfacing using an Lattice FPGA
- The course will conclude with the presentation of the students work. Previous experience in C/Java or other languages is preferable but not mandatory. The students will program their own Android Smartphone.

#### 227-0085-27L

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Description</th>
<th>Credits</th>
<th>Hours</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>P&amp;S: Android Application Development (AAD)</td>
<td>Does not take place this semester. The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.</td>
<td>3</td>
<td>W</td>
<td>M. Magno</td>
</tr>
</tbody>
</table>

#### Abstract

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

#### Objective


Although the App-Industry is dominated by the giant Apps right now, it is still crucial that one knows how those Apps function and how those Apps are communicating with their hardware. This course offers the opportunity for the participants to understand the development of application using Android Studio. Most importantly, participants will get a chance to do hands-on software design specific to Android smartphone and the data acquisition from sensors, GPS, google maps and other internal devices. The main goal of the course if providing the students with the basic principle and software programming for build up every android application. The course include 4-5 weeks project were the students alone or in group will build up a working demo of a target application. The course will conclude with the presentation of the students work. Previous experience in C/Java or other languages is preferable but not mandatory. The students will program their own Android Smartphone.

The course will be taught in English by the ITET center for project based learning.

#### 227-0085-28L

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Description</th>
<th>Credits</th>
<th>Hours</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>P&amp;S: iCEBreaker FPGA For IoT Sensing Systems</td>
<td>The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.</td>
<td>3</td>
<td>W</td>
<td>M. Magno, C. Vogt</td>
</tr>
</tbody>
</table>

#### Abstract

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

#### Objective

Ultra Low Lattice FPGA – High Level Programming – Peripherals Interfacing using an Lattice FPGA

Field-programmable gate array (FPGA) is an integrated circuit designed to be configured by a customer or a designer after manufacturing, so they are also "field-programmable". The FPGA configuration is generally specified using a hardware description language (HDL), similar to that used for an application-specific integrated circuit (ASIC). However more and more nowadays producers and open source community are providing higher level tools to program them similiar than processors. On the other side still it is important know the hardware architectures. This course will give to the students the opportunity to program FPGA in a high level way and use them to connect with external peripherals such as display, sensors, etc. In particular, the course will use the iCEBreaker FPGA boards that is specifically designed for students and engineers. They work out of the box with the latest open source FPGA development tools and next-generation open CPU architectures. The course will also iCEBreaker can be expandable through its Pmod connectors, so the students can make use of a large selection of third-party modules. The course will include a project where the students will learn how to build a ful working system for the next generation of Internet of Things intelligent smart sensing.

The course will be taught in English by the new Project-based learning centre.

#### 227-0085-29L

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Description</th>
<th>Credits</th>
<th>Hours</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>P&amp;S: Embedded Deep Learning with Huawei Atlas 200</td>
<td>The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.</td>
<td>3</td>
<td>W</td>
<td>M. Magno</td>
</tr>
</tbody>
</table>

#### Abstract

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
Objective

Deep neural networks (DNNs) have become the leading method for a wide range of data analytics tasks, after a series of major victories at the ImageNet Large Scale Visual Recognition Challenge (ILSVRC). For ILSVRC, the task was to classify images into 1000 different classes, many of which are difficult to distinguish (e.g., many classes are difficult to distinguish from one another like different breeds of dogs). All that was given were 1.2 million labelled images. Meanwhile, this recipe for success has taken over many more areas, from image-based tasks like segmenting objects in images, detecting objects, enhancing images using super-resolution and compression artificia reduction, to robotics and reinforcement learning, and a wide range of industrial applications.

DNNs and their subtype convolutional neural networks (CNNs) have not been new in the 2013 when the wave of success has started, but they got this huge boost through the new availability of large-scale dataset and—at least as importantly—the availability of the necessary compute resources by using GPUs to perform the computations required during training. While GPUs were then also used to stem the high computation effort of DNNs during inference (e.g., classifying images directly using a trained DNN rather than training the DNN itself), the high demand, the need for cost efficiency, and the goal of deploying DNNs not just in data centers but pervasively in everyday devices, wearable, and low-latency industrial or interactive applications, has triggered the development of various application-specific processors which are much faster, vastly more energy efficient, and cheaper at the same time—such as the Google TPU, Graphcore, …, and Huawei’s Ascend/Atlas platforms.

In this course, you will learn:

1) the basics of deep neural networks, how they work, and what challenges there are for inference,
2) how platforms with specialized hardware accelerators, specifically the Huawei Atlas 200, can be used for running DNN inference and getting a practical application running, and
3) work on your own project using DNNs and hardware accelerators based on your own ideas or on some of our proposals.

The course will be taught in English by the new D-ITET center for Project-Based Learning and a special guest lecturer from Huawei. Individual interactions/help can also be in (Swiss) German.

Most sessions will be around 1 hour of lecture and 2 hours of practical computer exercises. We will start an introduction and then you will have ca. 8 weeks to work on your project, which will concluded with a final presentation of your results.

227-0085-31L

P&S: Vision Goes Vegas ★
Does not take place this semester.
The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective
Computer Vision beschäftigt sich unter anderem damit, Maschinen zu befähigen ihre Umwelt zu sehen und das wahrgenommene Bild zu verstehen. In unserem Projekt soll ein System entwickelt werden, das Spielkarten erkennen kann und, einer guten Strategie folgend, erfolgreich Black-Jack spielen kann. Die Teilnehmer des Projektes werden kleine Teams bilden und gemeinsam mit einem Assistenten die Aufgabe erarbeiten und eine Implementierung erstellen. Am Ende des Semesters sollen die Programme im öffentlichen Wettstreit gegeneinander antreten!


Als Voraussetzung sollte Interesse an Computer Vision mitgebracht werden und die Bereitschaft, sich in einem Team von Mitstudierenden einbringen. Kenntnisse in C++ sind notwendig.

Der Kurs wird von Prof. Fisher Yu mitbegutachtet.

Dieses P&S wird in englischer Sprache durchgeführt.

227-0085-32L

P&S: Magnetic Fields in Our Daily Life ★
The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective
Magnetic fields can be found everywhere but are rarely directly perceptible. This also leads to sometimes irrational fears, such as of electrosmog. The power supply with direct current, 16.67 Hz and 50 Hz alternating current is indispensable today. Wherever electricity flows, magnetic fields are generated. That is why magnetic fields are omnipresent. But where do particularly high fields occur? How high can these fields be before they cause damage to health? Many studies have already dealt with this question and country-specific guidelines have been defined on this basis. But are these actually adhered to? Where are the legal limits exceeded? What are the consequences? The P&S will deal with this topic and an invited guest will speak.

The participants of the P&S will pursue small research projects of their own. To do this, they will be equipped with mobile measuring devices that can be connected to a smartphone to search for and characterise various magnetic field sources. How strong are the magnetic fields in our environment really? Can they pose a danger? How can they be shielded? These questions will be systematically investigated.

At the end of the P&S, the individual groups present the findings

227-0085-33L

P&S: Accelerating Genome Analysis with FPGAs, GPUs, and New Execution Paradigms ★
The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
Objective

Genome analysis is a cornerstone for groundbreaking scientific and medical advancements, including personalized healthcare. However, the field faces significant computational challenges, such as algorithmic bottlenecks and the handling of large datasets. This course aims to provide a comprehensive understanding of these computational facets, spanning across the computing stack from algorithms, software & tools, to microarchitecture & hardware accelerators.

The course will cover how advanced hardware solutions like FPGAs and GPUs can expedite genome analysis by reducing computational time and energy consumption. In parallel, it will delve into the use and development of heuristic algorithms & tools for accelerating genome analysis across various computational platforms. These algorithms, for example, can offer tradeoffs between computational intensity and accuracy. Students will engage in hands-on projects focused on optimizing existing methods or innovating new solutions for genome analysis. The curriculum’s dual emphasis on hardware solutions and versatile algorithmic strategies offers students a holistic view of the current challenges and potential resolutions within the realm of genome analysis.

The course is conducted in English.

Course website: https://safari.ethz.ch/projects_and_seminars/doku.php?id=bioinformatics

Content

The students carry out a hands-on project under the supervision of their mentors. We also offer the following lectures that the students are encouraged to follow to make impactful progress on their projects.

Lecture 1a: P&S Course Introduction & Scope
Lecture 1b: Project Overview and Q&A

Lecture 2: Introduction to Genome Analysis

Lecture 3: From Molecules to Data: An Overview of DNA Sequencing Technologies

Lecture 4a: Fundamentals of Sequence Alignment: Algorithms and Applications
Lecture 4b: Optimizing Sequence Search: Hashing, Indexing, and Filtering Techniques

Lecture 5a: Building the Blueprint of Life: Genome Assembly
Lecture 5b: Generating Insights from Genome Analysis: Variant Calling and Functional Genomics

Lecture 6a: GateKeeper
Lecture 6b: SneakySnake
Lecture 6c: GRIM-Filter

Lecture 7a: GenASM
Lecture 7b: Scrooge

Lecture 8: SeGraM

Lecture 9: GenStore

Lecture 10a: GenPIP
Lecture 10b: TargetCall

Lecture 11a: BLEND
Lecture 11b: AirLift

Lecture 12a: Raw Nanopore Signal Analysis & RawHash

Lecture notes

See: https://safari.ethz.ch/projects_and_seminars/doku.php?id=bioinformatics

Learning Materials

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1. Overview paper on co-designing hardware and software for genome analysis: https://people.inf.ethz.ch/omutlu/pub/AcceleratingGenomeAnalysis_dac23.pdf
2. Survey on the main steps in the genome analysis pipeline and their bottlenecks: https://people.inf.ethz.ch/omutlu/pub/IntelligentGenomeAnalysis_csbj22.pdf
5. Example of accelerating genomic sequence matching with FPGAs or GPUs: https://people.inf.ethz.ch/omutlu/pub/SneakySnake_UniversalGenomePrealignmentFilter_bioinformatics20.pdf
7. Examples of software/hardware co-design for genomic sequence matching:

Prerequisites / notice

- No prior knowledge in bioinformatics or genome analysis is required.
- An interest in optimizing efficiency and solving complex problems is essential.
- Basic to good knowledge in C or C++ programming language is required.
- Previous coursework in Digital Design and Computer Architecture, or an equivalent course, is desirable.
- Experience in either FPGA implementation, GPU programming, or algorithm design is highly beneficial but not mandatory.
DRAM is predominantly used to build the main memory systems of modern computing devices. Emerging memory technologies (RRAM, PCM, STT-MRAM, FeRAM) provide an exciting opportunity to replace or complement DRAM. Simulation-based experimental studies are key for understanding the complex interactions between DRAM, emerging memory technologies, and modern applications. Ramulator is an extensible main memory simulator providing cycle-accurate performance models for a variety of commercial DRAM standards (e.g., DDR3/4, LPDDR3/4, GDDR5, HBM), emerging memory technologies, and academic proposals. Ramulator has a modular design that enables easy integration of additional standards, technologies and mechanisms. Ramulator is written in C++11 and can be easily integrated to full-system simulators such as gem5.

In this P&S, you will design new memory and memory controller mechanisms for improving overall system performance, energy consumption, reliability, security, scalability and cost. You will extend Ramulator with these new designs and evaluate their performance, energy consumption, and reliability using modern applications. This will be the right P&S for you if you would like to learn about the state-of-the-art and future memory and memory controller designs and their interaction with modern applications.

This P&S will also enable you to hands-on simulate and understand the memory system behavior of modern workloads such as machine learning, graph analytics, genome analysis.

The course is conducted in English.

Lecture notes
See https://safari.ethz.ch/projects_and_seminars/doku.php?id=ramulator

Learning Materials

An old version of Ramulator:
https://github.com/CMU-SAIF/ramulator

Original Ramulator paper:

An example study of modern workloads and DRAM architectures using Ramulator:

An example recent study of a new DRAM architecture using Ramulator:

An example recent study of a new virtual memory system architecture using Ramulator:

Several examples of new ideas enabled by Ramulator based evaluation

Prerequisites / notice
A good knowledge of modern C++ is mandatory for this course. We do not teach basic programming in this course. If your skills are not adequate, it is unlikely you will be able to complete the project work and pass the course. We will hand out a mandatory assignment in the first week of the course where you are asked to complete basic tasks (e.g., building the executable, navigating through the source code, writing a simple extension to Ramulator 2.0) to make sure you are equipped with the necessary skills. If you are unable to complete these tasks in the first week, it is unlikely you will be able to complete the project work and pass the course.

227-0085-34L P&S: Exploration of Emerging Memory Systems  ■  W  3 credits  3P  O. Mutlu
The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract
The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective
This P&S will also enable you to hands-on simulate and understand the memory system behavior of modern workloads such as machine learning, graph analytics, genome analysis.

The course is conducted in English.

Course website: https://safari.ethz.ch/projects_and_seminars/doku.php?id=ramulator

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**227-0085-35L**  
**P&S: FPGA-based Exploration of DRAM and RowHammer**  
*W* 3 credits  *3P*  
A. G. Yaglikci, A. Olgun

**Abstract**  
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

**Objective**  
DRAM is predominantly used to build the main memory systems of modern computing devices. To improve the performance, reliability, and security of DRAM, it is critical to perform experimental characterization and analysis of existing cutting-edge DRAM chips.

DRAM Bender is an FPGA-based DRAM testing infrastructure that enables the programmer to perform all low-level DRAM operations (i.e., DDR commands) in a cycle-accurate manner. DRAM Bender provides a simple and intuitive high-level programming interface (in C++ and Python) that completely hides the low-level details of the FPGA from programmers. Programmers implement test routines in C++, and the test routines automatically get translated into the low-level memory controller operations in the FPGA. DRAM Bender developers write low-level hardware description language code to enable new and faster studies.

In this P&S, you will have the chance to learn how DRAM is organized and operates in a low-level and gain practical experience in using DRAM Bender while developing SoftMC programs for new DRAM characterization studies related to performance, reliability, and security. You may also improve the FPGA-based testing infrastructure itself to enable new studies. And, who knows, you might discover new security vulnerabilities like RowHammer and RowPress.

This will be the right P&S for you if you are interested in DRAM technology and would like to learn more about it as well as FPGA technology and how it can be used for practical purposes such as understanding and mitigating RowHammer attacks, generating true random numbers, reducing memory latency, fingerprinting and identifying devices, and improving reliability.

The course is conducted in English.

Course website: [https://safari.ethz.ch/projects_and_seminars/doku.php?id=softmc](https://safari.ethz.ch/projects_and_seminars/doku.php?id=softmc)

See: [https://safari.ethz.ch/projects_and_seminars/doku.php?id=softmc](https://safari.ethz.ch/projects_and_seminars/doku.php?id=softmc)

**Literature**  
Lecture notes

Prerequisites / notice

A good knowledge of modern C++ is mandatory for this course. If your skills are not adequate, it is unlikely you will be able to complete the project work and pass the course. We will hand out a mandatory assignment in the first week of the course where you are asked to complete basic tasks (e.g., building the executable, navigating through the source code, writing a simple extension to Ramulator 2.0) to make sure you are equipped with the necessary skills. If you are unable to complete these tasks in the first week, it is unlikely you will be able to complete the project work and pass the course.

- Digital Circuits (or equivalent course) AND Computer Engineering
- Good knowledge of modern C++ and common Linux tools (e.g., git, ssh, and gcc)
- Interest in low-level system exploration and memory
- Interest in discovering why things do or do not work and solving problems

**Competencies**

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<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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- Digital Circuits (or equivalent course) AND Computer Engineering
- Good knowledge of modern C++ and common Linux tools (e.g., git, ssh, and gcc)
- Interest in low-level system exploration and memory
- Interest in discovering why things do or do not work and solving problems

**227-0085-36L**  
**P&S: Genome Sequencing on Mobile Devices**  
*W* 3 credits  *3P*  
C. Firtina

**Abstract**  
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
Objective

Genome analysis is the foundation of many scientific and medical discoveries, and serves as a key enabler of personalized medicine. This analysis is currently limited by the inability of existing technologies to read an organism’s complete genome. Instead, a dedicated machine (called sequencer) extracts a large number of shorter random fragments of an organism’s DNA sequence, known as reads. Small, handheld sequencers such as ONT MinION and Flongle make it possible to sequence bacterial and viral genomes in the field, thus facilitating disease outbreak analyses such as COVID-19, Ebola, and Zika. However, large, capable computers are still needed to perform genome assembly, which tries to reassemble read fragments back into an entire genome sequence. This limits the benefits of mobile sequencing and may pose problems in rapid diagnosis of infectious diseases, tracking outbreaks, and near-patient testing. The problem is exacerbated in developing countries and during crises where access to the internet network, cloud services, or data centers is even more limited.

In this course, we will cover the basics of genome analysis to understand the speed-accuracy tradeoff in using computationally-lightweight heuristics versus accurate computationally-expensive algorithms. Such heuristic algorithms typically operate on a smaller dataset that can fit in the memory of today’s mobile device. Students will experimentally evaluate different heuristic algorithms and observe their effect on the end results. This evaluation will give the students the chance to carry out a hands-on project to implement one or more of these heuristic algorithms in their smartphones and help the society by enabling on-site analysis of genomic data.

The course is conducted in English.

Course website: https://safari.ethz.ch/projects_and_seminars/doku.php?id=genome_seq_mobile

Lecture notes
See: https://safari.ethz.ch/projects_and_seminars/doku.php?id=genome_seq_mobile

Literature
Learning Materials
===============
3. An example of how to accelerate genomic sequence matching by two orders of magnitude with the help of FPGAs or GPUs: https://arxiv.org/abs/1910.09020
5. An example of using a different computing paradigm for accelerating read mapping step and improving its energy consumption: https://arxiv.org/pdf/1708.04329
7. An example of a purely software method for fast genome sequence analysis: http://www.biomedcentral.com/content/pdf/1471-2164-14-S1-S13.pdf
9. Accelerating Genome Analysis, Invited Talk BSC, Onur Mutlu: https://www.youtube.com/watch?v=tVpg0XqU_c4

Prerequisites / notice
Prerequisites of the course:
- No prior knowledge in bioinformatics or genome analysis is required.
- A good knowledge in C programming language and programming is required.
- Interest in making things efficient and solving problems.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Leadership and Responsibility: assessed

Personal Competencies
- Adaptability and Flexibility: assessed
- Critical Thinking: assessed
- Self-direction and Self-management: assessed

227-0085-37L P&S: Memory-Centric Computing ■

W 3 credits 3P O. Mutlu

Abstract

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
Many modern and important workloads such as machine learning, computational biology, graph processing, databases, video analytics, and real-time data analytics suffer greatly from the data movement bottleneck. These workloads are exemplified by irregular memory accesses, relatively low data reuse, low cache line utilization, low arithmetic intensity (i.e., ratio of operations per accessed byte), and large datasets that greatly exceed the main memory size. The computation in these workloads cannot usually compensate for the data movement costs. In order to alleviate this data movement bottleneck, we need a paradigm shift from the traditional processor-centric design, where all computation takes place in the compute units, to a more data-centric design where processing elements are placed closer to or inside where the data resides. This paradigm of computing is known as Processing-in-Memory (PIM).

This is your perfect P&S if you want to become familiar with the main PIM technologies, which represent “the next big thing” in Computer Architecture. You will work hands-on with the first real-world PIM architecture, will explore different PIM architecture designs for important workloads, and will develop tools to enable research of future PIM systems. Projects in this course span software and hardware as well as the software/hardware interface. You can potentially work on developing and optimizing new workloads for the first real-world PIM hardware or explore new PIM designs in simulators, or do something else that can forward our understanding of the PIM paradigm.

Prerequisites of the course:
- Digital Circuits AND Computer Engineering (or equivalent courses)
- Familiarity with C/C++ programming.
- Interest in future computer architectures and computing paradigms.
- Interest in discovering why things do or do not work and solving problems
- Interest in making systems efficient and usable

The course is conducted in English.
The course has two main parts:
1. Weekly lectures on processing-in-memory.
2. Hands-on project: Each student develops his/her own project.

Lecture notes
See: https://safari.ethz.ch/projects_and_seminars/

Literature
Learning materials

Summary papers about recent research in PIM:

An analysis of a real-world processing in memory architecture.

Repository: https://github.com/CMU-SAFARI/DAMOV
DAMOV simulator.
https://github.com/CMU-SAFARI/ramulator-pim

UPMEM SDK documentation: The first real-world PIM architecture.
https://sdk.upmem.com/2023.1.0/

An example recent study of 3D-stacked PIM for consumer workloads.

An example recent study of a PIM accelerator for graph processing.

An example recent study of a PIM accelerator for graph processing.

An example recent study of a Processing-in-Memory system.

Prerequisites of the course:
- Digital Circuits AND Computer Engineering (or equivalent courses).
- Familiarity with C/C++ programming.
- Interest in future computer architectures and computing paradigms.
- Interest in discovering why things do or do not work and solving problems
- Interest in making systems efficient and usable

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<td>Critical Thinking</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
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</tr>
<tr>
<td>Self-direction and Self-management</td>
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</tbody>
</table>

P&S: Controlling Biological Neuronal Networks Using W 4 credits 5P J. Vörös

Machine Learning
Abstract

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective

The way memory and learning is achieved in the brain is an unsolved problem. Due to its relative simplicity, in-vitro neuroscience can help us discover the fundamentals of information processing in the brain. For this we can simulate a small number of biological neurons on top of an array of microelectrodes. Such an approach allows us to simulate the electrical activity of the neurons when they get stimulated.

Following this approach, we can investigate biological neural networks, that have about 5-50 neurons and a controlled network architecture. Still, their behavior remains highly unpredictable. Therefore, it is not yet clear how such networks need to be stimulated electrically in order to control their behavior. However, we can use machine learning to find a mapping between a stimulus and a desired response. More specifically, we can use reinforcement learning, since finding the right stimulation pattern is an instance of the so-called multi-armed bandit problem.

This P&S consists of two parts. In the first part we will introduce you to the way neurons can be simulated. You will learn how neurons work and how they communicate. The second part will be about machine learning. We will discuss the basics of both artificial neural networks (ANN) and reinforcement learning. As homework exercises you will implement a reward function for a provided reinforcement learner, which will control your biological networks. In addition you will implement an ANN, that replaces unsatisfactorily performing stimulation patterns with new patterns, that this network evaluates to perform better.

If the current situation will allow, the developed ANNs will be tested on real neurons in our laboratory.

This P&S will be given in English. In total, the P&S takes 8 afternoons and about 50 hours of homework (ANN implementation).

<table>
<thead>
<tr>
<th>Course Code</th>
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<tbody>
<tr>
<td>227-0085-39L</td>
<td>P&amp;S: Python for Science &amp; Machine Learning</td>
<td>3 credits</td>
<td>Digital Circuits AND Computer Engineering (or equivalent courses)</td>
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<td>No prior knowledge in ANN implementation is required.</td>
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<td>Abstract</td>
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<td>The category of &quot;Laboratory Courses, Projects, Seminars&quot; includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.</td>
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<td>Objective</td>
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<td>This beginner course to programming with Python - with a focus on applications in science and technology - is ideal starting point for future courses. We will start with an introduction to the dev environment and tools for effective development to get you started. Then we will learn the basics of Python with exercises, and discover popular modules for data processing and visualisation that will be useful for your later studies and career. We conclude with an introduction to popular machine learning techniques and some time for you to implement your own small free-style projects.</td>
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<td>By the end of the semester, you will</td>
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<td>- be familiar with your PC's command-line interface and know how to use available dev environments effectively.</td>
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<td>- have learned the basics of Python and be able to write basic programs that do what you want (most of the time) with the help of modules.</td>
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<td>- be able to process, visualize and analyze numerical data, e.g. lab measurements, images, etc.</td>
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<td>- have first experience with machine learning techniques.</td>
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<td>- maintain your first git repository and know how to collaborate with others on coding projects.</td>
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<td>Language: English / German (if necessary)</td>
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<tr>
<td>227-0085-44L</td>
<td>P&amp;S: Understanding and Designing Modern SSDs (Solid-State Drives)</td>
<td>3 credits</td>
<td>Digital Circuits AND Computer Engineering (or equivalent courses)</td>
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<td>No prior knowledge in NAND flash memory is required.</td>
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<td>does not take place this semester.</td>
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<td>NAND flash memory is the de facto standard in architecting a storage device in modern computing systems. As modern computing systems process a large amount of data at an unprecedented scale, a storage device needs to meet high requirements on storage capacity and I/O performance. A NAND flash-based SSD can provide an order(s) of magnitude higher I/O performance compared to traditional hard-disc drives (HDDs), with a much lower cost-per-bit value over any other SSDs based on emerging non-volatile memory (NVM) technologies.</td>
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<td>NAND flash memory has several unique characteristics, such as the erase-before-write property (i.e., a flash cell needs to be first erased before programming it), limited lifetime (i.e., a cell can reliably store data for a certain number of program/erase cycles), and large operation units (e.g., a NAND flash chip reads/writes data in a page (e.g., 16 KiB) granularity). To achieve high performance and large capacity of the storage system while hiding the unique characteristics of NAND flash memory, it is critical to design efficient SSD firmware, commonly called Flash-Translation Layer (FTL). An FTL is responsible for many critical management tasks, such as address translation, garbage collection, wear-leveling, and I/O scheduling, that significantly affect the performance, reliability, and lifetime of the SSD.</td>
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<td>In this P&amp;S, we will cover how a modern NAND flash-based SSD is organized and operates, from the basics of underlying NAND flash devices and various SSD-management tasks at the FTL-level. You will build a practical SSD simulator by refactoring MQSim, a state-of-the-art simulator for high-end SSDs, to support advanced features of modern NAND flash chips and essential SSD-management tasks. This will allow you to have the chance to obtain a comprehensive background of modern storage systems and research experience on system optimization with rigorous evaluation.</td>
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<td>Prerequisites of the course:</td>
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<td>- No prior knowledge in NAND flash-based storage systems is required.</td>
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<td>- Digital Circuits AND Computer Engineering (or equivalent courses)</td>
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<td>- Good knowledge in C/C++ programming language is required.</td>
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<td>- Interest in system optimizations</td>
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<td>See: <a href="https://safari.ethz.ch/projects_and_seminars/">https://safari.ethz.ch/projects_and_seminars/</a></td>
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## Literature

- **Inside NAND Flash Memories:** [https://search.library.ethz.ch/permalink/f/823s1o/ELENDING603606](https://search.library.ethz.ch/permalink/f/823s1o/ELENDING603606)
- **Inside Solid State Drives (SSDs):** [https://search.library.ethz.ch/permalink/f/823s1o/ELENDING1030264](https://search.library.ethz.ch/permalink/f/823s1o/ELENDING1030264)
- **MQSim**, an open-source multi-queue SSD simulator
  
  Source code: [https://github.com/CMU-SAFARI/MQSim](https://github.com/CMU-SAFARI/MQSim)
  
  
  
  
  

## Prerequisites / notice

- No prior knowledge of NAND flash-based storage systems is required.
- Digital Circuits AND Computer Engineering (or equivalent courses).
- Good knowledge of C/C++ programming language is required.
- Interest in system optimizations

## Competencies

### Subject-specific Competencies

- Concepts and Theories
  - assessed
- Techniques and Technologies
  - assessed

### Method-specific Competencies

- Analytical Competencies
  - assessed
- Problem-solving
  - assessed
- Project Management
  - assessed

### Social Competencies

- Communication
  - assessed

### Personal Competencies

- Critical Thinking
  - assessed
- Self-awareness and Self-reflection
  - assessed
- Self-direction and Self-management
  - assessed

## P&S: Robotic Maze Solving with a TI-RSLK Robot (RMaze) ■

**W 3 credits 3P M. Magno**

**Does not take place this semester.**

**Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.**

### Objective

Microcontroller programming (C) – Peripherals Interfacing using a MSP433 MCU – Control of a Robot in a maze

The course will focus on teaching how to build and program a Texas Instrument robotic system learning kit (TI-RSLK). It is a robot kit, which includes a 2 wheeled robot, a line sensor to determine lines on the floor as well as sensors to recognize walls. The robot is driven by a MSP432 state of the art ARM Cortex M4 processor.

This course will give the students the opportunity to learn how to program the microcontroller of this robot to navigate in a small maze. For this, the students will learn how to control the motors and, consequently the movement of the robot with the peripherals of the microcontroller. Next to the movement, also the control and readout of the attached sensors will be part of the P&S course.

Once the students are able to read sensor values and control the motors of the robot, this course will conclude with a 4-week project. Within this project the students will design their own algorithm, such that the robot can navigate autonomously within a maze. A small competition at the end of the P&S will find the fastest robot of the group.

The course will be taught in English by the new D-ITET center for Project-based learning, the programming toolchain will be installed on the student’s own laptop. Experience with microcontroller programming (C) is an advantage, however not required. A short introduction will be given during the course.

This course will be taught in English or in German if necessary.

## P&S: Embedded Systems With Drones ■

**W 4 credits 4P M. Magno**

**Does not take place this semester.**

**Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.**

### Abstract

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
Objective

Drones can be fun to use but understanding the hardware and software and building and programming them to be intelligent and autonomous is even better. This course gives the basis of the embedded systems having the drones as the primary target. The course will introduce embedded systems and, in particular, the microcontroller ARM Cortex-M, focusing on all the crucial blocks such as Interrupts, GPIO, ADC’s, Timers, and Serial communication protocols. Apart from the core topics, real-time and power-efficient algorithms for attitude and motor control are also discussed, making the drone efficient. Finally, exciting drone exercises are supported in the course to experiment with the development kit. The course will end with a 4-5 weeks project where the students will make the drone fly with some specific goal. It is not required any previous knowledge except C language.

The course will be taught in English and organized by the new Project-Based Learning center.

227-0085-47L
P&S: Machine Learning on Smart Phone

Abstract

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective

Machine Learning with Smart Phone Sensors – Programming Android Phones – Neural Networks – Keras/Tensor Flow – Projects and App on smartphones

Smartphones have several sensors that can acquire much useful information, for instance where we are, what we are doing, with whom we are together, what is our constitution, what are our needs. Based on this information our ‘smartphone’ offers us the appropriate computational power to process them in loco without sending the sensor data to the cloud. This course focus on giving the bases of machine learning and embedded systems. The student will learn the tools to implement a machine learning algorithm, such as TensorFlow and others in their android phones to have an advanced smartphone. The course will end with 4 weeks project where the students can target a specific application scenario. It is not required any previous experience in machine learning. Phyton is a plus but the basis of Phyton will be given in the course to be able to complete the project.

The course will be taught in English and organized by the new Project-based Learning center.

227-0085-48L
P&S: Introduction to Program Nao Robots for Robocup Competition

Abstract

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective


The course will introduce the software package and the full SDK and API. The students will learn how to program (mainly in C and Phyton) the robot to access the full functionality. To improve the hands-on skills of students the course will end with a 5 weeks project where the students will make the drone fly with some specific goal. It is not required any previous knowledge but programming skills are a plus.

The course will be taught in English and organized by the new Project-based Learning center.

227-0085-49L
P&S: Smart Patch Projects

Abstract

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective

Wearable devices, PCB Design, Firmware developing, multi-sensors, Communication.

The Smart Patch project will design autonomous, low power and mesh enabled multi-sensor wearable smart patches. They will be based on the always-on smart sensing paradigm to continuously acquire process and stream physiological data in real-time. They can be trained to autonomously detect illness symptoms or other physical conditions, such as stress. The students will work in a team to design a sub-block of the smart patch. According to the students’ background, they will be associated with designing the hardware or the firmware. Together in a team; they will learn how to structure problems and identify solutions, system analysis, and simulation, as well as presentation and documentation techniques. They will get access to D-ITET labs and state-of-the-art engineering tools (Matlab, Simulink, Firmware development IDE, PCB Design, etc.)

The projects will be done under the Smart Patches: a flagship project for D-ITET students. (pbl.ee.ethz.ch)

227-0085-53L
P&S: Motion Sensing Technologies for Magnetic Resonance Imaging (MRI)

Abstract

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
Objective Current MRI scans are limited by patient motion. In clinics, radiologists are often confronted with images with severe motion artefacts in their images. They either have to make a diagnosis although the image artefacts were they could miss crucial information, or they have to send the patient back into the scanner for reacquisition. Such reacquisition might inflict additional costs in the six-figure range per scanner per year.

Further, in research, MRI images from ultra-high field systems are already limited by motion from the cardio-balistic and respiratory movement. Resulting in subpar performance if not addressed appropriately.

The key to overcoming such motion artefacts is estimating the motion and correct for it. Preferably this is done prospective in real-time or otherwise afterwards retrospective in the image reconstruction. Such methods are instrumental in brain imaging since the brain's movement is well described by the rigid body behaviour of the skull.

To do such motion correction, one needs a motion-sensing technology to measure the movement of the human skull with high precision, accuracy and temporal resolution. All this has to be done while being integrated into an MRI machine where powerful static magnetic fields are present, kW of pulsed RF power and MVA of changing magnetic field gradients are present.

In this P&S we explore different motion sensing technologies suitable for deployment in an MRI machine. What you can expect is that we discuss the theory of multiple sensing technologies and then implement an optical, shortwave RF and NMR phase motion sensor. We will spend most of our time in the lab constructing such sensors and testing them on our robotic test bench. Finally, we would also experiment in our MRI facilities, where we would perform motion correction experiments.

227-0085-54L P&S: Optics and Spectroscopy Lab W 3 credits 4P J. Leuthold

Course notes: Does not take place this semester. Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.

Abstract The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective The goal of this P&S is to learn the basics of working with optics and how to assemble optical systems. It is intended to show the practical side to the many optics lectures that are offered at D-ITET. The course will give a very brief introduction on laser safety, basic building blocks for optics and information on how to handle such elements. The following classes allow the students to test very basics properties of lenses and lasers and how the corresponding optomechanics can be used to arrange a simple setup. After this, the different student groups rotate through four different experiments where they get the chance to build and align different optical setups and perform various measurements. No prior knowledge is required.

227-0085-56L P&S: Intelligent Architectures via Hardware/Software Cooperation W 3 credits 3P O. Mutlu

Course notes: Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.

Abstract The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective Modern general-purpose processors are agnostic to an application 19s high-level semantic information. Hence, they employ prediction-based techniques to enable computational and memory optimizations, such as prefetching, cache management policies, memory data placement, instruction scheduling, and many others. As such, the potential of such optimizations is limited due to the limited information the underlying hardware can discover on its own and such optimizations come with large area, power and complexity overheads required by the hardware for prediction purposes. Purely-hardware optimizations cannot achieve their performance potential and waste power, complexity and hardware area, since they are not aware of the application characteristics. On the other hand, purely-software optimizations are fundamentally tied up and limited by the underlying hardware.

A promising way to increase the performance of modern applications is to co-design software and hardware. Hence, lately both industry and academia are making serious attempts to improve performance, energy and security using hardware/software cooperative schemes such as application-specific hardware accelerators (e.g., Google 19s Tensor Processing Unit) and application-specific extensions in general-purpose processors (e.g., Media Engine in Apple M1).

In this course, we will explore several different topics around hardware/software co-design such as: (i) new hardware/software interfaces (e.g., virtual memory, instruction set architecture) to enhance performance, energy and security, (ii) hardware/software co-design schemes to improve the performance of the memory subsystem in killer memory-intensive applications (e.g., sparse and irregular workloads), (iii) hardware/software cooperative machine-learning-based techniques for different microarchitectural components such as prefetchers, caches and branch predictors, which would continuously learn from the vast amount of memory accesses seen by a processor and adapt to the varying workload and system conditions.

If you are enthusiastic about working hands-on to design both software and hardware, this is your P&S. You will have the opportunity to study modern applications, propose software changes to better match the underlying hardware components, design new hardware components that better match the overlying software and come up with new machine-learning techniques to design efficient microarchitectural components. You will also learn how to program industry-supported microarchitectural simulators and study the performance of modern workloads after your hardware/software modifications.

Prerequisites of the course:
- Digital Circuits AND Computer Engineering (or equivalent courses)
- Familiarity with C/C++ programming and strong coding skills.
- Interest in future computer architectures and computing paradigms.
- Interest in discovering why things do or do not work and solving problems
- Interest in making systems efficient and usable

Preferable:
- Hands-on experience with Machine Learning frameworks (depends on the topic you choose)

The course is conducted in English.

See: https://safari.ethz.ch/projects_and_seminars/
Ultrasound is one of the most used medical imaging techniques and it enables many applications, including the monitoring of musculoskeletal activity during movement, the imaging of carotid artery, and the control of prosthetic devices for human-machine interfaces. Recent developments showcased wearable ultrasound probes operating at minimal power consumption, enabling multi-day continuous monitoring of physiological parameters, and many companies and research centers are actively working on the development of the next generation of truly-wearable ultrasound for a number of monitoring and diagnostics applications.

The goal of this course is the development of the main skills required for successfully developing a wearable ultrasound probe. The students will learn about ultrasound basics, transducer control, signal processing for ultrasound, beamforming and generation of images, microcontroller basics for ultrasound, and practical procedures for performing ultrasound experiments. The course will also introduce the students to Python (applied to ultrasound signal processing) and will include a crash course on Nordic (nRF52 family) microcontrollers. In the final weeks of the course, the students will work on an assigned project.

The course will be taught in English.

Ultrasound is one of the most used medical imaging techniques and it enables many applications, including the monitoring of musculoskeletal activity during movement, the imaging of carotid artery, and the control of prosthetic devices for human-machine interfaces. Recent developments showcased wearable ultrasound probes operating at minimal power consumption, enabling multi-day continuous monitoring of physiological parameters, and many companies and research centers are actively working on the development of the next generation of truly-wearable ultrasound for a number of monitoring and diagnostics applications.

To sustain such recent developments, it is important to be familiar with all sub-components (hardware and software) of such biomedical systems.
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

### Objective

Autonomous mobile robotics is a promising field that spans from food delivery robots to the Perseverance Mars rover. In this P&S you will be introduced to the fundamental building blocks of robotics, by hands on experience in the context of the F1TENTH autonomous racing and the Robot Operating System (ROS)!

Autonomous racing pushes the boundaries in algorithmic design and implementation in the fields of perception, planning and control. Thus it serves researchers as a limits test for autonomous driving and is an important building step in the field of general self driving and AI. F1TENTH is an open-source autonomous racing competition involving a racing car in the scale of 1:10.

This P&S allows you to apply hands-on robotics and is the right fit for you if you want to further delve into this fascinating field of embedded systems, perception, planning and control. Lastly, you will get experience in the widely used ROS framework.

### Prerequisites / notice

- Can use the Linux-Terminal (e.g. navigating folder structure and ssh)
- Interest in autonomous driving
- 20GB of free space on your laptop

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**P&S: Autonomous Cars and Robots**

Objective: Enabling smart and low-power IoT sensor nodes – Firmware programming, sensor acquisition and signal processing, digital interfaces, wireless connectivity (Bluetooth and WiFi) combined with an onboard Neural Network (NN) classifier.

Abstract: Microprocessors (MCU) are everywhere today, from ultra-low power wearable devices to robots and embedded systems for the industry. In general, combining an MCU with sensors, a wireless interface, and onboard signal processing is the foundation for most electronic devices. In this practical course, the students will have the opportunity to improve their C programming skills on an actual device, with several sensors (microphones, accelerometers, vibrometers, temperature, humidity), a dual Bluetooth-WiFi wireless interface, and an AI accelerator for onboard data analysis and processing.

The kit used in this course is directly provided by STMicroelectronics and can be found here: https://www.st.com/en/evaluation-tools/steval-stwinkt1.html. Combining theory (20%) and practical implementation (80%) should enable students to conduct high-level firmware programming for microcontrollers.

After seven practical exercises and hands-on lessons, students will have the opportunity to propose and implement their own idea making use of the previously acquired knowledge and the supervisor's support.

The primary programming language will be C. A basic knowledge of Python is suggested but optional.

The course will be taught in English.

The course unit can only be taken once. Repeated enrollment in a later semester is not chargeable.

Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.

The course can only be registered for once. Repeat registration in a later semester is not chargeable.

Cooperation and Teamwork

Techniques and Technologies

Content

Lecture notes

Prerequisites / notice

Students should be able to write python code. Attending the Computational Thinking lecture is enough.

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**P&S: Clinical Genomics**

Objective: Automated mobile robotics is a promising field that spans from food delivery robots to the Perseverance Mars rover. In this P&S you will be introduced to the fundamental building blocks of robotics, by hands on experience in the context of the F1TENTH autonomous racing and the Robot Operating System (ROS)!

Abstract: Autonomous mobile robotics is a promising field that spans from food delivery robots to the Perseverance Mars rover. In this P&S you will be introduced to the fundamental building blocks of robotics, by hands on experience in the context of the F1TENTH autonomous racing and the Robot Operating System (ROS)!

The kit used in this course is directly provided by STMicroelectronics and can be found here: https://www.st.com/en/evaluation-tools/steval-stwinkt1.html. Combining theory (20%) and practical implementation (80%) should enable students to conduct high-level firmware programming for microcontrollers.

After seven practical exercises and hands-on lessons, students will have the opportunity to propose and implement their own idea making use of the previously acquired knowledge and the supervisor's support.

The primary programming language will be C. A basic knowledge of Python is suggested but optional.

The course will be taught in English.

The course unit can only be taken once. Repeated enrollment in a later semester is not chargeable.

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The course can only be registered for once. Repeat registration in a later semester is not chargeable.

Cooperation and Teamwork

Techniques and Technologies

Content

Lecture notes

Prerequisites / notice

Students should be able to write python code. Attending the Computational Thinking lecture is enough.
Bioinformatics and the computational analysis of next-generation sequencing data are the foundation of many medical discoveries, personalized medicine, high-throughput diagnostic techniques, and the early detection of cancer and autoimmune diseases. A dedicated machine (called a sequencer) extracts lots of random fragments of a DNA sequence, known as reads. Small, handheld sequencers such as ONT MinION and Flongle make it possible to sequence bacterial and viral genomes on-site. This enables disease outbreak analyses (i.e., for COVID-19 or Ebola) and the on-site analysis of patient samples. A prominent example is the study of the human microbiome in liquid biopsy samples (i.e., blood samples). The microbiome is strongly related to human health and allows for the early diagnosis of diseases like Parkinson's, Alzheimer's, and cancer.

In this course, we will cover the basics of genome analysis for medical applications, high-throughput diagnostics, and the early detection and prevention of diseases.

Students will experimentally evaluate different algorithms and machine-learning techniques to uncover somatic mutations in cancer and develop tools dedicated to microbiome discovery and high-throughput disease diagnostics.

The course is conducted in English.

Content
Course website: https://safari.ethz.ch/projects_and_seminars/fall2024/doku.php?id=clinical_genomics

Prerequisites / notice
- No prior knowledge in bioinformatics or genome analysis is required.
- Proficiency in C/C++ programming and bash scripting is required.
- Interest in clinical applications, human health, and an ambition to make things efficient and to solve new problems.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management assessed

Social Competencies
- Communication assessed
- Cooperation and Teamwork assessed
- Customer Orientation assessed
- Leadership and Responsibility assessed
- Self-presentation and Social Influence assessed
- Sensitivity to Diversity assessed
- Negotiation assessed

Personal Competencies
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

227-0085-68L  P&S: Digital Audio

W 4 credits  L. Benini

Only for Electrical Engineering and Information Technology BSc.

Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.

Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective
Real-time digital audio processing on a modern microcontroller

Modern microcontrollers are sufficiently powerful to run real-time audio processing algorithms. Since such microcontrollers can be programmed using a high-level programming language (e.g., C++) and they support floating-point computations, implementation of audio-processing algorithms is quite simple.

In this P&S you will
- learn the basics of digital signal processing (DSP),
- solder a PCB with surface-mount (SMD) components,
- learn to program modern microcontrollers, and
- implement an audio effect (signal processing algorithm) of your choice on a real-time system that you soldered yourself :smile:

There will be a weekly in-person class/exercise session taught by the P&S supervisors (4h per week). In addition, the students will work independently to solder the PCB and to implement their algorithm; this is estimated to take an additional 4h per week.

Prerequisites:
- you play a music instrument and/or have a strong interest in audio processing or music
- you are motivated to work on your project independently in addition to the supervised 4h per week

Group Projects
Number  Title  Type  ECTS  Hours  Lecturers
227-0091-10L  Group Project I  W  6 credits  5A  Lecturers

Abstract
Students must work in groups in supervised projects for 150 to 180 hours minimum. The topics of the group work are open and can be technical of specific nature or more general in the context of engineering.

Objective
see above

227-0092-10L  Group Project II  W  6 credits  5A  Lecturers

Abstract
Students must work in groups in supervised projects for 150 to 180 hours minimum. The topics of the group work are open and can be technical of specific nature or more general in the context of engineering.

Objective
see above

Internship in Industry
The internship in industry can only be enrolled for during bachelor's studies according to the 2016 regulations. According to the 2018 regulations, an internship in industry can be taken at master's level.

Please note the conditions for internships in industry as set forward by the "Guidelines for the "Laboratory Courses - Projects - Seminars ", see https://www.ee.ethz.ch/content/dam/ethz/special-interest/itet/department/Studies/Bachelor/Regulations/Richtlinien_Praktika-Projekte-Seminare_v5_final.pdf (German only).

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>227-0093-10L</td>
<td>Internship in Industry</td>
<td>W</td>
<td>6</td>
<td>external organisers</td>
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</tr>
<tr>
<td></td>
<td>Only for students in the Bachelor’s Programme Electrical Engineering and Information Technology, Regulations 2016. For students enrolled in the 2018 Programme Regulations, see “227-1550-10L Internship in Industry” at Master’s level.</td>
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<tr>
<td></td>
<td>Abstract The main objective of the 12-week internship is to expose bachelor’s students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.</td>
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<td>Objective see above</td>
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<tr>
<td></td>
<td>Prerequisites / notice Please note the conditions for Internships in industry as set forward by the &quot;Guidelines for the &quot;Laboratory Courses - Projects - Seminars &quot;, see <a href="https://ethz.ch/content/dam/ethz/special-interest/itet/department/Studies/Bachelor/Regulations/Richtlinien_Praktika-Projekte-Seminare_v5_final.pdf">https://ethz.ch/content/dam/ethz/special-interest/itet/department/Studies/Bachelor/Regulations/Richtlinien_Praktika-Projekte-Seminare_v5_final.pdf</a> (German only).</td>
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✈✈ Additional Subjects

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0651-00L</td>
<td>Applied Circuit and PCB-Design</td>
<td>W</td>
<td>2</td>
<td>4G</td>
<td>A. Blanco Fontao</td>
</tr>
<tr>
<td></td>
<td>The student must motivate the reasons that lead him/her to enroll by means of an e-mail to the person in charge of the course (<a href="mailto:balfonso@ethz.ch">balfonso@ethz.ch</a>). Failing to do so will result in a registration rejection. Final admission to the course is at the discretion of the lecturer.</td>
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<tr>
<td></td>
<td>Abstract Participants learn how to design a predefined electronic circuit and how to lay out the pertaining circuit board. CAE and CAD activities for design and simulation are carried out with the aid of Altium Designer.</td>
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<td></td>
<td>Objective The goal is to become acquainted with all those practical aspects of electronic circuit and PCB design by working through a modest but complete application example. This involves analysis of specifications, the evaluation of electronic parts, efficient testing and failure search, electromagnetic compatibility (EMC), the usage of industrial CAE/CAD tools for circuit simulation and PCB layout, generating production data for the board manufacturer, board mounting, testing and start up.</td>
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<tr>
<td></td>
<td>Content Content: - Development - from the idea to the final product - Analysis of given circuit specifications - Searching the Internet for electronics parts - Choosing electronic parts: avoiding mistakes - Setting up the Altium Designer environment - Structure of component libraries - Preparing schematic symbols for CAE - Preparing footprints for CAD - Linking component libraries and databases - Introduction to Concord Pro and Supply Chain Management - Structure of schematic diagrams and circuits - Assigning schematic functions to physical parts - Capturing a predefined circuit - Hints for improved testing and failure analysis - Checking schematic data - Simulation of mixed-signal circuits using Spice - Introduction to PCB manufacturing - Turning circuit schematics into a workable layout using Altium Designer - Component placement on the PCB - Manual and automatic interconnect routing - Design for EMC and High-Speed - Preparation of production data for the board manufacturer - Documentation for manufacturing and assembly - PCB assembly (component mounting and soldering) - Final circuit testing and start-up.</td>
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<tr>
<td></td>
<td>Literature All necessary documents will be available as electronic documents (PDF).</td>
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<td>Prerequisites / notice - The course is recommended to all students who plan to design an electronic circuit or a PCB in an upcoming term project or as part of their master thesis. Attending this course during the term before will ensure they are optimally prepared and will allow them to fully focus on their project. - The number of participants is limited. - For their own students and staff, the Department of Information Technology and Electrical Engineering provides electronic components and consumables free of charge. All other participants have to bear a 200 CHF fee for those items.</td>
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</table>
## Competencies

### Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

### Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

### Social Competencies
- Cooperation and Teamwork

### Personal Competencies
- Creative Thinking
- Self-direction and Self-management

### Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

### Social Competencies
- Cooperation and Teamwork

### Personal Competencies
- Creative Thinking
- Self-direction and Self-management

#### 5th Semester: Third Year Core Courses

*Can be freely combined, a list of recommendations is available under https://ee.ethz.ch/studies/bachelor/third-year/core-courses.html*

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0101-00L</td>
<td>Discrete-Time and Statistical Signal Processing</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
</tbody>
</table>

**Abstract**
The course is about some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.

**Objective**
The course is about some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust "inversion" of a linear filter.

**Content**
1. Discrete-time linear systems and filters: state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.
2. The discrete Fourier transform and its use for digital filtering.
3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.

**Lecture notes**
Lecture Notes

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0102-00L</td>
<td>Discrete Event Systems</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>L. Josipovic, L. Vanbever, R. Wattenhofer</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to discrete event systems. We start out by studying popular models of discrete event systems. Then we analyze discrete event systems from an average-case and from a worst-case perspective, and study verification. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Petri Nets.

**Objective**
Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by exploring the limits of what is computable and what is not. In doing so, we will consider three distinct models of computation which are often used to model discrete event systems: finite automata, push-down automata and Turing machines (ranked in terms of expressiveness power). In the second part of the course we analyze discrete event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply continuous time markov chains and queueing theory for an understanding of the typical behavior of a system. Then we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queueing. In the last part of the course we introduce methods that allow to formally verify certain properties of Finite Automata and Petri Nets. These are some typical analysis questions we will look at: Do two given systems behave the same? Does a given system behave as intended? Does the system eventually enter a dangerous state?

**Content**
1. Regular Languages
2. Non-Regular Languages
3. Markov Chains
4. Stochastic Discrete Event Systems
5. Worst-Case Event Systems
6. Verification of Finite Automata
7. Petri Nets

**Lecture notes**
Available at https://disco.ethz.ch/courses/des/
Abstract
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Literature

Prerequisites / notice
MATLAB is used for system analysis and simulation.
### Content

Fields of application and application examples of power electronic converters, basic concept of switch-mode voltage and current conversion, pulse-width modulation (PWM); derivation and operating modes (continuous and discontinuous current mode) of DC/DC converter topologies, buck / boost / buck-boost converter; extension to DC/AC conversion using differences of unipolar output voltages varying over time; single-phase diode rectifier; boost-type PWM rectifier featuring sinusoidal input current; tolerance band AC current control and cascaded output voltage control with inner constant switching frequency current control; local and global averaging of switching frequency discontinuous quantities for calculation of component stresses; three-phase AC/DC conversion, center-tap rectifier with impressed output current, thyristor function, thyristor center-tap and full-bridge converter, rectifier and inverter operation, control angle and recovery time, inverter operation limit; basics of inductors and single-phase transformers, design based on scaling laws; Isolated DC/DC converter, flyback and forward converter, single-switch and two-switch circuit; single-phase DC/AC conversion, four-quadrant converter, unipolar and bipolar modulation, fundamental frequency model of AC-side operating behaviour; three-phase DC/AC converter with star-connected three-phase load, zero sequence (common-mode) and current forming differential-mode output voltage components, fundamental frequency modulation and PWM with singe triangular carrier and individual carrier signals of the phases.

### Lecture notes

Lecture notes and associated exercises including correct answers, simulation program for interactive self-learning including visualization/animation features.

### Prerequisites / notice

Prerequisites: Basic knowledge of electrical engineering / electric circuit analysis and signal theory.

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tr>
<td>Techniques and Technologies</td>
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<th>Method-specific Competencies</th>
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<th>assessed</th>
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<tr>
<td>Decision-making</td>
<td>Media and Digital Technologies</td>
<td>fostered</td>
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<tr>
<td>Problem-solving</td>
<td>Project Management</td>
<td>fostered</td>
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<th>Social Competencies</th>
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<tr>
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<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
<td>fostered</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
<td>fostered</td>
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<tr>
<th>Personal Competencies</th>
<th>Adaptability and Flexibility</th>
<th>fostered</th>
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<tbody>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>fostered</td>
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<td>Critical Thinking</td>
<td>fostered</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
<td>fostered</td>
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### 227-0116-00L VLSI 1: HDL Based Design for FPGAs

**W 6 credits 5G F. K. Gürkaynak**

#### Abstract

This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

#### Objective

Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

#### Content

This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

#### Lecture notes

Textbook and all further documents in English.

#### Literature


#### Prerequisites:

Basics of digital circuits.

#### Examination:

In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details: https://iis-students.ee.ethz.ch/lectures/vlsi-i/

### 227-0121-00L Communication Systems

**W 6 credits 4G C. Studer, S. M. Moser**

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 956 of 2653
After attending the lectures, participating in the exercise sessions, and working on the homework problems (which include MATLAB coding assignments), the students will be able to:

- understand the fundamentals of digital communication systems
- explain the principles of modulation, demodulation, detection, and error correction
- analyze error rates of simple digital communication systems
- implement simple MATLAB simulations to calculate error rates

The course focuses on the fundamentals of digital communication systems. The course starts with analog modulation and discusses the main building blocks of modern digital communication systems. The topics include:

- essential components of digital communication systems
- analog and digital modulation
- baseband and passband representation; up- and down-conversion
- communication channels as LTI systems
- discretizing communication systems; sampling and quantization
- noise, signal-to-noise ratio (SNR), and interference
- detection theory and error rates
- basics of forward error correction
- basics of information theory
- orthogonal frequency-division multiplexing (OFDM)
- building blocks of modern communication systems

The exercises cover theoretical aspects as well as the basics of software-based communication-system modeling in MATLAB.

Lecture notes
Lecture notes will be distributed electronically at the beginning of the semester.

Literature

Competencies
Subject-specific Competencies
- Concepts and Theories
- assessed
- Techniques and Technologies
- assessed

Method-specific Competencies
- Analytical Competencies
- assessed
- Problem-solving
- assessed

Personal Competencies
- Critical Thinking
- fostered
- Integrity and Work Ethics
- fostered

227-0124-00L Embedded Systems

Abstract
An embedded system is a combination of hardware and software, either fixed in function or programmable, that is designed for a specific application scenario or for a specific task within a larger system. They are part of industrial machines such as agricultural and manufacturing equipment, automotive systems, medical equipment, household appliances, sensor networks, and the Internet of Things.

Objective
Understanding the specific requirements and problems that arise in embedded system applications.

- Understanding the hardware structure of a microcontroller and an embedded system; memory architecture and memory map, internal and external peripherals, low-power and low-energy design as well as instruction sets and computational accelerators.
- Understanding the firmware structure of a microcontroller and an embedded system; low-level instruction set, hardware-software interfaces, communication between components, embedded real-time operating systems, real-time scheduling, shared resources, low-power and low-energy programming as well as computational accelerators.
- Using formal models and methods for designing and optimizing embedded systems.
- Gaining experience with practical applications of the C programming language, embedded real-time operating systems, and debug functionalities of the associated design environment to design, implement, and verify embedded firmware.
- Through project-based activities, students will gain substantial experience in applying the C programming language in the context of embedded systems. Projects will involve developing and implementing firmware, utilizing embedded real-time operating systems, and exploring the debugging functionalities within design environments. This hands-on approach aims to bridge the gap between theoretical knowledge and practical application, allowing students to experience the full lifecycle of embedded system development from design to implementation and verification.

Content
This lecture focuses on the design of embedded systems using formal models and methods.

- Besides the theoretical lecture, the course contains laboratory sessions where students transfer the learned theoretical aspects into praxis by programming a microcontroller and interfacing it with sensors and actuators.
- Students will be exposed to a commercial microcontroller, and the development board extend with a custom-designed embedded systems educational platform.
- Specifically, the following topics will be covered in the course: hardware and software structures of embedded systems, low-level instruction set, memory architecture and memory map, peripherals, hardware-software interfaces, communication between components, firmware design methodologies, firmware design using the C programming language, embedded real-time operating systems, real-time scheduling, shared resources, low-power, and low-energy designs as well as computational accelerators.

Lecture notes
Lecture material, publications, exercise sheets, and laboratory documentation will be available on the course’s Moodle page.

Literature

Prerequisites / notice
Prerequisites: C programming, circuit theory, digital logic, binary number representations.
Recommended: basic knowledge of assembly programming and computer architecture.

Competencies
Subject-specific Competencies
- Concepts and Theories
- assessed
- Techniques and Technologies
- assessed

227-0145-00L Solid State Electronics and Optics

Abstract
"Solid State Electronics" is an introductory condensed matter physics course covering crystal structure, electron models, classification of metals, semiconductors, and insulators, band structure engineering, thermal and electronic transport in solids, magnetoresistance, and optical properties of solids.

Objective
Understand the fundamental physics behind the mechanical, thermal, electric, magnetic, and optical properties of materials.

Prerequisites / notice
Recommended background: Undergraduate physics, mathematics, semiconductor devices
Analog Integrated Circuits

Abstract
This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies. Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.

Content
Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors.

The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.

Lecture notes
Handouts of presented slides. No script but an accompanying textbook is recommended.

Literature

Qubits, Electrons, Photons

Abstract
In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis).

Objective
Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics.

Starting from the axioms of quantum mechanics, we will derive the fascinating theory describing spin and qubits, electron transitions and transfer, photons and LASER: quantum mechanics is different because it mocks our daily Euclidean intuition!

In this way, students will work out a robust quantum mechanics (theoretical!!!) basis which will help them in their advanced studies of the following masters: EEIT (batteries), Biomedical Engineering (NMR, bioelectronics), Quantum Engineering, Micro- and Nanosystems.

IMPORTANT: “qubits” from the point of view of NMR (and NOT from that of quantum computing!).

Content
• Lagrangian and Hamiltonian: Symmetries and Poisson Brackets
• Postulates of QM: Hilbert Spaces and Operators
• Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator
• Density Operator
• Spin: Qubits, Bloch Equations, and NMR
• Entanglement
• Symmetries and Corresponding Operators
• Schrödinger's Wave Mechanics: Electrons in a Periodic Potential and Energy Bands
• Harmonic Oscillator: Creation and Annihilation Operators
• Identical Particles: Bosons and Fermions
• Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER
• Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener

Lecture notes
No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM, while corresponding videos of the previous years are available in Moodle !!!

Literature

Supplementary material will be uploaded in Moodle.

( as rigorous and profound presentation of the mathematical framework) G. Dell’Antonio, “Lectures on the Mathematics of Quantum Mechanics I”, 2015, Springer

( as account of those formidable years) G. Gamow, “Thirty Years that Shook Physics”, 1985, Dover Publications Inc.

Prerequisites / notice
The course has been intentionally conceived to be self-consistent with respect to QM for those master students not having encountered it in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) QM introduction course like the D-ITET “Physics II”.

A solid base of Analysis I & II as well as of Linear Algebra is really helpful.
### Biomedical Imaging

**Abstract**

Introduction to diagnostic medical imaging based on electromagnetic and acoustic fields including X-ray planar and tomographic imaging, radio-tracer based nuclear imaging techniques, magnetic resonance imaging and ultrasound-based procedures.

**Objective**

Upon completion of the course students are able to:

- Explain the physical and mathematical foundations of diagnostic medical imaging systems
- Characterize system performance based on signal-to-noise ratio, contrast-to-noise ratio and transfer function
- Design a basic diagnostic imaging system chain including data acquisition and data reconstruction
- Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications

**Content**

- Introduction (intro, overview, history)
- Signal theory and processing (foundations, transforms, filtering, signal-to-noise ratio)
- X-rays (production, tissue interaction, contrast, modular transfer function)
- X-rays (resolution, detection, digital subtraction angiography, Radon transform)
- X-rays (filtered back-projection, spiral computed tomography, image quality, dose)
- Nuclear imaging (radioactive tracer, collimation, point spread function, SPECT/PET)
- Nuclear imaging (detection principles, image reconstruction, kinetic modelling)
- Magnetic Resonance (magnetic moment, spin transitions, excitation, relaxation, detection)
- Magnetic Resonance (plane wave encoding, Fourier reconstruction, pulse sequences)
- Magnetic Resonance (contrast mechanisms, gradient- and spin-echo, applications)
- Ultrasound (mechanical wave generation, propagation in tissue, reflection, transmission)
- Ultrasound (spatial and temporal resolution, phased arrays)
- Ultrasound (Doppler shift, implementations, applications)
- Summary, example exam questions

**Lecture notes**

Lecture notes and handouts

**Literature**

Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

Analysis, Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming

**Prerequisites / notice**

Analysis, Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming

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### Bioelectronics and Biosensors

**Abstract**

The course introduces bioelectricity and the sensing concepts that enable obtaining information about neurons and their networks. The sources of electrical fields and currents in the context of biological systems are discussed. The fundamental concepts and challenges of measuring bioelectronic signals and the basic concepts to record optogenetically modified organisms are introduced.

**Objective**

During this course the students will:

- learn the basic concepts in bioelectronics including the sources of bioelectronic signals and the methods to measure them
- be able to solve typical problems in bioelectronics
- learn about the remaining challenges in this field
Content

Lecture topics:

1. Introduction

Sources of bioelectronic signals
2. Membrane and Transport
3-4. Action potential and Hodgkin-Huxley

Measuring bioelectronic signals
5. Detection and Noise
6. Measuring currents in solutions, nanopore sensing and patch clamp pipettes
7. Measuring potentials in solution and core conductance model
8. Measuring electronic signals with wearable electronics, ECG, EEG
9. Measuring mechanical signals with bioelectronics

In vivo stimulation and recording
10. Functional electric stimulation
11. In vivo electrophysiology

Optical recording and control of neurons (optogenetics)
12. Measuring neurons optically, fundamentals of optical microscopy

13. Fluorescent probes and scanning microscopy, optogenetics, in vivo microscopy

14. Measuring biochemical signals

Lecture notes
A detailed script is provided to each lecture including the exercises and their solutions.

Literature
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites / notice
The course requires an open attitude to the interdisciplinary approach of bioelectronics.
In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>assessed</td>
<td>assessed</td>
<td>Communication</td>
<td>fostered</td>
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<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<tr>
<td>Analytical Competencies</td>
<td>assessed</td>
<td>Media and Digital Technologies</td>
<td>Customer Orientation</td>
<td>fostered</td>
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<td>Problem-solving</td>
<td>Leadership and Responsibility</td>
<td>fostered</td>
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<td>Project Management</td>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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<td>Adaptable and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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Number | Title                  | Type | ECTS | Hours | Lecturers |
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227-0014-20L | Computational Thinking | W    | 4 credits | 2V+1U | R. Wattenhofer |

Abstract
We learn: algorithmic principles, dynamic and linear programming, complexity, P vs. NP, approximation, reductions, cryptography, zero-knowledge proofs, relational databases, SQL, machine learning, regression, gradient descent, decision trees, deep neural networks, universal approximation, advanced layers and architectures, reinforcement learning, Turing machines, computability, and more.

Objective
Computation is everywhere, but what is computation actually? In this lecture we will discuss the power and limitations of computation. Computational thinking is about understanding machine intelligence: What is computable, and how efficiently?

Understanding computation lies at the heart of many exciting scientific, social, and even philosophical developments. Computational thinking is more than programming a computer, it means thinking in abstractions. Consequently, computational thinking has become a fundamental skill for everyone, not just computer scientists. For example, functions which can easily be computed but not inverted are at the heart of understanding data security and privacy. The design of efficient electronic circuits is related to computational complexity. Machine learning on the other hand has given us fascinating new tools to teach machines how to estimate functions. Thanks to clever heuristics, machines now appear to be capable of solving complex cognitive tasks. In this class, we study various problems together with the fundamental theory of computation.

The course uses Python as a programming language. Python is popular and intuitive, a programming language that looks and feels a bit like human instructions. The lecture will feature weekly exercises.

This course follows the flipped classroom paradigm. Students will self-study all important concepts by reading a chapter in the script, and by watching a few short video clips. The class meets every two weeks to answer questions, and for a quiz on the current topic.
Computation is everywhere, but what is computation actually? In this lecture we will discuss the power and limitations of computation. Computational thinking is about understanding machine intelligence: What is computable, and how efficiently?

Understanding computation lies at the heart of many exciting scientific, social and even philosophical developments. Computational thinking is more than programming a computer, it means thinking in abstractions. Consequently, computational thinking has become a fundamental skill for everyone, not just computer scientists. For example, functions which can easily be computed but not inverted are at the heart of understanding data security and privacy. The design of efficient electronic circuits is related to computational complexity. Machine learning on the other hand has given us fascinating new tools to teach machines how to estimate functions. Thanks to clever heuristics, machines now appear to be capable of solving complex cognitive tasks. In this class, we study various problems together with the fundamental theory of computation.

The course uses Python as a programming language. Python is popular and intuitive, a programming language that looks and feels a bit like human instructions. The lecture will feature weekly exercises.

This course follows the flipped classroom paradigm. Students will self-study all important concepts by reading a chapter in the script, and by watching a few short video clips. The class meets every two weeks to answer questions, and for a quiz on the current topic.

The script is available here: https://disco.ethz.ch/courses/coti/

This class is suitable for students who have a basic understanding of programming.

For additional Python programming experience we recommend attending the CodeJam lab: https://disco.ethz.ch/courses/codejam/

For practical deep learning experience we recommend attending the HODL lab: https://disco.ethz.ch/courses/hodl/

### High-Frequency Design Techniques

**Abstract**
Introduction to wireless, radio spectrum. Review of vectors and complex numbers, AC circuit analysis, matching networks, distributed circuit design, transmission lines and transmission line equations, reflection coefficients, the Smith Chart and its software, voltage standing wave ratio (VSWR), skin effect, matrix analysis, scattering parameters, electromagnetic fields and waves, amplifier design.

**Objective**
Familiarize students with the essential tools and principles exploited in the high-frequency design. Introduction to circuit simulation. Introduction to amplifier design.

**Content**
Introduction to wireless, radio spectrum. Review of vectors and complex numbers, AC circuit analysis, matching networks, distributed circuit design, transmission lines and transmission line equations, reflection coefficients, the Smith Chart and its software, voltage standing wave ratio (VSWR), skin effect, matrix analysis, scattering parameters, electromagnetic fields and waves, amplifier design.

**Lecture notes**
A detailed script is provided for each lecture, including the exercises and their solutions.

**Literature**

### Introduction to Electric Power Transmission: System & Technology

**Abstract**
Introduction to theory and technology of electric power transmission systems.

**Objective**
At the end of this course, the student will be able to: describe the structure of electric power systems, name the most important components and describe what they are needed for, apply models for transformers and overhead power lines, explain the technology of lines, know about electrical safety, calculate electric withstand strength of gas gaps, stationary power flows and other basic parameters in simple power systems.

**Content**
Structure of electric power systems, transformer and power line models, analysis of and power flow calculation in basic systems, technology and principle of electric power systems.

**Lecture notes**
Lecture script in English, exercises and sample solutions.
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: fostered
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Electives

This is only a small selection. Other courses from the ETH course catalogue may be chosen. Please consult the "Richtlinien zu Projekten, Praktika, Seminare" (German only), https://ethz.ch/content/dam/ethz/special-interest/itet/department/Studies/Bachelor/Regulations/Richtlinien_Praktika-Projekte-Seminare_final_v6.pdf).

Economics, Law and Management Electives

These subjects are particularly suitable for students planning to apply to the Master's Degree Program in Energy Science and Technology (MSc EST) or Management, Technology and Economics (MSc MTEC).

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>351-0778-00L</td>
<td>Discovering Management</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td>B. Clarysse, S. Brusoni, V. Hoffmann, T. Netland</td>
</tr>
</tbody>
</table>

Abstract

Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

Objective

The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
1. broaden understanding of management principles and frameworks
2. advance insights into the sources of corporate and entrepreneurial success
3. develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

Content

The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. The theory sessions will be assessed via a multiple choice exam.

Lecture notes

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed
- Self-direction and Self-management: fostered

Prerequisite: Participation and successful completion of

Data: 15.06.2024 12:39   Autumn Semester 2024   Page 962 of 2653
the module Discovering Management (351-0778-00L) is mandatory.

Abstract
This course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

Objective
The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

Content
Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.

Students have the option to either do this alone or in a group of two students.

Literature
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. Students following this course should also be enrolled for course 351-0778-00L, "Discovering Management".

Competencies

351-0511-00L Managerial Economics

Not for MSc students belonging to D-MTEC!

W 4 credits 3V O. Krebs, P. Egger, M. Köthenbürger

Abstract
"Managerial Economics" provides an introduction to the theories and methods from Economics and Management Science to analyze economic decision-making in the context of markets. The course targets students with no prior knowledge in Economics and Management.

Objective
The objective of this course is to provide an introduction to microeconomic thinking. Based on the fundamental principles of economic analysis (optimization and equilibrium), the focus lies on understanding key economic concepts relevant for understanding and analyzing economic behavior of firms and consumers in the context of markets. Market demand and supply are derived from the individual decision-making of economic agents and market outcomes under different assumptions about the market structure and market power (perfect competition, monopoly, oligopoly, game theory) are studied. This introductory course aims at providing essential knowledge from the fields of Economics and Management relevant for economic decision-making in the context of both the private and public sector.

Literature

Prerequisites / notice
The course targets both Bachelor and Master students. No prior knowledge in the areas of Economics and Management is required.

Competencies

351-1109-00L Introduction to Microeconomics
dESS (Science in Perspective):
This course is only for students enrolled in a Bachelor's degree programme.

W 3 credits 2G M. Wörter, M. Beck

Abstract
The course introduces basic principles, problems and approaches of microeconomics. It describes economic decisions of households and firms, and their coordination through perfectly competitive markets.

Objective
Students acquire a deeper understanding of basic microeconomic models.

They acquire the ability to apply these models in the interpretation of real world economic contexts.

Students acquire a reflective and contextual knowledge on how societies use scarce resources to produce goods and services and distribute them among themselves.

Content
Market, budget constraint, preferences, utility function, utility maximisation, demand, technology, profit function, cost minimisation, cost functions, perfect competition, information and communication technologies

Lecture notes
Course material in e-learning environment https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php

Literature

Prerequisites / notice
This course "Einführung in die Mikroökonomie" (363-1109-00L) is intended for Bachelor students and LE 363-0503-00 "Principles of Microeconomics" for Master students.
### Introduction to Law

**W 2 credits 2V**  
O. Streiff Gnöpff

**Abstract**  
This class introduces students into basic features of the legal system. Fundamental issues of constitutional law, administrative law, private law and the law of the EU are covered. The focus is on legal problems related to space. Active participation is expected in short interactive sequences.

**Objective**  
Students are able to identify basic structures of the legal system. They understand selected topics of public and private law. They are able to apply the fundamentals in more advanced law classes and to recognize the relevance of law in their own field.

**Content**  
- Basic concepts of law, sources of law.  
- Private law: Contract law (particularly contract for work and services), tort law, property law.  
- Public law: Human rights, administrative law, procurement law, procedural law.  
- Insights into the law of the EU.

**Lecture notes**  
Jaap Hage, Bram Akkermans (Eds.), Introduction to Law, Cham 2017 (Online Resource ETH Library)

**Literature**  
Further documents will be available online (https://moodle-app2.let.ethz.ch/course/view.php?id=22904).

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### Startups and Law

**W 2 credits 2V**  
P. Peyrot

**Abstract**  
The students shall obtain a basic knowledge about the legal environment of entrepreneurs. They shall be able to recognize and evaluate legal issues connected to an entrepreneurial activity and suggest possible solutions.

**Objective**  
- They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise.  
- They shall be able to contribute to the legal management of the company and to discuss legal issues.  
- They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company.

**Lecture notes**  
A comprehensive script will be made available online on the moodle platform.

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### The Role of Intellectual Property in the Engineering and Technical Sector

**W 2 credits 2V**  
K. Houshang Pour Islam

**Abstract**  
The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.
Objective

In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

Prerequisites / notice

The lecture addresses students in the fields of engineering, science and other related technical fields.

Engineering Electives

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0105-00L</td>
<td>Introduction to Estimation and Machine Learning</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Mathematical basics of estimation and machine learning, with a view towards applications in signal processing.</td>
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<td><strong>Objective</strong></td>
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<td></td>
<td>Students master the basic mathematical concepts and algorithms of estimation and machine learning</td>
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<td><strong>Content</strong></td>
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<td></td>
<td>Review of probability theory; basics of statistical estimation; least squares and linear learning; Hilbert spaces; singular-value decomposition; kernel methods, neural networks, and more</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes will be handed out as the course progresses.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>solid basics in linear algebra and probability theory</td>
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<td>227-0110-00L</td>
<td>Electromagnetic Waves: Materials, Effects, and Antennas</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>D. Bortis</td>
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<td><strong>Abstract</strong></td>
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<td>This course provides profound knowledge about electromagnetic waves. Various types of materials, nonlinear and resonant effects, and antenna applications are discussed.</td>
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<td>You can describe wave propagation in classical and nonclassical materials and know the fundamental solutions. You know how waves interact with matter and about nonlinear, scattering and resonant effects. You can apply the acquired knowledge in scattering, waveguiding, radiation, and antenna problems.</td>
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<td></td>
<td><strong>Content</strong></td>
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<td>The lecture covers the following topics:</td>
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<td>• Generic time-harmonic electromagnetic fields</td>
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<td>• Fundamental solutions of the wave equation</td>
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<td>• Wave propagation in various types of materials</td>
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<td>• Interaction of waves with matter</td>
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<td>• Nonlinear effects</td>
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<td>• Resonant effects</td>
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<td></td>
<td>• Applications like scattering, waveguiding, radiation</td>
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<td></td>
<td>• Radio frequency and optical antennas</td>
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<td>Lecture notes</td>
<td>Lecture notes and slides will be handed out during the lectures.</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Critical Thinking</td>
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<td>fostered</td>
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<tr>
<td>227-0517-10L</td>
<td>Fundamentals of Electric Machines</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>D. Bortis</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>This course introduces different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.</td>
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<td><strong>Objective</strong></td>
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<td>The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are to evaluate machine types for given specifications and to acquire the ability to perform a rough design of an electrical machine while considering the versatile aspects with respect to magnetic, electrical, mechanical and thermal limitations. Exercises are used to consolidate the presented theoretical concepts.</td>
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Autumn Semester 2024
Content

- Fundamentals in magnetic circuits and electromechanical energy conversion.
- Force and torque calculation.
- Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine).
- Complex space vector notation, rotating coordinate system (dq-transformation).
- Loss components in electric machines, scaling laws of electromechanical actuators.
- Mechanical and thermal modelling.

Lecture notes

Lecture notes and associated exercises including correct answers

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>fostered</td>
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<tr>
<td>Method-specific Competencies</td>
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<td></td>
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<td></td>
<td>Problem-solving</td>
<td>fostered</td>
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</tbody>
</table>

227-0652-00L

Maxwell, Einstein, and the GPS

Maxwell’s equations are reinterpreted in the framework of Einstein’s special relativity theory using the Lagrangian formalism in order to discover the deep interconnection between the electric and magnetic field. Its daily relevance is emphasized by pinpointing how GPS atomic clocks in satellites and on the earth are affected by frequency shifts which can be explained only in terms of relativity.

Objective

D-ITET is the depository of the Maxwell’s equations, which are dissected from all perspectives in the courses Physics I, Electromagnetic Fields and Waves, and Advanced Electromagnetic Waves.

Only one aspect is left over; the fact that they are not invariant with respect to the classical Galilean transformation… On the contrary, Maxwell’s equations predict that the light speed is the same for every inertial frame of reference. In this course, we will deepen how Einstein solved this clash elaborating the theory of “special relativity”. Maxwell's equations are thus naturally derived in a breath-taking fashion from the principle of stationary action within the Lagrangian formalism.

Not only its elegance, but also the daily importance of the relativity theory will be finally highlighted explaining how the GPS can work only if the relativistic view of synchronous clocks is taken into account.

Content

• Galileo-Newton, the Ether, Michelson-Morley’s Experiment
• Lorentz Transformations
• 4-Vectors in Minkowski’s Spacetime: Tensor Formalism
• The Lagrangian, the Principle of Stationary Action for Particles and Fields, Noether’s Theorem
• Maxwell’s Equations and the Energy-Momentum Tensor
• Waves
• Radiation from Accelerated Charged Particles
• Very First Notions of General Relativity: Einstein's Equivalence Principle and Time Dilation
• Sagnac's Effect
• GPS

Lecture notes

No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM, while corresponding videos of the previous years are available in Moodle !!!

Literature

• (Special Relativity) L. Susskind and A. Friedman, “Special Relativity and Classical Field Theory: The Theoretical Minimum”, 2019, Hachette Book Group USA

Supplementary material will be uploaded in Moodle.

Prerequisites / notice

Notions of a course on Electromagnetism like D-ITET “Electromagnetic Fields and Waves” are indispensable.

Furthermore, a solid base of Analysis I & II as well as of Linear Algebra is really helpful.
Competencies

- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: fostered

- Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: assessed

- Social Competencies
  - Communication: fostered
  - Cooperation and Teamwork: fostered
  - Customer Orientation: fostered
  - Leadership and Responsibility: fostered
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: assessed
  - Negotiation: fostered

- Personal Competencies
  - Adaptability and Flexibility: assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: assessed
  - Self-direction and Self-management: assessed

Seminar in Computer Architecture

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credits</th>
<th>Subject</th>
<th>Supervisor</th>
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<tbody>
<tr>
<td>227-2211-00L</td>
<td>2 credits</td>
<td>8</td>
<td>S. Sadrosadati, Y. Liang, O. Mutlu</td>
</tr>
</tbody>
</table>

Objective

In this seminar course, we will cover fundamental and cutting-edge research papers in computer architecture. The course will consist of multiple components that are aimed at improving students' technical skills in computer architecture, critical thinking and analysis on computer architecture concepts, as well as technical presentation of concepts and papers in both spoken and written forms.

Content

Topics will center around computer architecture. We will, for example, discuss papers on hardware security; new execution paradigms like processing in memory; architectural acceleration mechanisms for key applications like machine learning, graph processing and bioinformatics; memory systems; interconnects; various fundamental and emerging paradigms in computer architecture; hardware/software co-design and cooperation; fault tolerance; energy efficiency; heterogeneous and parallel systems; technology scaling; new execution models, etc.

Prerequisites / notice

- Digital Design and Computer Architecture OR Digital Circuits / Computer Engineering
- Students should (1) have done very well in Digital Design and Computer Architecture, Digital Circuits or a similar course and (2) show a genuine interest in Computer Architecture.

Digital Creativity for Circular Construction

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credits</th>
<th>Subject</th>
<th>Supervisor</th>
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</thead>
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<tr>
<td>101-0531-00L</td>
<td>8 credits</td>
<td>7.5P</td>
<td>C. De Wolf</td>
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</tbody>
</table>

Objective

The course is about digital innovation towards a circular economy in the built environment. How can we bring together two worlds that are often too distinct: low-impact construction and digital innovation? Bringing digital tools already used in other sectors into the construction sector, students will learn about circular construction (e.g., reuse of materials) through hands-on learning practices.

Abstract

The course is about digital innovation towards a circular economy in the built environment. How can we bring together two worlds that are often too distinct: low-impact construction and digital innovation? Bringing digital tools already used in other sectors into the construction sector, students will learn about circular construction (e.g., reuse of materials) through hands-on learning practices.

1. Apply circular principles using recovered building materials.
2. Compare different digital technologies applied in circular construction (e.g., LiDAR scanning, drone imagery, photogrammetry, computational design, AI, computer vision, XR, LCA tools etc.)
3. Understand the potential and limitations of AI for circular construction, e.g., use machine learning to detect and digitize materials (computer vision) or to support creativity in the early design phases of circular construction (generative AI).
4. Communicate the importance and urgency of circular construction.
5. Assess the environmental impact implications of their design and technology decisions through a preliminary Life Cycle Assessment (LCA).
Students will receive an introduction to circular principles by experts from the building industry and visit of (de-)construction sites where circular construction is exemplified. They will explore how to use digital technologies such as LiDAR scanning, photogrammetry, scan-to-BIM, computer vision, computational design, digital fabrication, blockchain technology and learn about the design implications using reclaimed building materials. This course is meant as an overview/introduction of many digital technologies that could be useful for circularity and gives the tools to students to further study the technologies they are most interested in on their own. Creativity in writing, filmmaking, design, construction, etc. is expected from the students. This course will give the tools to students to learn more on LCA if they wish to deepen their knowledge further.

**Course Details**

**Language:** English

Courses are on Tuesday afternoons in Kunsthalle or a room at ETH, but also require out-of-the-semester work and significant homework and site visits outside of class hours.

**Prerequisites / notice**

Interest in Digitalisation and Construction. Flexibility: This is a hands-on course, where students explore digital technologies and opportunities/challenges of reuse. Flexibility (e.g. adapting to unforeseen circumstances), responsibility (e.g. arriving on time for safety briefing), and spontaneity (e.g. finding innovative solutions) is expected from the students to adapt to the contingencies from demolition and construction sites with reused materials. The course is mandatory for MIBS students. If you are a first year MIBS student, please do not apply, you are automatically accepted. All other students from other departments should apply. Please only register for the course if you really intend to participate on all course dates (see course catalog). Please only register for the course if you are willing to send us a letter of motivation and really intend to participate; otherwise, you will deprive someone else of a place. All non-MIBS students who register go onto a waiting list until 11.09.2024 and up to 25 of them will be selected by the lecturer.

To register:
1. Enroll before 05.09.2024.
2. Send a short letter of motivation (max. 300 words) and a 1-page CV to cea-course@ibi.baug.ethz.ch by 05.09.2024.

**Collaborators:** Kunsthalle Zürich, ETH AI Center, Design++

**Competencies**

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Social Competencies**

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity

**Personal Competencies**

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

**Prerequisites / notice**

Lecture notes are handed out during the individual lessons.

The lecture is partly given by experts from industry.

It is supplemented by an excursion to one of the industry partners.

**Lecture notes**

**Language:** English

Courses are on Tuesday afternoons in Kunsthalle or a room at ETH, but also require out-of-the-semester work and significant homework and site visits outside of class hours.

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### 151-0621-00L Microsystems I: Process Technology and Integration  **W 6 credits  3V+2U**  M. Haluska, C. Hierold

**Abstract**

Students are introduced to the fundamentals of semiconductors, the basics of micromachining and silicon process technology and will learn about the fabrication of microsystems and devices by a sequence of defined processing steps (process flow).

**Objective**

Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystem devices by the combination of unit process steps (= process flow).

**Content**

- Introduction to microsystems technology (MST) and micro electro mechanical systems (MEMS)
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.
- Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties.

Application of selected technologies will be demonstrated on case studies.

**Lecture notes**

Handouts (available online)

**Literature**

- S.M. Sze: Semiconductor Devices, Physics and Technology
- W. Menz, J. Mohr, O.Paul: Microsystem Technology
- Hong Xiao: Introduction to Semiconductor Manufacturing Technology
- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications

**Prerequisites / notice**

Prerequisites: Physics I and II

### 252-0834-00L Information Systems for Engineers  **W 4 credits  2V+1U**  G. Fourny

**Abstract**

This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it.

The course also covers support for data cubes (analytics).

**Objective**

Do you want to be able to query your own data productively and efficiently in your future semester projects, bachelor's thesis, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This courses teaches you how to do so as well as the dos and don'ts.

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.
Content

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook

Literature

- Lecture material (slides).


Prerequisites / notice

The lecture is hybrid, meaning you can attend with us in the lecture hall, or on Zoom, or watch the recordings on YouTube later. Exercise sessions are in presence.

For non-CS/DS students only, BSc and MSc

Elementary knowledge of set theory and logics

Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies

- Communication
- Sensitivity to Diversity
- Negotiation

Personal Competencies

- Creative Thinking
- Critical Thinking

Materials and Mechanics in Medicine

W 4 credits 3G  M. Zenobi-Wong, J. G. Snedeker

Abstract

Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Objective

Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Content

Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

Lecture notes

course website on Moodle

Literature


Academic Press

Man-Technology-Environment Electives ("MTU")

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>151-0227-00L</td>
<td>Basics of Air Transport (Aviation I)</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>P. Wild</td>
</tr>
</tbody>
</table>

Abstract

In general the course explains the main principles of air transport and elaborates on simple interdisciplinary topics. Working on broad 14 different topics like aerodynamics, manufacturers, airport operations, business aviation, business models etc. the students get a good overview in air transportation. The program is taught in English and we provide 11 different experts/lecturers.

Objective

The goal is to understand and explain basics, principles and contexts of the broader air transport industry. Further, we provide the tools for starting a career in the air transport industry. The knowledge may also be used for other modes of transport. Ideal foundation for Aviation II - Management of Air Transport.

Content

Weekly: 1h independent preparation; 2h lectures and 1 h training with an expert in the respective field

Concept: This course will be taught as Aviation I. A subsequent course - Aviation II - covers the "Management of Air Transport".

Content: Transport as part of the overall transportation scheme; Aerodynamics; Aircraft (A/C) Designs & Structures; A/C Operations; Aviation Law; Maintenance & Manufacturers; Airport Operations & Planning; Aviation Security; ATC & Airspace; Air Freight; General Aviation; Business Jet Operations; Business models within Airline Industry; Military Aviation.

Lecture notes

Preparation materials & slides are provided prior to each class

Literature

Technical visit: This course includes a guided tour at Zurich Airport and Dubendorf Airfield (baggage sorting system, apron, Tower & Radar Simulator at Skyguide Dubendorf).

Prerequisites / notice

The lecture is planned as class teaching.
**Competencies**

**Subject-specific Competencies**
- Concepts and Theories assessed
- Techniques and Technologies assessed

**Method-specific Competencies**
- Analytical Competencies assessed
- Decision-making fostered
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management fostered

**Social Competencies**
- Communication assessed
- Cooperation and Teamwork fostered
- Customer Orientation assessed
- Leadership and Responsibility fostered
- Sensitivity to Diversity assessed

**Personal Competencies**
- Adaptability and Flexibility fostered
- Critical Thinking assessed
- Creative Thinking fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

**Competencies**

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**Personal Competencies**
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- Critical Thinking assessed
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- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

**Abstract**

Lecture Series about selected topics of space research and exploration consisting of individual talks given by different leading experts from academia and industry.

**Objective**

- experience the interdisciplinarity of space research and exploration spanning physics, engineering, geosciences, biology and more
- get familiar with the Swiss space research and industry landscape
- enhance their communication skills by broadening their research horizon
- have the opportunity for direct learning by posing questions to experts

**Content**

The field of space research and exploration is intrinsically interdisciplinary. Cutting edge space activities are dominated by an interplay between the scientifically desirable and the technologically possible. The 'Lecture Series: Space Research and Exploration' aims to shed light on key questions engaged by leading scientists and engineers today. It consists of weekly lectures, given by different speakers with vast experience in their respective field (e.g., Human Spaceflight, System Engineering of Spacecraft, Space Life Sciences, Space-based astrophysics). Subsequent to the talk, the student will have the opportunity to deepen their understanding by asking questions to the presenter in a moderated Q&A.

Confirmed speakers will be announced by the start of the semester (see lecture from last year for previous speakers).

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories fostered
- Techniques and Technologies fostered

**Method-specific Competencies**
- Project Management fostered

**Social Competencies**
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Sensitivity to Diversity fostered

**Personal Competencies**
- Adaptability and Flexibility fostered
- Critical Thinking fostered
- Creative Thinking fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

**Science in Perspective**

Only courses offered under "GESS Science in Perspective" count in this category. See "Offered in" tab in course view. For more information, please refer to https://gess.ethz.ch/en/studies/science-in-perspective/SiP-FAQs.html

**Science in Perspective**

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-ITET

**Language Courses**

see Science in Perspective: Language Courses ETH/UZH

**Bachelor's Project**

The Bachelor's Thesis is the final part of the bachelor's program and should therefore only be taken in the semester in which the bachelor's diploma is acquired.

The minimum requirement for enrollment is the successful completion of:
- basic examination (examination blocks A+B) and
- subjects of the second year (examination blocks 1-3)

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
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<tr>
<td>227-0100-00L</td>
<td>Bachelor's Thesis</td>
<td>O</td>
<td>12 credits</td>
<td>26D</td>
<td>Supervisors</td>
</tr>
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</table>

A 14 week long Bachelor's Thesis is the final part of the bachelor's program and shall therefore be taken during the semester in which the bachelor's diploma is acquired.

The minimum requirement for enrollment is the successful completion of:
- basic examination (examination blocks A+B)
- subjects of the second year (examination blocks 1-3)

Supervisor must be a professor at D-ITET or associated, see a link to the lists of those at https://ee.ethz.ch/studies/bachelor/third-year/bachelor-project.html

During the Bachelor's Thesis, students will gain initial experience in the independent solution of a technical-scientific problem by applying the acquired specialist and social skills. A Bachelor's Thesis should take about half of a student's time during one semester, i.e., about 300-400 hours. The thesis includes an oral presentation and a written report, and it is graded.

**Abstract**

see above
Prerequisites / notice

A 14 week long Bachelor's Thesis is the final part of the bachelor's program and shall therefore be taken during the semester in which the bachelor's diploma is acquired.

The minimum requirement for enrollment is the successful completion of:
- basic examination (examination blocks A+B)
- subjects of the second year (examination blocks 1-3)

Supervisor must be a professor at D-ITET or associated, see a link to the lists of those at https://ee.ethz.ch/studies/bachelor/third-year/bachelor-project.html

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227-1101-00L How to Write Scientific Texts

**E- 0 credits U. Koch**

**Abstract**

This four-hour course covers the basics of writing and presenting scientific work. The focus lies on the structure and the main elements of a scientific text. Formatting guidelines, citation rules, good practice of scientific writing and hints to convince the audience are part of the course.

**Objective**

- You can write scientific texts using the correct structure
- You can convincingly present scientific work
- You can differentiate the scientific style from novels and news
- You can adhere to citation rules and scientific integrity

**Content**

The block course covers the following topics:

- Structure of Scientific Texts
- Structure of Scientific Presentations
- Formatting of Scientific Elements (figures, equations, tables)
- Citation Rules and Scientific Integrity

The lecture will be given in two parts on two afternoons. Some exercises will be built into the lecture.

**Literature**

Scientific Integrity, see https://ethz.ch/en/research/ethics-and-animal-welfare/research-integrity.html

**Prerequisites / notice**

You should be writing either a bachelor/semester/master thesis or a scientific publication in the immediate future.

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### Competencies

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**Electrical Engineering and Information Technology Bachelor - Key for Type**

- O Compulsory
- W+ Eligible for credits and recommended
- W Eligible for credits
- E- Recommended, not eligible for credits
- Z Courses outside the curriculum
- Dr Suitable for doctorate

**Key for Hours**

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<th>V</th>
<th>lecture</th>
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<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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</tbody>
</table>

| P | practical/laboratory course |
| A | independent project |
| D | diploma thesis |
| R | revision course / private study |

**ECTS**

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Folien werden zur Verfügung gestellt.

This course looks into scientific theories and also empirical findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>871-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern, M. Rau</td>
</tr>
<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in the programs &quot;Teaching Diploma&quot; or &quot;Teaching Certificate&quot;. It is about learning in childhood and adolescence.</td>
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<tr>
<td></td>
<td>Abstract: This course looks into scientific theories and also empirical studies on human learning and relates them to the school.</td>
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<td></td>
<td>Objective: Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.</td>
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<td></td>
<td>Content: Thematische Schwerpunkte: Lernen als Verhaltensänderung und als Informationsverarbeitung; Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen; Intelligenztheorien, Geschlechtsunterschiede beim Lernen</td>
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<td></td>
<td>Lecture notes: Foliendruck zur Verfügung gestellt.</td>
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<td></td>
<td>Prerequisites / notice: This lecture is only apt for students who intend to enrol in the programs &quot;Lehrdipлом&quot; or &quot;Didaktisches Zertifikat&quot;. It is about learning in childhood and adolescence.</td>
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<tr>
<td>871-0240-22L</td>
<td>Coping with Psychosocial Demands of Teaching (EW4 W 2DZ)</td>
<td>2 credits</td>
<td>3S</td>
<td>S. Maurer, P. Caprez, I. Sargenti</td>
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<tr>
<td></td>
<td>Abstract: In this class, students will learn concepts and skills for coping with psychosocial demands of teaching</td>
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<td>Objective: Students possess theoretical knowledge and practical competences to be able to cope with the psychosocial demands of teaching.</td>
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<td></td>
<td>(1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks).</td>
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<td>(2) They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. illegal or psychological services).</td>
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<tr>
<td>871-0242-05L</td>
<td>Cognitively Activating Instructions in MINT Subjects (W 2 credits)</td>
<td>2 credits</td>
<td>2S</td>
<td>R. Schumacher</td>
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<tr>
<td></td>
<td>Abstract: This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.</td>
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<td>Objective: Get to know cognitively activating instructions in MINT subjects</td>
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<td>Prerequisites / notice: Für eine reimäßiglose Semesterplanung wird um frühe Anmeldung und persönliche Erscheinen zum ersten Lehrveranstaltungstermin ersucht.</td>
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<tr>
<td>871-0242-07L</td>
<td>Human Intelligence (W 1 credit)</td>
<td>1 credit</td>
<td>1S</td>
<td>E. Stern</td>
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<td></td>
<td>Abstract: The focus will be on the book &quot;Intelligenz: Grosse Unterschiede und ihre Folgen&quot; by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.</td>
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<td>Objective: - Understanding of research methods used in the empirical human sciences</td>
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<td>- Getting to know intelligence tests</td>
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<td></td>
<td>- Understanding findings relevant for education</td>
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<tr>
<td>871-0228-00L</td>
<td>Formation of Knowledge in STEM Fields in Primary and Secondary School</td>
<td>2 credits</td>
<td>1S</td>
<td>U. Markwalder</td>
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<tr>
<td></td>
<td>Abstract: Adressates to students enrolled either in Teaching Diploma* (TD) or Teaching Certificate (TC) (excluding Teaching Diploma Sport).</td>
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<td></td>
<td>Objective:</td>
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</table>
This course unit can only be enrolled after successful participation in the course 871-0240-00L “Human Learning (EW 1)”.

Abstract
Course promotes exchange between student teachers and elementary school teachers in STEM teaching with 3 parts: 1) block seminar (ca. 16 h), 2) collaboration with elementary school teacher in a class (ca. 34 h, with approx. 50% spent in the elementary or middle school class and ca. 50% for preparation), and 3) final report (ca. 10 h). Registration implies participation in all 3 parts.

Objective
Deepening the understanding of knowledge formation and learning processes of primary and secondary students from a cognitive and developmental psychology perspective for students. The assistant ship provides didactic experience and exposure to a different school level (more heterogeneous groups such as for example low-performing to very high-performing Children, language problems etc.).

Content
Students learn more about the potential and challenges of pupils. They get to know the early stages of knowledge as well as the development of pre-concepts of students in their subject area. The seminar with a phase of cooperation consists of three phases: In the block seminar, pre-concepts are discussed in their own subject as well as theoretical inputs from developmental and cognitive psychology. During the cooperation phase, a teaching task defined by the primary and secondary school teachers is actively undertaken in a class. Finally, a final report is written, which contains a description of the students’ level of knowledge. This seminar is only suitable for students who can adapt flexibly to the needs of pupils from lower class levels.

Prerequisites / notice
https://www.minterlink.ch/student

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Tasks</th>
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<tbody>
<tr>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
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<td>Leadership and Responsibility</td>
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<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Critical Thinking</td>
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<td>Self-awareness and Self-reflection</td>
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</table>

Subject Didactics and Professional Training

Important: You can only enroll in the courses of this category if you have not more than 12 CP left for possible additional requirements.

Number | Title | Type | ECTS | Hours | Lecturers |
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<tbody>
<tr>
<td>227-0857-00L</td>
<td>Subject Didactics I for D-MAVT and D-ITET</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>Q. Lohmeyer, R. Büchi</td>
</tr>
</tbody>
</table>

Abstract
Didactics I focuses on teaching techniques as building blocks of typical lessons. This is done on the basis of the findings of teaching and learning research and their implementation in practice. The aim is the planning and implementation of effective teaching sequences as well as their evaluation and reflection.

Objective
- They can plan, conduct and critically reflect single lessons.
- They orient themselves towards the academic goals and take into account existing knowledge, the professional environment and the ambitions of the students.
- They can apply the basic teaching principles meaningfully in their subject and suitably structure the learning phases.
- They can reduce and present complex technical content such that it is in a form suitable for the students to learn.
- They have considered examples of the common conceptual errors encountered by students
- The students can plan, conduct and critically reflect single lessons.

Content
- Planning a teaching unit
- Opening a lecture
- Direct Instruction
- Embedded exercises
- Learning objectives
- Practicing teaching
- Excursion Fachhochschule

Lecture notes
Lecture materials are provided via Moodle.

Prerequisite / notice
Prerequisite: Educational science course already completed or at the same time.

Competencies

<table>
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<tbody>
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<td>Leadership and Responsibility</td>
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<tr>
<td>Personal Competencies</td>
<td>Critical Thinking</td>
</tr>
</tbody>
</table>

227-0859-10L | Teaching Internship Including Examination Lessons | O | 6 credits | 13P | R. Büchi |

Abstract
The teaching internship can just be visited if all other courses of TC are completed. Repetition of the teaching internship is excluded even if the examination lessons are to be repeated.

Objective
- Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.
- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Lecture notes
Dokument: schriftliche Vorbereitung für Prüfungslektionen.

Literature
Wird von der Praktikumslehrperson bestimmt.

227-0854-00L Mentored Work Subject Didactics Electrical Engineering and Information Technology

Prerequisites: successful completion of FD I and FD II

Abstract
In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

Objective
The objective is for the students:
- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

Content

Typisch soll die Arbeit 3 - 4 Unterrichtseinheiten à 45 Minuten abdecken (bei Einzelarbeit), bei Arbeit zu zweit mindestens 6 solche Einheiten.


Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.

Lecture notes
Eine kurze Anleitung zur mentorierten Arbeit in Fachdidaktik wird zur Verfügung gestellt.

Literature
K. Frey, Allgemeine Didaktik, FH-Skript bzw. Lehrbuch des Praktikumslehrers.

Prerequisites / notice
Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird die Arbeit versorgt werden.
The course teaches the fundamentals of digital communication systems. The main topics are analog and digital modulation, signals and linear time-invariant systems, baseband and passband representations, continuous-time and discrete-time channels, noise, inter-symbol interference, detection theory, as well as the basics of forward error correction and information theory.

After attending the lectures, participating in the exercise sessions, and working on the homework problems (which include MATLAB coding assignments), the students will be able to:
- understand the fundamentals of digital communication systems
- explain the principles of modulation, demodulation, detection, and error correction
- analyze error rates of simple digital communication systems
- implement simple MATLAB simulations to calculate error rates

The course focuses on the fundamentals of digital communication systems. The course starts with analog modulation and discusses the main building blocks of modern digital communication systems. The topics include:
- essential components of digital communication systems
- analog and digital modulation
- baseband and passband representation; up- and down-conversion
- communication channels as LTI systems
- discretizing communication systems; sampling and quantization
- noise, signal-to-noise ratio (SNR), and interference
- detection theory and error rates
- basics of forward error correction
- basics of information theory
- orthogonal frequency-division multiplexing (OFDM)
- building blocks of modern communication systems

The exercises cover theoretical aspects as well as the basics of software-based communication-system modeling in MATLAB.

The course is about some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm. A recurrent theme throughout the course is the stable and robust "inversion" of a linear filter.

The course is about some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust "inversion" of a linear filter.

The course covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

Optical Communication Fundamentals

The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.
Content

* Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.


* Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.

* Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection and techniques, Error correction coding.

* Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.

* Chapter 7: Optical Amplifiers: Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

Lecture notes

Lecture notes are handed out.

Literature

Govind P. Agrawal; "Fiber-Optic Communication Systems"; Wiley, 2010

Prerequisites / notice


227-0417-00L Information Theory I W 6 credits 4G A. Lapidoth

Abstract

This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equipartition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

Objective

The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

Content

The entropy rate of a source, Typical sequences, the asymptotic equipartition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

Literature

T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

Specialisation Courses

These specialisation courses are particularly recommended for the area of "Communication", but you are free to choose courses from any other field in agreement with your tutor.

A minimum of 40 credits must be obtained from specialisation courses during the Master's Programme.

Number Title Type ECTS Hours Lecturers

227-0102-00L Discrete Event Systems W 6 credits 4G L. Josipovic, L. Vanbever, R. Wattenhofer

Abstract

Introduction to discrete event systems. We start out by studying popular models of discrete event systems. Then we analyze discrete event systems from an average-case and from a worst-case perspective, and study verification. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Petri Nets.

Objective

Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by exploring the limits of what is computable and what is not. In doing so, we will consider three distinct models of computation which are often used to model discrete event systems: finite automata, push-down automata and Turing machines (ranked in terms of expressiveness power). In the second part of the course we analyze discrete event systems. We first examine discrete event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply continuous time markov chains and queueing theory for an understanding of the typical behavior of a system. Then we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queueing. In the last part of the course we introduce methods that allow to formally verify certain properties of Finite Automata and Petri Nets. These are some typical analysis questions we will look at: Do two given systems behave the same? Does a given system behave as intended? Does the system eventually enter a dangerous state?

Content

1. Regular Languages
2. Non-Regular Languages
3. Markov Chains
4. Stochastic Discrete Event Systems
5. Worst-Case Event Systems
6. Verification of Finite Automata
7. Petri Nets

Lecture notes

Available at https://disco.ethz.ch/courses/des/
<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
<th>227-0103-00L Control Systems</th>
<th>W</th>
<th>6 credits</th>
<th>2V+2U</th>
<th>F. Dörrfler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
<td>MATLAB is used for system analysis and simulation.</td>
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<td>Techniques and Technologies</td>
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<td>Decision-making</td>
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<td>Creative Thinking</td>
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<td>Problem-solving</td>
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<td>Critical Thinking</td>
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**Abstract**

Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

**Objective**

Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

**Content**


**Literature**


**Prerequisites / notice**

Prerequisites: Signal and Systems Theory II.
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
  - Register Transfer Level (RTL) synthesis and its limitations.
  - Building blocks of digital VLSI circuits.
  - Functional verification techniques and their limitations.
  - Modular and largely reusable testbenches.
  - Assertion-based verification.
  - Synchronous versus asynchronous circuits.
  - The case for synchronous circuits.
  - Periodic events and the Anceau diagram.
  - Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

**Lecture notes**
Textbook and all further documents in English.

**Prerequisites**
Prerequisites:
- Basics of digital circuits.

**Examination:** In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English or German.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

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**227-0147-10L**
**VLSI 3: Full-Custom Digital Circuit Design**

**W 6 credits 2v+3u**
C. Studer, O. Castañeda Fernández

**Abstract**
This third course in our VLSI series is concerned with full-custom digital integrated circuits. The goals include learning the design of digital circuits on the schematic, layout, gate, and register-transfer levels. The use of state-of-the-art CAD software (Cadence Virtuoso) in order to simulate, optimize, and characterize digital circuits is another important topic of this course.

**Objective**
- At the end of this course, you will
  - understand the design of the main building blocks of state-of-the-art digital integrated circuits
  - be able to design and optimize digital integrated circuits on the schematic, layout, and gate levels
  - be able to use standard industry software (Cadence Virtuoso) for drawing, simulating, and characterizing digital circuits
  - understand the performance trade-offs between delay, area, and power consumption

**Content**
The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack towards logic gates and increasingly complex digital circuit structures. The topics of this course include:
- Nanometer MOSFETs
- Static and dynamic behavior of complementary MOS (CMOS) inverters
- CMOS gate design, sizing, and timing
- Full-custom standard-cell design
- Wire models and parasitics
- Latch and flip-flop circuits
- Gate-level timing analysis and optimization
- Static and dynamic power consumption; low-power techniques
- Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
- Arithmetic and logic circuits
- Fixed-point and floating-point arithmetic
- Synchronous and asynchronous design principles
- Memory circuits (ROM, SRAM, and DRAM)
- In- and near-memory processing architectures
- Full-custom accelerator circuits for machine learning

The exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

**Literature**
N. H. E. Weste and D. M Harris, CMOS VLSI Design: A Circuits and Systems Perspective (4th Ed.), Addison-Wesley

**Prerequisites**
VLSI 3 can be taken in parallel with "VLSI 1: HDL-based design for FPGAs" and is designed to complement the topics of this course. Basic analog circuit knowledge is required.

**227-0166-00L**
**Analog Integrated Circuits**

**W 6 credits 4G**
T. Jang

**Abstract**
This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies.

**Objective**
Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.

**Content**
Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc.; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors.

The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.

**Literature**
The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is a complex process that involves several key components. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the important elements will be passed on. Students attending the lecture will further get engaged in critical discussion on societal, economical and environmental aspects related to the on-going exponential growth in the field of communications.

Objective

* Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.


* Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.

* Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.

* Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.

* Chapter 7: Optical Amplifiers: Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

Lecture notes are handed out.

Literature

Govind P. Agrawal; "Fiber-Optic Communication Systems"; Wiley, 2010

Summary of reliability and failure analysis terminology; physics of failure: materials properties, physical processes and failure mechanisms; failure analysis; basics and properties of instruments; quality assurance of technical systems (introduction); introduction to stochastic processes; reliability analysis; component selection and qualification; maintainability analysis (introduction); design rules for reliability, maintainability, reliability tests (introduction).

Prerequisites / notice


Optical Communication Fundamentals

Objective

The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation with single- and multi-layer networks

Content

1. Universal approximation with single- and multi-layer networks

2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory

3. Fundamental limits of deep neural network learning

4. Geometry of decision surfaces

5. Separating capacity of nonlinear decision surfaces

6. Vapnik-Chervonenkis (VC) dimension

7. VC dimension of neural networks

8. Generalization error in neural network learning

Lecture notes

Detailed lecture notes are available on the course web page https://www.mins.ee.ethz.ch/teaching/ntnt/

Prerequisites / notice

This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

Neural Network Theory

Abstract

Does not take place this semester.

Objective

The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation theorems, capacity of separating surfaces, generalization, fundamental limits of deep neural network learning, VC dimension.

Content

1. Universal approximation with single- and multi-layer networks

2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory

3. Fundamental limits of deep neural network learning

4. Geometry of decision surfaces

5. Separating capacity of nonlinear decision surfaces

6. Vapnik-Chervonenkis (VC) dimension

7. VC dimension of neural networks

8. Generalization error in neural network learning

Prerequisites / notice

This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

Image Analysis and Computer Vision

Abstract


Objective

Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.
At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during
This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta

Concepts and Theories
fostered
This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta
conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow
view. The lecture is suitable for both analog and digital designers. The way the exam is done allows for the different interests of the two
groups.

Content
At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during
the whole term to analyze circuits on a system level (analog continuous-time, analog discrete-time, mixed-signal and digital) and
understand how signals propagate through them. The theory and CMOS implementation of active Filters is then discussed in detail using
the example of Gm-C filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators
follows. The link to the practical design of circuits and systems is done with an overview over different quality measures and figures of
merit used in scientific literature and datasheets. Finally, an introduction to discrete-time and mixed-domain filters and circuits is given,
including sensor read-out amplifiers, correlated double sampling, and chopping, and an introduction to sigma-delta A/D and D/A conversion
on a system level.

Objective
This lecture does not go down to the details of transistor implementations. The lecture "227-0166-00L Analog Integrated Circuits"
complements This lecture very well in that respect.

Lecture notes
The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the
technical content.

Details: https://people.ee.ethz.ch/~haschmid/asfwiki/

The graph methods are also supported with teaching videos: https://tube.switch.ch/channels/d206c96c?order=episodes , and a Python-
based open-source tool to manipulate graphs is available on https://github.com/hanspi42/signalflowgrapher

Some material is protected by password; students from ETHZ who are interested can write to haschmid@ethz.ch to ask for the password
even if they do not attend the lecture.

Prerequisites / notice
Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated
Circuits, Transmission Lines and Filters. Suitable for Master Students as well as Doctoral Students.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered
Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Acoustics I
Introduction to the fundamentals of acoustics in the field of sound field calculations, measurement of acoustical events, outdoor sound
propagation and room acoustics of large and small enclosures.

Objective
Understanding of the basic acoustical concepts and methods. Ability to understand the technical and scientific literature. Confidence in the
use of measuring instruments.
Fundamentals of acoustics, calculation of sound fields, measurement and analysis of acoustical events, anatomy and properties of the ear, outdoor sound propagation, absorption and transmission of sound, room acoustics of large and small enclosures, noise and noise control.

Lecture notes

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: assessed

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed
- Self-direction and Self-management: fostered

Abstract
Maxwell’s equations are reinterpreted in the framework of Einstein’s special relativity theory using the Lagrangian formalism in order to discover the deep interconnection between the electric and magnetic field. Its daily relevance is emphasized by pinpointing how GPS atomic clocks in satellites and on the earth are affected by frequency shifts which can be explained only in terms of relativity.

Objective
D-ITET is the depository of the Maxwell’s equations, which are dissected from all perspectives in the courses Physics I, Electromagnetic Fields and Waves, and Advanced Electromagnetic Waves.

Content
- Galileo-Newton, the Ether, Michelson-Morley’s Experiment
- Lorentz Transformations
- 4-Vectors in Minkowski’s Spacetime: Tensor Formalism
- The Lagrangian, the Principle of Stationary Action for Particles and Fields, Noether’s Theorem
- Maxwell’s Equations and the Energy-Momentum Tensor
- Waves
- Radiation from Accelerated Charged Particles
- Sagnac’s Effect
- GPS

Not only its elegance, but also the daily importance of the relativity theory will be finally highlighted explaining how the GPS can work only if the relativistic view of synchronous clocks is taken into account.

Literature
- (Special Relativity) L. Susskind and A. Friedman, “Special Relativity and Classical Field Theory: The Theoretical Minimum”, 2019, Hachette Book Group USA

Supplementary material will be uploaded in Moodle.

+ (on the GPS) E.D. Kaplan, C. Hegarty, “Understanding GPS/GNSS”, 2017, ARTECH HOUSE USA

Prerequisites / notice
Notions of a course on Electromagnetism like D-ITET “Electromagnetic Fields and Waves” are indispensable. Furthermore, a solid base of Analysis I & II as well as of Linear Algebra is really helpful.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

Advanced Machine Learning

W 10 credits 3V+2U+4A C. Cotrini Jimenez

Data: 15.06.2024 12:39 Autumn Semester 2024
Abstract

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- **Fundamentals:**
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- **Supervised learning:**
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- **Unsupervised learning:**
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

<table>
<thead>
<tr>
<th>263-4640-00L</th>
<th>Network Security</th>
<th>W</th>
<th>8 credits</th>
<th>2V+2U+3A</th>
<th>P. De Vaere, S. Frei, K. Paterson, A. Perrig</th>
</tr>
</thead>
</table>

Abstract

Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems. This course provides an in-depth study of network attack techniques and methods to defend against them.

Objective

- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

Content

The course will cover topics spanning four broad themes with a focus on the first two themes:

1. Network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. Network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. Analysis and inference topics such as traffic monitoring and network forensics; and

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

Prerequisites / notice

This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.
Competencies

Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

Social Competencies

- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies

- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: assessed

Abstract

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

Objective

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

Content

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure $A$ one maps its elements to vectors in a linear space, and shows that the set $A$ is mapped to linearly independent vectors. It then follows that the cardinality of $A$ is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments,
- Spaces of polynomials and tensor product methods,
- Eigenvalues of graphs and their application,
- The Combinatorial Nullstellensatz and the Chevalley-Warning theorem.

Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lecture notes

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Prerequisites / notice

Students are expected to have a mathematical background and should be able to write rigorous proofs.

Track: Computers and Networks

The core courses and specialisation courses below are a selection for students who wish to specialise in the area of "Computers and Networks", see https://www.ee.ethz.ch/studies/main-master/areas-of-specialisation.html.

The individual study plan is subject to the tutor's approval.

Core Courses

These core courses are particularly recommended for the field of "Computers and Networks". You may choose core courses form other fields in agreement with your tutor.

A minimum of 24 credits must be obtained from core courses during the MSc EEIT.

Foundation Core Courses

Fundamentals at bachelor level, for master students who need to strengthen or refresh their background in the area.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0102-00L</td>
<td>Discrete Event Systems</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>L. Josipovic, L. Vanbever, R. Wattenhofer</td>
</tr>
</tbody>
</table>

Abstract

Introduction to discrete event systems. We start out by studying popular models of discrete event systems. Then we analyze discrete event systems from an average-case and from a worst-case perspective, and study verification. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Petri Nets.

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Objective

Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by exploring the limits of what is computable and what is not. In doing so, we will consider three distinct models of computation which are often used to model discrete event systems: finite automata, push-down automata and Turing machines (ranked in terms of expressiveness power). In the second part of the course we analyze discrete event systems. We first examine discrete event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply continuous time markov chains and queueing theory for an understanding of the typical behavior of a system. Then we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queueing. In the last part of the course we introduce methods that allow to formally verify certain properties of Finite Automata and Petri Nets. These are some typical analysis questions we will look at: Do two given systems behave the same? Does a given system behave as intended? Does the system eventually enter a dangerous state?

Content

1. Regular Languages
2. Non-Regular Languages
3. Markov Chains
4. Stochastic Discrete Event Systems
5. Worst-Case Event Systems
6. Verification of Finite Automata
7. Petri Nets

Lecture notes

Available at https://disco.ethz.ch/courses/des/

[bertsekas] Data Networks
Dimitri Bertsekas, Robert Gallager

[borodin] Online Computation and Competitive Analysis
Allan Borodin, Ran El-Yaniv.
Cambridge University Press, 1998

[burch] Symbolic Model Checking
Inf. Comput. 98, 2 (June 1992), pp. 142-170

[boudec] Network Calculus
J.-Y. Le Boudec, P. Thiran
Springer, 2001

[cassandras] Introduction to Discrete Event Systems
Christos Cassandras, Stéphane Lafortune.

[fiat] Online Algorithms: The State of the Art
A. Fiat and G. Woeginger

D. Hochbaum

[murata] Petri Nets: Properties, Analysis and Applications
Tadato Murata

[schickinger] Diskrete Strukturen (Band 2: Wahrscheinlichkeitsrechnung und Statistik)
T. Schickinger, A. Steger
Springer, Berlin, 2001

[sipser] Introduction to the Theory of Computation
Michael Sipser.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Social Competencies
Communication assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed

227-0121-00L Communication Systems W 6 credits 4G C. Studer, S. M. Moser

Abstract

The course teaches the fundamentals of digital communication systems. The main topics are analog and digital modulation, signals and linear time-invariant systems, baseband and passband representations, continuous-time and discrete-time channels, noise, error correction, interference, detection theory, as well as the basics of forward error correction and information theory.

Objective

After attending the lectures, participating in the exercise sessions, and working on the homework problems (which include MATLAB coding assignments), the students will be able to:
- understand the fundamentals of digital communication systems
- explain the principles of modulation, demodulation, detection, and error correction
- analyze error rates of simple digital communication systems
- implement simple MATLAB simulations to calculate error rates
The course focuses on the fundamentals of digital communication systems. The course starts with analog modulation and discusses the main building blocks of modern digital communication systems. The topics include:
- essential components of digital communication systems
- analog and digital modulation
- baseband and passband representation; up- and down-conversion
- communication channels as LTI systems
- discretizing communication systems; sampling and quantization
- noise, signal-to-noise ratio (SNR), and interference
- detection theory and error rates
- basics of forward error correction
- basics of information theory
- orthogonal frequency-division multiplexing (OFDM)
- building blocks of modern communication systems

Lecture notes
Lecture notes will be distributed electronically at the beginning of the semester.

Literature

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Problem-solving
- Critical Thinking
- Integrity and Work Ethics

ECTS
227-0124-00L

Objective
Understanding the specific requirements and problems that arise in embedded system applications.

Content
This lecture focuses on the design of embedded systems using formal models and methods.

Besides the theoretical lecture, the course contains laboratory sessions where students transfer the learned theoretical aspects into praxis by programming a microcontroller and interfacing it with sensors and actuators.

Specifically, the following topics will be covered in the course: hardware and software structures of embedded systems, low-level instruction set, memory architecture and memory map, peripherals, hardware-software interfaces, communication between components, firmware design methodologies, firmware design using the C programming language, embedded real-time operating systems, real-time scheduling, shared resources, low-power, and low-energy designs well as computational accelerators.

Lecture notes
Lecture material, publications, exercise sheets, and laboratory documentation will be available on the course's Moodle page.

Literature

Prerequisites / notice
Recommended: basic knowledge of assembly programming and computer architecture.

Competencies
- Basic knowledge of assembly programming

Advanced Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-2210-00L</td>
<td>Computer Architecture</td>
<td>W</td>
<td>8</td>
<td>6G+1A</td>
<td>S. Sadrosadati, O. Mutlu</td>
</tr>
</tbody>
</table>

Abstract
Computer architecture is the science & art of designing and optimizing hardware components and the hardware/software interface to create a computer that meets design goals. This course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.

Objective
We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), new paradigms like processing-in-memory, parallel computing systems (including multicore processors, coherence and consistency, GPUs), heterogeneous computing, interconnection networks, specialized systems for major data-intensive workloads (e.g. graph analytics, bioinformatics, machine learning), etc. We will focus on fundamentals as well as cutting-edge research. Significant attention will be given to real-life examples and tradeoffs, as well as critical analysis of modern computing systems.

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## Content

The principles presented in the lecture are reinforced in the laboratory through 1) the design and implementation of a cycle-accurate simulator, where we will explore different components of a modern computing system (e.g., pipeline, memory hierarchy, branch prediction, prefetching, caches, multithreading), and 2) the extension of state-of-the-art research simulators (e.g., Ramulator) for more in-depth understanding of specific system components (e.g., memory scheduling, prefetching).

See the course website for detailed and complete content of past incarnations of the course: [https://safari.ethz.ch/architecture](https://safari.ethz.ch/architecture)

## Lecture notes

All the materials (including lecture slides) will be provided on the course website: [https://safari.ethz.ch/architecture/](https://safari.ethz.ch/architecture/)

The video recordings of the lectures are expected to be made available after lectures.

See [https://safari.ethz.ch/architecture](https://safari.ethz.ch/architecture) for past examples.

## Literature

We will provide required and recommended readings in every lecture. They will mainly consist of research papers presented in major Computer Architecture and related conferences and journals.

See [https://safari.ethz.ch/architecture](https://safari.ethz.ch/architecture) for past examples.

## Prerequisites / notice

Digital Design and Computer Architecture ([https://safari.ethz.ch/digitaltechnik](https://safari.ethz.ch/digitaltechnik))

## Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
</tr>
</tbody>
</table>

## Prerequisites / notice

Experience with Linux, low-level systems programming and computer architecture.
The first part of the course covers general security concepts and hardware-based support for security. In the second part, the focus is on system design and methodologies for building secure systems.

### Objective
- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

### Content
The course will cover topics spanning four broad themes with a focus on the first two themes:
1. **Network defense mechanisms** such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. **Network attacks** such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. **Analysis and inference topics** such as traffic monitoring and network forensics;
4. **New technologies related to next-generation networks**.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

### Prerequisites / Notice
This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course. The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.
Lecture Notes

Subject-specific Competencies
Concepts and Theories
- assessed
Techniques and Technologies
- assessed

Analytical Competencies
- assessed

Decision-making
- assessed
Media and Digital Technologies
- assessed
Problem-solving
- assessed
Project Management
- assessed

Communication
- fostered
Cooperation and Teamwork
- fostered
Customer Orientation
- fostered
Leadership and Responsibility
- fostered
Self-presentation and Social Influence
- fostered
Sensitivity to Diversity
- fostered
Negotiation
- fostered

Adaptability and Flexibility
- fostered
Critical Thinking
- assessed
Integrity and Work Ethics
- fostered
Self-awareness and Self-reflection
- fostered
Self-direction and Self-management
- assessed

V 2U

Specialisation Courses

These specialisation courses are particularly recommended for the area of "Computers and Networks", but you are free to choose courses from any other field in agreement with your tutor.

A minimum of 40 credits must be obtained from specialisation courses during the Master's Programme.

Number Title Type ECTS Hours Lecturers
227-0101-00L Discrete-Time and Statistical Signal Processing W 6 credits 4G H.-A. Loeliger

Objective
The course is about some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, MMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.

Content
1. Discrete-time linear systems and filters:
- state-space realizations, z-transform and spectrum,
- decimation and interpolation, digital filter design,
- stable realizations and robust inversion.
2. The discrete Fourier transform and its use for digital filtering.
3. The statistical perspective:
- probability, random variables, discrete-time stochastic processes;
- detection and estimation: MAP, ML, Bayesian MMSE, LMMSE;
- Wiener filter, LMS adaptive filter, Viterbi algorithm.

227-0103-00L Control Systems W 6 credits 2V+2U F. Dörfler

Objective
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Content

Literature

Prerequisites / notice
Prerequisites: Signal and Systems Theory II.
MATLAB is used for system analysis and simulation.

227-0116-00L VLSI 1: HDL Based Design for FPGAs W 6 credits 5G F. K. Gürgaynak

Objective
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Content
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.
Content
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- System Verilog.
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

Lecture notes
Textbook and all further documents in English.

Literature

Prerequisites / notice
Prerequisites:
Basics of digital circuits.

Examination:
In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

<table>
<thead>
<tr>
<th>227-0377-10L</th>
<th>Physics of Failure and Reliability of Electronic Devices and Systems</th>
<th>W</th>
<th>3 credits</th>
<th>2V</th>
<th>I. Shorubalko, M. Held</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Understanding the physics of failures and failure mechanisms enables reliability analysis and serves as a practical guide for electronic devices design, integration, systems development and manufacturing. The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.</td>
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<tr>
<td>Objective</td>
<td>Provide an understanding of the physics of failure and reliability. Introduce the degradation and failure mechanisms, basics of failure analysis, methods and tools of reliability testing.</td>
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<tr>
<td>Content</td>
<td>Summary of reliability and failure analysis terminology; physics of failure: materials properties, physical processes and failure mechanisms; failure analysis; basics and properties of instruments; quality assurance of technical systems (introduction); introduction to stochastic processes; reliability analysis; component selection and qualification; maintainability analysis (introduction); design rules for reliability, maintainability, reliability tests (introduction).</td>
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<tr>
<td>Lecture notes</td>
<td>Comprehensive copy of transparencies</td>
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<table>
<thead>
<tr>
<th>227-0447-00L</th>
<th>Image Analysis and Computer Vision</th>
<th>W</th>
<th>6 credits</th>
<th>3V+1U</th>
<th>E. Konukoglu, E. Erdil, F. Yu</th>
</tr>
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<tbody>
<tr>
<td>Objective</td>
<td>Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.</td>
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<tr>
<td>Content</td>
<td>This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.</td>
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<tr>
<td>Lecture notes</td>
<td>Course material Script, computer demonstrations, exercises and problem solutions</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.</td>
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<table>
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<tr>
<th>227-0555-00L</th>
<th>Distributed Systems</th>
<th>W</th>
<th>4 credits</th>
<th>3G+1A</th>
<th>R. Wattenhofer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Enrolled students will be notified by e-mail about the lecture start.</td>
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<tr>
<td>Objective</td>
<td>The objective of the course is for students to understand the theoretical principles and practical considerations of distributed systems. This includes the main models of fault-tolerant distributed systems (crash failures, byzantine failures, and selfishness), and the most important algorithms, protocols and impossibility results. By the end of the course, students should be able to reason about various concepts such as consistency, durability, availability, fault tolerance, and replication.</td>
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</table>
We discuss the following concepts related to fault-tolerant distributed systems: client-server, serialization, two-phase protocols, three-phase protocols, Paxos, two generals problem, crash failures, impossibility of consensus, Byzantine faults, agreement, termination, validity, Byzantine agreement, ring algorithm, asynchronous Byzantine agreement, authentication, signatures, reliable and atomic broadcast, eventual consistency, blockchain, cryptocurrencies such as bitcoin and ethereum, proof-of-work, proof-of-

Script and exercise sheets are available on the web page. The script is self-contained, but links to additional material are available on the web page. This lecture takes place in roughly the second half of the semester, as the lecture is the second part of the lecture "Computer Systems" (252-0217-00). Students may attend at most one of the two lectures, NOT both.

227-0627-00L

Abstract
This lecture gives an overview of the requirements and the architecture of parallel computer systems, performance, reliability and costs.

Objective
Understand the function, the design and the performance modeling of parallel computer systems.

Content
The lecture "Applied Computer Architecture" gives technical and corporate insights into innovative Computer Systems/Architectures (CPU, GPU, FPGA, dedicated processors) and their real implementations and applications. Often the designs have to deal with technical limits. Which computer architecture allows the control of the over 1000 magnets at the Swiss Light Source (SLS) at the PSI? Which architecture is behind the alarm center of the Swiss Railway (SBB)? Which computer architectures are applied for driver assistance systems? Which computer architecture is hidden behind a professional digital audio mixing desk? How can data streams of about 30 TB’s, produced by a proton accelerator, be processed in real time? Can the weather forecast also be processed with GPUs? How could a fast trading system be set up for the stock exchange? How can a good computer architecture be found? Which are the driving factors in successful computer architecture design?

Lecture notes
Script and exercises sheets.

Prerequisites / notice
Basic computer architecture.

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competences assessed
- Decision-making fostered
- Problem-solving fostered
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

227-2211-00L

Abstract
In this seminar course, we will cover fundamental and cutting-edge research papers in computer architecture. The course will consist of multiple components that are aimed at improving students’ technical skills in computer architecture, critical thinking and analysis on computer architecture concepts, as well as technical presentation of concepts and papers in both spoken and written forms.

Objective
The main objective is to learn how to rigorously analyze and present papers and ideas on computer architecture. We will have rigorous presentation and discussion of selected papers during lectures and a written report delivered by each student at the end of the semester. This course is for those interested in computer architecture. Registered students are expected to attend every lecture, participate in the discussion, and create a synthesis report at the end of the course.

Content
Topics will center around computer architecture. We will, for example, discuss papers on hardware security; new execution paradigms like processing in memory; architectural acceleration mechanisms for key applications like machine learning, graph processing and bioinformatics; memory systems; interconnects; various fundamental and emerging paradigms in computer architecture; hardware/software co-design and cooperation; fault tolerance; energy efficiency; heterogeneous and parallel systems; technology scaling; new execution models, etc.

Lecture notes
All the materials will be posted on the course website: https://safari.ethz.ch/architecture_seminar/

Links to past course materials, including the synthesis report assignment, can be found in this page: https://safari.ethz.ch/architecture_seminar

Literature
Key papers and articles, on both fundamentals and cutting-edge topics in computer architecture will be provided and discussed. These will be posted on the course website.

Prerequisites / notice
Digital Design and Computer Architecture OR Digital Circuits / Computer Engineering

This course provides a comprehensive overview of embedded control systems. The concepts introduced are implemented and verified on a microprocessor-controlled haptic device.
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has

Lecture notes
Lecture notes, lab instructions, supplemental material

Lecture notes
Prerequisite courses are Control Systems I and Informatics I.

This course is restricted to 33 students due to limited lab infrastructure. Interested students please contact Marianne Schmid Daners (E-

Detailed information can be found on the course website
http://www.idsc.ethz.ch/education/lectures/embedded-control-systems.html

The course discusses various algebraic aspects of wireless communication and a wide range of security-related topics in the domain of

After this course, students should be able to describe and classify security goals of and attacks on various wireless networks and

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the

An embedded system is a microprocessor used as a component in another piece of technology, such as cell phones or automobiles. In this

Subjects covered in lectures and practical lab exercises include:
- The application of C-programming on a microprocessor
- Digital I/O and serial communication
- Quadrature decoding for wheel position sensing
- Queued analog-to-digital conversion to interface with the analog world
- Pulse width modulation
- Timer interrupts to create sampling time intervals
- System dynamics and virtual worlds with haptic feedback
- Introduction to rapid prototyping

Social Competencies
Cooperation and Teamwork

Personal Competencies
Critical Thinking

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic

Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the

The course can be found at
https://moodle-app2.let.ethz.ch/course/view.php?id=15757

This course is restricted to 33 students due to limited lab infrastructure. Interested students please contact Marianne Schmid Daners (E-

The individual study plan is subject to the tutor's approval.

Core Courses

These core courses are particularly recommended for the field of “Electronics and Photonics”. You may choose core courses form other fields in agreement with your tutor.

A minimum of 24 credits must be obtained from core courses during the MSc EEIT.

Track: Electronics and Photonics

The core courses and specialisation courses below are a selection for students who wish to specialise in the area of “Electronics and Photonics”, see

The individual study plan is subject to the tutor's approval.

Core Courses

These core courses are particularly recommended for the field of “Electronics and Photonics”. You may choose core courses form other fields in agreement with your tutor.

A minimum of 24 credits must be obtained from core courses during the MSc EEIT.

Foundation Core Courses
The lecture covers the following topics:

- Generic time-harmonic electromagnetic fields
- Fundamental solutions of the wave equation
- Wave propagation in various types of materials
- Interaction of waves with matter
- Nonlinear effects
- Resonant effects
- Applications like scattering, waveguiding, radiation
- Radio frequency and optical antennas

Content

This lecture provides profound knowledge about electromagnetic waves. Various types of materials, nonlinear and resonant effects, and antenna applications are discussed.

Abstract

You can describe wave propagation in classical and nonclassical materials and know the fundamental solutions. You know how waves interact with matter and about nonlinear, scattering and resonant effects. You can apply the acquired knowledge in scattering, waveguiding, radiation, and antenna problems.

Subject-specific Competencies

- Understand the fundamental physics behind the mechanical, thermal, electric, magnetic, and optical properties of materials.
- Undergraduate physics, mathematics, semiconductor devices

Prerequisites / notice

Recommended background: Undergraduate physics, mathematics, semiconductor devices

Literature


Prerequisites / notice

Fundamentals at bachelor level, for master students who need to strengthen or refresh their background in the area.

Exam:

- Written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English or German.

Further details:

https://iis-students.ee.ethz.ch/lectures/vlsi-i/

Lecturers

F. K. Gürkaynak

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
227-0110-00L | Electromagnetic Waves: Materials, Effects, and Antennas | W | 6 credits | 4G | N. Yazdani, V. Wood
227-0116-00L | VLSI 1: HDL Based Design for FPGAs | W | 6 credits | 5G | F. K. Gürkaynak
227-0145-00L | Solid State Electronics and Optics | W | 6 credits | 4G | N. Yazdani, V. Wood
227-0166-00L | Analog Integrated Circuits | W | 6 credits | 4G | T. Jang
Objective Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

Content Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc.; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesis with switched capacitors.

The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.

Lecture notes Handouts of presented slides. No script but an accompanying textbook is recommended.


## Advanced Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0146-00L</td>
<td>Data Conversion System Design</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>T. Burger, G. Cervelli, R. Reutemann</td>
</tr>
</tbody>
</table>

Abstract This course provides a thorough treatment of integrated data conversion systems from system level specifications and trade-offs, over architecture choice down to circuit implementation.

Content - Introduction: examples of data conversion architectures; information representation; abstraction, categorization and symbolic representation; basic conversion algorithms; data converter application; tradeoffs among key parameters; ADC taxonomy.
- Dual-slope & successive approximation register (SAR) converters: dual slope principle & converter; SAR ADC operating principle; SAR implementation with a capacitive array; range extension with segmented capacitors.
- Algorithmic & pipelined A/D converters: algorithmic conversion principle; sample & hold stage; pipelined converter; multiplying DAC; flash sub-ADC and n-bit MDAC; redundancy for correction of non-idealities, error correction.
- Performance metrics and non-linearity: ideal ADC; offset, gain error, differential and integral non-linearities; capacitor mismatch; impact of capacitor mismatch on SAR ADC's performance.
- Flash, folding an interpolating analog-to-digital converters: flash ADC principle, thermometer to binary coding, sparkle correction; limitations of flash converters; the folding principle, residue extraction; folding amplifiers; cascaded folding; interpolation for folding converters; cascaded folding and interpolation.
- Noise in analog-to-digital converters: types of noise; noise calculation in electronic circuit, kT/C-noise, sampled noise; noise analysis in switched-capacitor circuits; aperture time uncertainty and sampling jitter.
- Delta-sigma A/D-converters: linearity and resolution; from delta-modulation to delta-sigma modulation; first-order delta-sigma modulation, circuit level implementation; clock-jitter & SNR in delta-sigma modulators; second-order delta-sigma modulation, higher-order modulation, design procedure for a single-loop modulator.

Lecture notes Slides are available online under https://iis-students.ee.ethz.ch/lectures/analog-to-digital-converters/

- H. T. Staszewski et. al., CMOS Data Converters for Communications, Springer, 2010

Prerequisites / notice It is highly recommended to attend the course "Analog Integrated Circuits" of Prof. T. Jang as a preparation for this course.

Competencies - Subject-specific Competencies: Concepts and Theories, Techniques and Technologies.

Optical Communication Fundamentals

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0301-00L</td>
<td>Optical Communication Fundamentals</td>
<td>W</td>
<td>6</td>
<td>2V+1U+1P</td>
<td>J. Leuthold</td>
</tr>
</tbody>
</table>

Abstract The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system.

Objective An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the important elements will be passed on. Students attending the lecture will further get engaged in critical discussion on societal, economical and environmental aspects related to the on-going exponential growth in the field of communications.

Content - Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.
- Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.
- Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.
- Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.
- Chapter 7: Optical Amplifiers: Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

Lecture notes Lecture notes are handed out.


Prerequisites / notice Fundamentals of Electromagnetic Fields & Bachelor Lectures on Physics.
Nano-Optics

Abstract
Nano-Optics is the study of light-matter interaction at the sub-wavelength scale. It is a flourishing field of fundamental and applied research enabled by the rapid advance of nanotechnology. Nano-optics embraces topics such as plasmonics, optical antennas, optical trapping and manipulation, and high-super-resolution imaging and spectroscopy.

Objective
Understanding concepts of light localization and light-matter interactions on the sub-wavelength scale.

Content
We start with the angular spectrum representation of fields to understand the classical resolution limit. We continue with the theory of strongly focused light, the point spread function, and resolution criteria of conventional microscopy, before turning to super-resolution techniques, based on near- and far-fields. We introduce the local density of states and approaches to control spontaneous emission rates in inhomogeneous environments, including optical antennas. Finally, we touch upon optical forces and their applications in optical tweezers.

Prerequisites / notice
- Electromagnetic fields and waves (or equivalent)
- Physics I-II

VLSI 3: Full-Custom Digital Circuit Design

Abstract
This third course in our VLSI series is concerned with full-custom digital integrated circuits. The goals include learning the design of digital circuits on the schematic, layout, gate, and register-transfer levels. The use of state-of-the-art CAD software (Cadence Virtuoso) in order to simulate, optimize, and characterize digital circuits is another important topic of this course.

Objective
At the end of this course, you will
• understand the design of the main building blocks of state-of-the-art digital integrated circuits
• be able to design and optimize digital integrated circuits on the schematic, layout, and gate levels
• be able to use standard industry software (Cadence Virtuoso) for drawing, simulating, and characterizing digital circuits
• understand the performance trade-offs between delay, area, and power consumption

Content
The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack towards logic gates and increasingly complex digital circuit structures. The topics of this course include:
• Nanometer MOSFETs
• Static and dynamic behavior of complementary MOS (CMOS) inverters
• CMOS gate design, sizing, and timing
• Full-custom standard-cell design
• Wire models and parasitics
• Latch and flip-flop circuits
• Gate-level timing analysis and optimization
• Static and dynamic power consumption; low-power techniques
• Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
• Arithmetic and logic circuits
• Fixed-point and floating-point arithmetic
• Synchronous and asynchronous design principles
• Memory circuits (ROM, SRAM, and DRAM)
• In- and near-memory processing architectures
• Full-custom accelerator circuits for machine learning

The exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

Literature
C. Studer, O. Castillo-Fernández

Prerequisites / notice
VLSI 3 can be taken in parallel with “VLSI 1: HDL-based design for FPGAs” and is designed to complement the topics of this course. Basic analog circuit knowledge is required.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Specialisation Courses

These specialisation courses are particularly recommended for the area of “Electronics and Photonics”, but you are free to choose courses from any other field in agreement with your tutor.

A minimum of 40 credits must be obtained from specialisation courses during the Master’s Programme.

Number Title Type ECTS Hours Lecturers
227-0111-10L Communication Electronics II W 6 credits 2V+2U H. Wang

Abstract
This course focuses on the advanced concepts and designs of wireless circuits and systems. The first half introduces key building blocks and popular topologies of low noise amplifiers, power amplifiers, T/R switches, phase shifters, variable gain amplifiers, and combiners/splitters. The second half will cover advanced phased array systems for 5G/6G, satellite communication (SATCOM), and radars.

227-0121-00L Communication Systems W 6 credits 4G C. Studer, S. M. Moser

Abstract
The course teaches the fundamentals of digital communication systems. The main topics are analog and digital modulation, signals and linear time-invariant systems, baseband and passband representations, continuous-time and discrete-time channels, noise, inter-symbol interference, detection theory, as well as the basics of forward error correction and information theory.

Objective
After attending the lectures, participating in the exercise sessions, and working on the homework problems (which include MATLAB coding assignments), the students will be able to:
• understand the fundamentals of digital communication systems
• explain the principles of modulation, demodulation, detection, and error correction
• analyze error rates of simple digital communication systems
• implement simple MATLAB simulations to calculate error rates
Content
The course focuses on the fundamentals of digital communication systems. The course starts with analog modulation and discusses the main building blocks of modern digital communication systems. The topics include:
- essential components of digital communication systems
- analog and digital modulation
- baseband and passband representation; up- and down-conversion
- communication channels as LTI systems
- discretizing communication systems; sampling and quantization
- noise, signal-to-noise ratio (SNR), and interference
- detection theory and error rates
  - basics of forward error correction
  - basics of information theory
- orthogonal frequency-division multiplexing (OFDM)
- building blocks of modern communication systems
The exercises cover theoretical aspects as well as the basics of software-based communication-system modeling in MATLAB.

Lecture notes
Lecture notes will be distributed electronically at the beginning of the semester.

Literature

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
Method-specific Competencies
- Analytical Competencies
- Problem-solving
Personal Competencies
- Critical Thinking
- Integrity and Work Ethics

227-0155-00L Machine Learning on Microcontrollers  ■  W  6 credits  4G  M. Magno

Abstract
Machine Learning (ML) and artificial intelligence are pervading the digital society. Today, even low power embedded systems are incorporating ML, becoming increasingly "smart". This lecture gives an overview of ML methods and algorithms to process and extract useful near-sensor information in end-nodes of the "internet-of-things", using low-power microcontrollers: processors (ARM-Cortex-M; RISC-V).

Objective
Learn how to Process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ExG bio-signals, cameras, ...). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers.

Content
The final goal of the course is a deep understanding of machine learning and its practical implementation on single- and multi-core microcontrollers, coupled with performance and energy efficiency analysis and optimization. The main topics of the course include:
- Sensors and sensor data acquisition with low power embedded systems
- Machine Learning: Overview of supervised and unsupervised learning and in particular supervised learning (Bayes Decision Theory, Decision Trees, Random Forests, kNN-Methods, Support Vector Machines, Convolutional Networks and Deep Learning)
- Low-power embedded systems and their architecture. Low Power microcontrollers (ARM-Cortex M) and RISC-V-based Parallel Ultra Low Power (PULP) systems-on-chip.
- Low power smart sensor system design: hardware-software tradeoffs, analysis, and optimization. Implementation and performance evaluation of ML in battery-operated embedded systems.

The laboratory exercises will show how to address concrete design problems, like motion, gesture recognition, emotion detection, image and sound classification, using real sensors data and real MCU boards.

Presentations from Ph.D. students and the visit to the Digital Circuits and Systems Group will introduce current research topics and international research projects.

Lecture notes
Script and exercise sheets. Books will be suggested during the course.

Prerequisites / Prerequisites:
C language programming. Basics of Digital Signal Processing. Basics of processor and computer architecture. Some exposure to machine learning concepts is also desirable

227-0157-00L Semiconductors Devices: Physical Bases and Simulation  ■  W  4 credits  3G  A. Schenck, C. I. Roman

Abstract
The course addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical simulation. Necessary basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided. Computer simulations of the most important devices and of interesting physical effects supplement the lectures.

Objective
The course aims at the understanding of the principle physics of modern semiconductor devices, of the foundations in the physical modeling of transport and its numerical simulation. During the course also basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided.

Content
The main topics are: transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model, hydrodynamic model), physical characterization of silicon (intrinsic properties, scattering processes), mobility of cold and hot carriers, recombination (Shockley-Read-Hall statistics, Auger recombination), impact ionization, metal-semiconductor contact, metal-insulator-semiconductor structure, and heterojunctions. The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

Lecture notes
The script (in book style) can be downloaded from: https://lis-students.ee.ethz.ch/lectures/

Prerequisites / Prerequisites:

227-0166-00L Analog Integrated Circuits  ■  W  6 credits  4G  T. Jang

Abstract
This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies. Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.
The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.
The course has the following main goals: (a) to give a comprehensive overview of challenges on communication equipment imposed by space missions: scenarios and challenges on flight equipment, (b) to present the theoretical fundamentals and existing practical solutions of communication technology for space flight missions, (c) to review existing and future communication technologies for inter-satellite links, links, inter-spacecraft links, as well as the technologies capable of enabling ultra-fast RF/mm-Wave, THz, and Laser communication links. After completing this course, a student will understand the challenges of space flight imposed on communication components and systems, the available existing solutions of those problems, the main components of communications systems suitable for a spacecraft, and future technologies capable of enabling ultra-fast RF/mm-Wave, THz, and Laser communication links.

The course begins with an introduction to signal-flow graphs in general and driving-point signal-flow graphs in particular. We will use them during the whole term to analyze circuits on a system level (analog continuous-time, analog discrete-time, mixed-signal and digital) and understand how signals propagate through them. The theory and CMOS implementation of active Filters is then discussed in detail using the example of Gm-C filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators are also discussed.

The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

This course is suitable for both analog and digital designers. The way the exam is done allows for the different interests of the two groups.

After completing this course, a student will understand the challenges of space flight imposed on communication components and systems, the available existing solutions of those problems, the main components of communications systems suitable for a spacecraft, and future technologies capable of enabling ultra-fast RF/mm-Wave, THz, and Laser communication links.
The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the technical content.

Details: https://people.ee.ethz.ch/~haschmid/aswiki/

The graph methods are also supported with teaching videos: https://tube.switch.ch/channels/d206c96c?order=episodes, and a Python-based open-source tool to manipulate graphs is available on https://github.com/hanspi42/signalflowgrapher

Some material is protected by password; students from ETHZ who are interested can write to haschmid@ethz.ch to ask for the password even if they do not attend the lecture.

Prerequisites / notice

Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.

Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria ...) and of the main properties of linear systems is necessary.

Competencies

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<td>Project Management</td>
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Social Competencies

| Communication                                      | Cooperation and Teamwork                           |
|                                                    | Customer Orientation                               |
| fostered                                            | Leadership and Responsibility                       |
|                                                    | Self-presentation and Social Influence             |
|                                                    | Sensitivity to Diversity                            |
|                                                    | Negotiation                                        |

Personal Competencies

| Adaptability and Flexibility                       | Creative Thinking                                  |
|                                                    | Critical Thinking                                  |
| fostered                                            | Integrity and Work Ethics                          |
|                                                    | Self-awareness and Self-reflection                 |
|                                                    | Self-direction and Self-management                 |

207-0615-00L Simulation of Photovoltaic Devices - From Materials to W 3 credits 2G U. Aeberhard

Abstract

The lecture provides an introduction to the theoretical foundations and numerical approaches for the simulation of photovoltaic power conversion, from the microscopic description of component materials to macroscopic continuum modelling of solar cells and network simulation or effective models for performance prediction of entire solar modules.

Objective

Get an overview of the current status of photovoltaic technology. Understand the physics of photovoltaic energy conversion and solar cell device operation. Know how to obtain and assess by simulation the key material properties and device parameters. Be able to use standard device simulation tools to analyze, optimize, and predict the performance of solar cells and modules.

Content

Photovoltaic technology: history and overview; The solar spectrum; Thermodynamics of solar energy conversion; Detailed balance models and efficiency limit; Microscopic rates of charge carrier generation and recombination; Optical simulation of solar cells; Models for charge transport in semiconductor devices; High-efficiency wafer-based (silicon) photovoltaics; Thin film photovoltaics based on disordered materials (amorphous silicon, organic PV); High-efficiency thin film photovoltaics (CIGS, CdTe, metal-halide perovskites); PV beyond the single junction detailed balance (Shockley-Queisser) limit; Simulation of photovoltaic modules; Energy yield and performance modelling for PV systems; Quantum simulation of nanostructure-based solar cell devices (bonus lecture)

Literature

- M. A. Green, „Solar cells: operating principles, technology, and system applications“, Prentice Hall, 1982.

Prerequisites / notice

Undergraduate physics (including basic quantum mechanics), mathematics, semiconductor devices, optics. Knowledge of some scripting language (e.g. python) is of advantage.
227-0617-00L  Solar Cells  W  4 credits  Y. Romanyuk, R. Carron

Abstract
Physics, technology, characteristics and applications of photovoltaic solar cells and systems.

Objective
The students will appreciate the potential of solar radiation and photovoltaics, learn the physics and technology of various solar cells, and get to know the design basics of PV modules and systems for different applications.

Content
Introduction to photovoltaics and economic aspects, solar radiation, semiconductor physics and operation of solar cells, technology of wafer-based (Si, GaAs, multi-junction) and thin-film (CIGS, CdTe, perovskite) solar cells, emerging technologies, design of PV modules, systems and plants including system components such as inverters and controllers, procedures with software demonstration, integration in buildings and other specific examples such as concentrated photovoltaics and power generation for space applications.

Lecture notes
Lecture slides (PDF files in English) will be available on Moodle and lecture recordings will be available on the ETH video portal.

Prerequisites / notice
Prerequisites: Basic knowledge of semiconductors.

Competencies
Subject-specific Competencies  Concepts and Theories  assessed
Techniques and Technologies  assessed

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227-0618-00L  Modeling, Characterization and Reliability of Power Semiconductors  W  6 credits  C. Battaglia

Abstract
This lecture provides theoretical and experimental knowledge on the techniques for the characterization and numerical modeling of power semiconductors, as well on the related built-in reliability strategies.

Objective
The students shall get acquainted with the most important concepts and techniques for characterization, numerical modeling and built-in reliability of modern power semiconductor devices. This knowledge is intended to provide the future engineer with the theoretical background and tools for the design of dependable power devices and systems.

Content
This lecture consists of a theoretical part (50%) and of laboratory exercises and demonstrations (50%). The theoretical part covers the basic techniques and procedures for characterization, modeling and built-in reliability of modern power semiconductor devices with special attention to MOS and IGBT. The starting part on technology provides an overview on the main device families and includes a review of the most relevant application-oriented aspects of the device physics, thermal management, and packaging. The second section deals with the basic experimental characterization techniques for the definition of the semiconductor material properties, electrical characteristics, safe operating area, and junction temperature of the devices. The following section introduces the basic principles for electrical, thermal, and electro-thermal simulation of power semiconductors by Technology Computed Aided Design (TCAD) and compact modeling. Finally, procedures are methods to implement efficient built-in reliability programs targeted on power semiconductors. They include failure physics, dedicated failure analysis techniques, accelerated testing, defect screening, and lifetime modeling.

Lecture notes
Eiichi Ohno: “Introduction to Power Electronics”
B. Muri et al.: “Smart Power ICs”
B. J. Baliga: “Physics Modern Power Devices”
S. K. Ghandi: “Semiconductor Power Devices”

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227-0619-00L  Charge Transport in Energy Conversion and Storage Devices  W  6 credits  C. Battaglia

Abstract
The students will be introduced to the fundamental concepts of charge transport in solar cells, batteries, and electrolyzers. Emphasizing analogies between semiconductor physics and electrochemistry, this course is designed to provide a unified modern perspective of energy conversion and storage concepts for students in electrical engineering, materials science, physics, and chemistry.

Objective
By the end of this course, the students will (1) understand the fundamentals of electrical and ionic charge transport, (2) understand the operational principles of solar cells, batteries, and electrolyzers, and (3) understand fundamental limits for each device type. In addition, the students will learn how to simulate these devices during guided exercise sessions and develop an intuitive understanding on how to interpret the most important device characteristics.

Literature
R. Huggins, Advanced Batteries, DOI:10.1007/9780387674245

Prerequisites / notice
Be motivated to change the world to renewable energies!

This course is taught simultaneously at ETH Zurich and EPFL. All lectures will be recorded by zoom and made available to the students. Lectures will be streamed live from ETH Zurich with four lectures taught onsite at EPFL Lausanne.

A visit to Empa’s Energy Conversion and Storage Labs will be organized during the semester. Possibility to interact and meet your classmates from EPFL via online lecture platform and during two special lectures with guest lecturers from industry (one guest lecture by ABB at ETH Zurich, one guest lecture by Northvolt at EPFL). Travel expenses for students will be covered.

Elements of calculus will be reviewed during the lectures, where necessary, but we leave the hard work of solving coupled differential charge transport equations to the computer and focus on developing a strong intuition. Prior knowledge in semiconductor physics or electrochemistry is an advantage, but not a prerequisite.

Students are required to bring a windows-compatible computer with a common data analysis software to the exercises. Apps for simulating devices under different operating conditions will be made available to the students.

Competencies
Subject-specific Competencies  Concepts and Theories  assessed

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227-0652-00L  Maxwell, Einstein, and the GPS  W  6 credits  T. Zambelli

Abstract
Maxwell’s equations are reinterpreted in the framework of Einstein's special relativity theory using the Lagrangian formalism in order to discover the deep interconnection between the electric and magnetic field. Its daily relevance is emphasized by pinpointing how GPS atomic clocks in satellites and on the earth are affected by frequency shifts which can be explained only in terms of relativity.

Objective
Only one aspect is left over: the fact that they are not invariant with respect to the classical Galilean transformation… On the contrary, Maxwell’s equations predict that the light speed is the same for every inertial frame of reference. In this course, we will deepen how Einstein solved this clash elaborating the theory of “special relativity”. Maxwell's equations are thus naturally derived in a breath-taking fashion from the principle of stationary action within the Lagrangian formalism.

Not only its elegance, but also the daily importance of the relativity theory will be finally highlighted explaining how the GPS can work only if the relativistic view of synchronous clocks is taken into account.

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Content
- Galileo-Newton, the Ether, Michelson-Morley's Experiment
- Lorentz Transformations
- 4-Vectors in Minkowski's Spacetime: Tensor Formalism
- The Lagrangian, the Principle of Stationary Action for Particles and Fields, Noether's Theorem
- Maxwell's Equations and the Energy-Momentum Tensor
- Waves
- Radiation from Accelerated Charged Particles
- Sagnac's Effect
- GPS

Lecture notes
No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM, while corresponding videos of the previous years are available in Moodle !!!

Literature
- (Special Relativity) L. Susskind and A. Friedman, "Special Relativity and Classical Field Theory: The Theoretical Minimum", 2019, Hachette Book Group USA

Supplementary material will be uploaded in Moodle.

Prerequisites / notice
Furthermore, a solid base of Analysis I & II as well as of Linear Algebra is really helpful.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

227-0627-00L Applied Computer Architecture W 6 credits 4G A. Gunzinger
Abstract
This lecture gives an overview of the requirements and the architecture of parallel computer systems, performance, reliability and costs.

Objective
Understand the function, the design and the performance modeling of parallel computer systems.

Content
The lecture "Applied Computer Architecture" gives technical and corporate insights in innovative Computer Systems/Architectures (CPU, GPU, FPGA, dedicated processors) and their real implementations and applications. Often the designs have to deal with technical limits. Which computer architecture allows the control of the over 1000 magnets at the Swiss Light Source (SLS) at the PSI? Which architecture is behind the alarm center of the Swiss Railway (SBB)? Which computer architectures are applied for driver assistance systems? Which computer architecture is hidden behind a professional digital audio mixing desk? How can data streams of about 30 TB/s, produced by a protone accelerator, be processed in real time? How can a fast trading system be set up for the stock exchange? How can a good computer architecture be found? Which are the driving factors in succesful computer architecture design?

Lecture notes
Script and exercises sheets.

Prerequisites / notice
Prerequisites:
Basics of computer architecture.
### Competencies

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#### Method-specific Competencies

| Analytical Competencies | Decision-making | Problem-solving | Project Management | fostered |

#### Social Competencies

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#### Personal Competencies

| Negotiation | fostered |
| Adaptability and Flexibility | fostered |
| Creative Thinking | fostered |
| Critical Thinking | fostered |
| Integrity and Work Ethics | fostered |
| Self-awareness and Self-reflection | fostered |
| Self-direction and Self-management | fostered |

### 227-0653-00L Quantum Measurements and Optomechanics

**W** 4 credits 2V+1U M. Frimmer

#### Prerequisites / notice

1. Electrodynamics
2. Physics 1,2
3. Introduction to quantum mechanics

#### Competencies

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#### Content

The seminar aims at instructing graduate and PhD students in the basics of presentation techniques, i.e. "how to give a professional talk". Attendees have the opportunity to become acquainted with a current topic by a literature study, and to present the results thereof in a 20 minutes talk in English. The participation at the seminar gives also an overview on current problems in modern nano- and opto-electronics.

The students learn how to find the right literature for a certain topic quickly, as well as how to prepare a talk for a scientific conference, i.e. presentation techniques.

#### Lecture notes

Presentation material

### 227-0659-00L Integrated Systems Seminar

**W** 1 credit 1S M. Luisier

#### Abstract

In the "Fachseminar IIS" the students learn to communicate topics, ideas or problems of scientific research by listening to more experienced authors and by presenting scientific work in a conference-like situation for a specific audience.

#### Objective

The seminar aims at instructing graduate and PhD students in the basics of presentation techniques, i.e. "how to give a professional talk". Attendees have the opportunity to become acquainted with a current topic by a literature study, and to present the results thereof in a 20 minutes talk in English. The participation at the seminar gives also an overview on current problems in modern nano- and opto-electronics.

#### Content

The seminar topics' are simulation of nanoelectronic processes and devices, and the optical as well as electronical simulation of optoelectronic devices as lasers, photodiodes, etc.

### 227-0621-00L Emerging Memory Technologies

**W** 3 credits 1V+1U M. Yarema

#### Abstract

This course focuses on the current state and prospects of memory technologies, emerging beyond the silicon transistor era. We explore resistive PCM and RRAM, magnetic MRAM and ferroelectric FRAM memories, covering physics, device aspects and the latest research in the field. Through interactive lectures and laboratory sessions, students gain up-to-date knowledge and compare emerging memory techs.

In this course, students will learn about the leading contenders for post-silicon storage-class and main memory technologies. Decades of research have yielded several efficient memory device working principles, including phase-change of the structure (PCM), materials conversion (OxRAM), ion diffusion (CBRAM), magnetic properties (STT-MRAM, MTJ), and ferroelectricity (FRAM, FeFET). Currently, these memory technologies are transitioning from research to industry, and are predicted to have at least niche applications in the ever-growing hardware market. Some technologies, such as PCM, may even eventually surpass silicon-based flash memory, providing better performance and unique features.

Students will have the opportunity to compare emerging memory technologies with state-of-the-art SSD Flash, DRAM, and SRAM, as well as evaluate their potential. Through critical thinking discussions, students will acquire important skills for assessing the strengths and limitations of these emerging technologies.
Content

The course is organized as a series of lectures, focusing on selected memory technologies. This class also includes practical laboratory sessions for the PCM research topics. Students will spend 2 hours per week in the class or laboratory and additional 2-3 hours per week to prepare for the exam.

Literature

Lecture notes will be made available on the website.

Competencies

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227-0654-00L Carbon-based Nanoelectronics W 6 credits 2V+1U+1A M. Perrin

Abstract

This course explores the exciting realm of carbon-based nanoelectronics, where the remarkable quantum properties of materials like graphene, carbon nanotubes, graphene nanoribbons, and single molecules are used for building electronic devices.

Objective

The objective of this course is to understand how the electronic properties of carbon-based materials can be exploited for fabricating quantum devices. We will delve into both the theoretical and experimental aspects, discussing how these materials’ unique properties can be translated into device functionality.

On the theoretical side, we'll cover how the chemical structure of the material and its dimensionality, ranging from 0D to 2D, affects the electronic properties. We'll also discuss how charge carriers flow through the devices and what charge transport mechanisms are at play.

On the experimental side, we'll cover how such devices are fabricated, including how the materials are synthesized. We'll also discuss how to characterize the devices and assess their performance.

Content

The course will cover the following carbon-based materials:
- Single-molecule
- Graphene (single layer, bilayer, twisted bilayer)
- Graphene nanoribbons
- Carbon nanotubes

For each material, we will discuss:
- Electronic structure and charge transport properties
- Material synthesis and characterization
- Device integration and characterization

The course also includes a presentation by each student in which a related scientific publication is discussed. This presentation is compulsory and accounts for 50% of the grade.

Lecture notes

Lecture slides are distributed every week. In addition, relevant scientific articles and book chapters will be provided for self-study.

In addition to the slides, the following supplementary books can be recommended:

Prerequisites / notice

A basic knowledge of solid-state physics and quantum mechanics is required. The course is taught in English.

Competencies

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227-0671-00L Nanodevices and Circuits for the Beyond-Moore Era W 3 credits 2V M. Csontos, I. Shorubalko

Abstract

Big Data, AI and the Internet of Things demand new hardware which overcomes the limitations of von Neumann architectures. The lecture gives an insight how the fundamental physics and the resulting complex functionalities of nanodevices and circuits offer viable alternatives. Their increased computational power and energy efficiency are demonstrated through neuromorphic computing applications.

Objective

The students will gain a firm understanding in the theory and pioneering experiments of electronic and heat transport at atomic- to nanometer length-scales. Advanced device functionalities enabled by recently discovered material systems will be covered. The students will learn how to exploit such phenomena for designing nanodevices and circuits to energy-efficiently implement neuromorphic algorithms for a sustainable future of information technologies.

Lecture notes

The presentation slides and further material will be provided every week.

Basic knowledge of solid state physics and semiconductors.

Competencies

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227-1033-00L Neuromorphic Engineering I W 6 credits 2V+3U T. Delbrück, G. Indiveri, S.-C. Liu, M. Payvand

Registration in this class requires the permission of the instructors. Class size will be limited to available lab spots. Preference is given to students that require this class as part of their major.
This course covers various topics with an emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Understanding the characteristics of neuromorphic circuit elements.

Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational units and are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of novel robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

- Participate: The course is highly recommended for those who intend to take the spring semester course ‘Neuromorphic Engineering II’, that teaches the conception, simulation, and physical layout of such circuits with chip design tools.
- Prerequisites: Background in basics of semiconductor physics helpful, but not required.

**227-2037-00L**

**Physical Modelling and Simulation**

**Abstract**

This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.

**Objective**

Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

**Content**

The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use their own simulation programs or choose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

**227-2211-00L**

**Seminar in Computer Architecture**

**Abstract**

In this seminar course, we will cover fundamental and cutting-edge research papers in computer architecture. The course will consist of multiple components that are aimed at improving students' technical skills in computer architecture, critical thinking and analysis on computer architecture concepts, as well as technical presentation of concepts and papers in both spoken and written forms.

**Objective**

The main objective is to learn how to rigorously analyze and present papers and ideas on computer architecture. We will have rigorous presentation and discussion of selected papers during lectures and a written report delivered by each student at the end of the semester. This course is for those interested in computer architecture. Registered students are expected to attend every lecture, participate in the discussion, and create a synthesis report at the end of the course.

**Content**

Topics will center around computer architecture. We will, for example, discuss papers on hardware security; new execution paradigms like processing in memory; architectural acceleration mechanisms for key applications like machine learning, graph processing and bioinformatics; memory systems; interconnects; various fundamental and emerging paradigms in computer architecture; hardware/software co-design and cooperation; fault tolerance; energy efficiency; heterogeneous and parallel systems; technology scaling; new execution models, etc.

Topics will center around computer architecture. We will, for example, discuss papers on hardware security; new execution paradigms like processing in memory; architectural acceleration mechanisms for key applications like machine learning, graph processing and bioinformatics; memory systems; interconnects; various fundamental and emerging paradigms in computer architecture; hardware/software co-design and cooperation; fault tolerance; energy efficiency; heterogeneous and parallel systems; technology scaling; new execution models, etc.

**Lecture notes**

See https://safari.ethz.ch/architecture_seminar for past examples.

**Literature**

Key papers and articles, on both fundamentals and cutting-edge topics in computer architecture will be provided and discussed. These will be posted on the course website.

**Prerequisites / notice**

Students should (1) have done very well in Digital Design and Computer Architecture, Digital Circuits or a similar course and (2) show a genuine interest in Computer Architecture.
With guidance from a tutor, the individual silicon microsystem process steps that are required for the fabrication of an accelerometer are carried out:
- Photolithography, dry etching, wet etching, sacrificial layer etching, various cleaning procedures
- Packaging and electrical connection of a MEMS device
- Testing and characterization of the MEMS device
- Written documentation and evaluation of the entire production, processing and characterization

A document containing theory, background and practical course content is distributed at the Introductory lecture day of the course.

The document provides sufficient information for the participants to successfully participate in the course.

Participating students are required to attend all scheduled lectures and meetings of the course.

For safety and efficiency reasons the number of participating students is limited. We regret to restrict access to this course by the following rules:

Priority 1: master students of the master's program in "Micro and Nanosystems"

Priority 2: master students of the master's program in "Mechanical Engineering" with a specialization in Microsystems and Nanoscale Engineering (MAVT-tutors Profs Daraio, Dual, Hierold, Koumoutsakos, Nelson, Norris, Poulikakos, Pratsinis, Stemmer), who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.

Priority 3: master students, who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.

Priority 4: all other students (PhD, bachelor, master) with a background in silicon or microsystems process technology.

If there are more students in one of these priority groups than places available, we will decide by (in following order) best achieved grade from 151-0621-00L Microsystems Technology, registration to this practicum at previous semester, and by drawing lots.

Students will be notified at the first lecture of the course (introductory lecture) as to whether they are able to participate.

The course is offered in autumn and spring semester.

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
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<tr>
<td>327-2210-00L</td>
<td>Thin Films Technology - From Fundamentals to Oxide Electronics</td>
</tr>
</tbody>
</table>

Students who already took "327-2104-00L Inorganic Thin Films: Processing, Properties and Applications" AND "327-2132-00 Multifunctional Ferroic Materials: Growth and Characterisation" are not allowed to attend this course.

Abstract

Oxide films with a thickness of just a few atoms can now be grown with a precision matching that of semiconductors. This opens up a whole world of functional device concepts and fascinating phenomena that would not occur in the expanded bulk crystal.

We will give an introduction to thin films deposition techniques and applications with a focus on the growth of multifunctional oxide thin films.

Objective

In this course students will obtain an overarching view on thin film deposition techniques with a focus on epitaxial deposition processes.

The main learning objectives are:
- Identification of most relevant deposition technique for a given application.
- Understanding of growth mechanism and growth modes.
- Understanding strategies for engineering the functionalities of the films using the deposition process.
- Selection of the most appropriate characterization technique.
- Understanding device concepts and fundamental limits in the technology relevant ultra-thin limit.
- Assessing the relevance of scientific literature dealing with complex oxide thin films.

Content

A lab visit visit will be organized and students will participate to the design of thin films with atomic precision.

General description of the leading deposition routes including physical and chemical vapor deposition techniques (PVD and CVD) as well as so called "wet techniques" (e.g. spin coating and spray pyrolysis).

Growth modes and processes.

Part of the course discusses vacuum technologies.

Fundamental characterization techniques for application-relevant thin films as well as state of the art approaches for in situ and ex-situ determination of the structural, chemical and ferroic (ferromagnetic and ferroelectric) properties of films: (XRD for thin films, RHEED, EDX, scanning probe microscopy techniques, laser-optical characterization and many more)

Epitaxy for the advanced design and characterization of high quality thin films for energy efficient oxide electronics.

Types of ferroic order, multiferroics, multifunctional oxide materials, epitaxial strain related effects, oxide thin film based devices and examples.

Regular discussions on preselected scientific literature and mini-seminars will be organized.
### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

#### Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

#### Technology and Innovation Management

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0389-00L</td>
<td>Technology and Innovation Management</td>
<td>W</td>
<td>3</td>
<td>2G</td>
</tr>
</tbody>
</table>

#### Abstract
This course focuses on the sources of innovation (with a specific focus on digital technologies), the tools and techniques that organizations deploy to innovate routinely, and the strategic implications of technical change at different levels of analysis: individuals, firms and whole ecosystems.

#### Objective
This course intends to enable all students to:

- Acquire and understand the basic jargon, concepts and methods necessary to discuss, in a precise and concise manner, innovation processes and their outcomes at different levels of analysis
- Analyze the differences between individual and organizational decision processes and their innovative outcomes
- Evaluate critically the potential of different (digital) technologies to impact business organizations.

#### Content
Organizations and people are faced with a fundamental decision: they have to allocate resources between well-known tasks that reliably generate positive results; or explore new ways of doing things, new technologies, products and services. The latter is a high risk choice. Its rewards can be high, but the chances of success are small. How do firms organize to take these decisions? What kind of management skills are necessary to take them? What kind of tools and methods are deployed to sustain managerial decision-making in highly volatile environments? These are the central questions on which this course focuses, relying on a combination of lectures, case-based discussion, and guest speakers.

#### Literature
Readings will be available on the Moodle page

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### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: fostered

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

### Wearable and Mobile Technologies of the Future - Focus on Sports and Health

<table>
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<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1176-00L</td>
<td>Wearable and Mobile Technologies of the Future - Focus on Sports and Health</td>
<td>W</td>
<td>4</td>
<td>3G</td>
</tr>
</tbody>
</table>

#### Abstract
This course focuses on the progress in the field of wearable and unobtrusive technologies for sports and health. Topics as monitoring heart health and blood pressure, biofeedback and improvement of motor skills and performance are covered. The focus lies on learning about the principles and design of the new generation of non-invasive technologies in fitness-, athletic and medical applications.

#### Objective

Objective 1: Acquire knowledge about the latest technological advancements in wearable and unobtrusive technologies for sport and health.

Objective 2: Acquire skills to design novel non-invasive technologies for sport and health.
Adaptability and Flexibility

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods. Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods. Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lecture notes: Lectures will be on the blackboard only, but there will be a set of typed lecture notes which follow the class closely.

Prerequisites / notice: Students are expected to have a mathematical background and should be able to write rigorous proofs.

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**Track: Energy and Power Electronics**

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1006 of 2653
The core courses and specialisation courses below are a selection for students who wish to specialise in the area of "Energy and Power Electronics", see https://www.ee.ethz.ch/studies/main-master/areas-of-specialisation.html.

The individual study plan is subject to the tutor's approval.

Core Courses

These core courses are particularly recommended for the field of "Energy and Power Electronics". You may choose core courses from other fields in agreement with your tutor.

A minimum of 24 credits must be obtained from core courses during the MSc EEIT.

Foundation Core Courses

Fundamentals at bachelor level, for master students who need to strengthen or refresh their background in the area.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0113-00L</td>
<td>Power Electronics</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>J. Huber</td>
</tr>
</tbody>
</table>

Abstract

Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

Objective

Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

Content

Fields of application and application examples of power electronic converters, basic concept of switch-mode voltage and current conversion, pulse-width modulation (PWM); derivation and operating modes (continuous and discontinuous current mode) of DC/DC converter topologies, buck / boost / buck-boost converter; extension to DC/AC conversion using differences of unipolar output voltages varying over time; single-phase diode rectifier; boost-type PWM rectifier featuring sinusoidal input current; tolerance band AC current control and cascaded output voltage control with inner constant switching frequency current control; local and global averaging of switching frequency discontinuous quantities for calculation of component stresses, three-phase AC/DC conversion, center-tap rectifier with impressed output current, thyristor function, thyristor center-tap and full-bridge converter, rectifier and inverter operation, control angle and recovery time, inverter operation limit; basics of inductors and single-phase transformers, design based on scaling laws; Isolated DC/DC converter, flyback and forward converter, single-switch and two-switch circuit; single-phase AC/DC conversion, four-quadrant converter, unipolar and bipolar modulation, fundamental frequency model of AC-side operating behaviour; three-phase DC/AC converter with star-connected three-phase load, zero sequence (common-mode) and current forming differential-mode output voltage components, fundamental frequency modulation and PWM with single triangular carrier and individual carrier signals of the phases.

Lecture notes

Lecture notes and associated exercises including correct answers, simulation program for interactive self-learning including visualization/animation features.

Prerequisites / notice

Prerequisites: Basic knowledge of electrical engineering / electric circuit analysis and signal theory.

Competencies

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
- Social Competencies
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
- Personal Competencies
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

227-0517-10L Fundamentals of Electric Machines

Abstract

This course introduces to different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.

Objective

The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are to evaluate machine types for given specifications and to acquire the ability to perform a rough design of an electrical machine while considering the versatile aspects with respect to magnetic, electrical, mechanical and thermal limitations. Exercises are used to consolidate the presented theoretical concepts.

Content

- Fundamentals in magnetic circuits and electromechanical energy conversion.
- Force and torque calculation.
- Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine).
- Complex space vector notation, rotating coordinate system (dq-transformation).
- Loss components in electric machines, scaling laws of electromechanical actuators.
- Mechanical and thermal modelling.

Lecture notes

Lecture notes and associated exercises including correct answers.
### Advanced Core Courses

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<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0117-00L</td>
<td>High Voltage Engineering</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>C. Franck, U. Straumann</td>
</tr>
<tr>
<td>Abstract</td>
<td>High electric fields are used in numerous technological and industrial applications such as electric power transmission and distribution, X-ray devices, DNA sequencers, flue gas cleaning, power electronics, lasers, particle accelerators, copying machines, .... High Voltage Engineering is the art of gaining technological control of high electrical field strengths and high voltages. The students know the fundamental phenomena and principles associated with the occurrence of high electric field strengths. They understand the different mechanisms leading to the failure of insulation systems and are able to apply failure criteria on the dimensioning of high voltage components. They have the ability to identify weak spots in insulation systems and to propose options for improvement. Further, they know the different insulation systems and their dimensioning in practice.</td>
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<tr>
<td>Objective</td>
<td>- discussion of the field equations relevant for high voltage engineering, - analytical and numerical solutions/solving of this equations, as well as the derivation of the important equivalent circuits for the description of the fields and losses in insulations - introduction to kinetic gas theory - mechanisms of the breakdown in gaseous, liquid and solid insulations, as well as insulation systems - methods for the mathematical determination of the electric withstand of gaseous, liquid and solid insulations - application of the expertise on high voltage components - excursions to manufacturers of high voltage components</td>
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<tr>
<td>Content</td>
<td>- application of the expertise on high voltage components</td>
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<td>Social Competencies</td>
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<td>Cooperation and Teamwork</td>
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<td>Negotiation</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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<td>Competencies</td>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
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<td>Decision-making</td>
<td>fostered</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>fostered</td>
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<td>Problem-solving</td>
<td>fostered</td>
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<td></td>
<td>Project Management</td>
<td>fostered</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture Slides</td>
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<tr>
<td>Prerequisites</td>
<td>Prerequisites: Introductory course on power electronics is recommended.</td>
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<tr>
<td>227-0247-00L</td>
<td>Power Electronic Systems I</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>J. Biela, F. Krismer</td>
</tr>
<tr>
<td>Abstract</td>
<td>Basics of the switching behavior, gate drive and snubber circuits of power semiconductors are discussed. Soft-switching and resonant DC/DC converters are analyzed in detail and high frequency loss mechanisms of magnetic components are explained. Space vector modulation of three-phase inverters is introduced and the main power components are designed for typical industry applications.</td>
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<tr>
<td>Objective</td>
<td>Detailed understanding of the principle of operation and modulation of advanced power electronics converter systems, especially of zero voltage switching and zero current switching non-isolated and isolated DC/DC converter systems and three-phase voltage DC link inverter systems. Furthermore, the course should convey knowledge on the switching frequency related losses of power semiconductors and inductive power components and introduce the concept of space vector calculus which provides a basis for the comprehensive discussion of three-phase PWM converters systems in the lecture Power Electronic Systems II.</td>
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<tr>
<td>Content</td>
<td>Basics of the switching behavior and gate drive circuits of power semiconductor devices and auxiliary circuits for minimizing the switching losses are explained. Furthermore, zero voltage switching, zero current switching, and resonant DC/DC converters are discussed in detail; the operating behavior of isolated full-bridge DC/DC converters is detailed for different secondary side rectifier topologies; high frequency loss mechanisms of magnetic components of converter circuits are explained and approximate calculation methods are presented; the concept of space vector calculus for analyzing three-phase systems is introduced; finally, phase-oriented and space vector modulation of three-phase inverter systems are discussed related to voltage DC link inverter systems and the design of the main power components based on analytical calculations is explained.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes and associated exercises including correct answers.</td>
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<td>Prerequisites</td>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
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<td>Creative Thinking</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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<tr>
<td>227-0526-00L</td>
<td>Power System Analysis</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>G. Hug</td>
</tr>
<tr>
<td>Abstract</td>
<td>The goal of this course is understanding the stationary dependencies in electrical power systems. The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power networks.</td>
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<tr>
<td>Objective</td>
<td>The goal of this course is understanding the stationary dependencies in electrical power systems and the application of analysis tools in normal but also in faulty state.</td>
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Content
The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power grids. Approaches such as the Newton-Raphson algorithm applied to power flow equations, superposition technique for short-circuit analysis and symmetrical components are discussed as well as power flow computation techniques for distribution grids and state estimation.

Lecture notes
Lecture notes.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Media and Digital Technologies
- Problem-solving

Personal Competencies
- Critical Thinking

Specialisation Courses
These specialisation courses are particularly recommended for the area of "Energy and Power Electronics", but you are free to choose courses from any other field in agreement with your tutor.

A minimum of 40 credits must be obtained from specialisation courses during the Master's Programme.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0101-00L</td>
<td>Discrete-Time and Statistical Signal Processing</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course is about some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.</td>
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<tr>
<td>Objective</td>
<td>The course is about some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust &quot;inversion&quot; of a linear filter.</td>
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</tr>
<tr>
<td>Content</td>
<td>1. Discrete-time linear systems and filters: state-space realizations, z-transform and spectrum, decoding and interpolation, digital filter design, stable realizations and robust inversion. 2. The discrete Fourier transform and its use for digital filtering. 3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.</td>
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<tr>
<td>Lecture notes</td>
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<td>227-0103-00L</td>
<td>Control Systems</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>F. Dörfler</td>
</tr>
<tr>
<td>Abstract</td>
<td>Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.</td>
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<td>Prerequisites / notice</td>
<td>Prerequisites: Signal and Systems Theory II.</td>
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<tr>
<td></td>
<td>MATLAB is used for system analysis and simulation.</td>
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<tr>
<td>227-0121-00L</td>
<td>Communication Systems</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>C. Studer, S. M. Moser</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course teaches the fundamentals of digital communication systems. The main topics are analog and digital modulation, signals and linear time-invariant systems, baseband and passband representations, continuous-time and discrete-time channels, noise, inter-symbol interference, detection theory, as well as the basics of forward error correction and information theory.</td>
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<tr>
<td>Objective</td>
<td>After attending the lectures, participating in the exercise sessions, and working on the homework problems (which include MATLAB coding assignments), the students will be able to: - understand the fundamentals of digital communication systems - explain the principles of modulation, demodulation, detection, and error correction - analyze error rates of simple digital communication systems - implement simple MATLAB simulations to calculate error rates</td>
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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1009 of 2653
The course focuses on the fundamentals of digital communication systems. The course starts with analog modulation and discusses the main building blocks of modern digital communication systems. The topics include:
- essential components of digital communication systems
- analog and digital modulation
- baseband and passband representation; up- and down-conversion
- communication channels as LTI systems
- discretizing communication systems; sampling and quantization
- noise, signal-to-noise ratio (SNR), and interference
- detection theory and error rates
- basics of forward error correction
- basics of information theory
- orthogonal frequency-division multiplexing (OFDM)
- building blocks of modern communication systems

The course aims to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in constructing proofs of properties of linear control systems.

Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

Lecture notes
Lecture notes will be distributed electronically at the beginning of the semester.

Literature

Competencies

<table>
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<td>Problem-solving</td>
<td>Integrity and Work Ethics</td>
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</table>

227-0225-00L Linear System Theory

**Abstract**
The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in constructing proofs of properties of linear control systems.

**Objective**
Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

**Content**
- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

**Lecture notes**
Lecture notes will be distributed electronically at the beginning of the semester.

**Prerequisites / notice**
Available on the course Moodle platform.

**Competencies**

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227-0517-10L Fundamentals of Electric Machines

**Abstract**
This course introduces different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.

**Objective**
The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are to evaluate machine types for given specifications and to acquire the ability to perform a rough design of an electrical machine while considering the versatile aspects with respect to magnetic, electrical, mechanical and thermal limitations. Exercises are used to consolidate the presented theoretical concepts.

**Content**
- Fundamentals in magnetic circuits and electromechanical energy conversion.
- Force and torque calculation.
- Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine).
- Complex space vector notation, rotating coordinate system (dq-transformation).
- Loss components in electric machines, scaling laws of electromechanical actuators.
- Mechanical and thermal modelling.

**Lecture notes**
Lecture notes and associated exercises including correct answers

**Competencies**

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227-0523-00L Railway Systems I

**Abstract**
Basic characteristics of railway vehicles and their interfaces with the railway infrastructure:
- Transportation tasks and vehicle types
- Running dynamics
- Mechanical part of rail vehicles
- Brakes
- Traction chain and auxiliary supply
- Railway power supply
- Signalling systems
- Standards
- Availability and safety
- Traffic control and maintenance

**Lecture notes**
Lecture notes will be distributed electronically at the beginning of the semester.

**Literature**

**Competencies**

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<td>Problem-solving</td>
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</table>
Objective

- Overview of the technical characteristics of railway systems
- Know-how about the design and construction principles of rail vehicles
- Interrelationship between different fields of engineering sciences (mechanics, electro and information technology, transport systems)
- Understanding tasks and opportunities of engineers working in an environment which has strong economical and political boundaries
- Insight into the activities of the railway vehicle industry and railway operators in Switzerland
- Motivation of young engineers to start a career in the railway industry or with railway operators

Content

EST I (Herbstsemester) - Begriffen, Grundlagen, Merkmale

1. Einführung:
  1.1 Geschichte und Struktur des Bahnsystems
  1.2 Fahrdynamik

2. Vollbahnfahrzeuge:
  2.1 Mechanik: Kasten, Drehgestelle, Lauftechnik, Adhäsion
  2.2 Bremsen
  2.3 Traktionsantriebsysteme
  2.4 Hilfsbetriebe und Komfortanlagen
  2.5 Steuerung und Regelung

3. Infrastruktur:
  3.1 Fahrrad
  3.2 Bahnstromversorgung
  3.3 Sicherungsanlagen

4. Betrieb:
  4.1 Interoperabilität, Normen und Zulassung
  4.2 RAMS, LCC
  4.3 Anwendungsbeispiele

Voraussichtlich ein oder zwei Gastreferate

Geplante Exkursionen:
- Betriebszentrale SBB, Zürich Flughafen
- Reparatur und Unterhalt, SBB Zürich Altstetten
- Fahrzeugfertigung, Stadler Bussnang

Lecture notes

Abgabe der Unterlagen (gegen eine Schutzgebühr) zu Beginn des Semesters. Rechtzeitig eingeschriebene Teilnehmer können die Unterlagen auf Wunsch und gegen eine Zusatzgebühr auch in Farbe beziehen.

Prerequisites / notice

Dozent: Dr. Markus Meyer, Emkamatik GmbH

Voraussichtlich ein oder zwei Gastvorträge von anderen Referenten.

EST I (Herbstsemester) kann als in sich geschlossene einsemestrige Vorlesung besucht werden. EST II (Frühjahrssemester) dient der weiteren Vertiefung der Fahrzeugtechnik und der Integration in die Bahnninfrastruktur.

Competencies

Subject-specific Competencies

Concepts and Theories

Assessed

Techniques and Technologies

Assessed

Method-specific Competencies

Analytical Competencies

Assessed

Personal Competencies

Critical Thinking

Assessed

227-0536-00L Multiphysics Simulations for Power Systems W 4 credits 2V+2U J. Smajic

Abstract

The goals of this course are a) understanding the fundamentals of the electromagnetic, thermal, mechanical, and coupled field simulations and b) performing effective simulations of primary equipment of electric power systems. The course is understood complementary to 227-0537-00L "Technology of Electric Power System Components", but can also be taken separately.

Objective

The student should learn the fundamentals of the electromagnetic, thermal, mechanical, and coupled fields simulations necessary for modern product development and research based on virtual prototyping. She / he should also learn the theoretical background of the finite element method (FEM) and its application to low- and high-frequency electromagnetic field simulation problems. The practical exercises of the course should be done by using one of the commercially available field simulation software (Infolytica, ANSYS, and / or COMSOL).

After completing the course the student should be able to properly and efficiently use the software to simulate practical design problems and to understand and interpret the obtained results.

Content

1. Electromagnetic Fields and Waves: Simulation Aspects (1 lecture, 2 hours)
   a. Short review of the governing equations
   b. Boundary conditions
   c. Initial conditions
   d. Linear and nonlinear material properties
   e. Coupled fields (electro-mechanical and electro-thermal coupling)

2. Finite Element Method for electromagnetic simulations (5 lectures and 3 exercises, 16 hours)
   a. Scalar-FEM in 2-D (electrostatic, magnetostatic, eddy-currents, etc.)
   b. Vector-FEM in 3-D (3-D eddy-currents, wave propagation, etc.)
   c. Numerical aspects of the analysis (convergence, linear solvers, preconditioning, mesh quality, etc.)
   d. Matlab code for 2-D FEM for learning and experimenting

3. Practical applications (5 lectures and 5 exercises, 20 hours)
   a. Dielectric analysis of high-voltage equipment
   b. Nonlinear quasi-electrostatic analysis of surge arresters
   c. Eddy-currents analysis of power transformers
   d. Electromagnetic analysis of electric machines
   e. Very fast transients in gas insulated switchgears (GIS)
   f. Electromagnetic compatibility (EMC)

227-0567-00L Design of Power Electronic Systems W 6 credits 4G F. Krismer
Abstract

Complete design process: from given specifications to a complete power electronic system; selection / design of suitable passive power components; static and dynamic properties of power semiconductors; optimized EMI filter design; heat sink optimization; additional circuitry, e.g. gate driver; system optimization.

Objective

Basic knowledge of design and optimization of a power electronic converter system; furthermore, lecture and exercises thoroughly discuss key subjects of power electronics that are important with respect to a practical realization, e.g., how to select or design suitable power components, to understand switching operations, calculation of high frequency losses, EMI filter design and realization, thermal considerations.

Content

Complete design process: from given specifications to a complete power electronic system. Selection and / or design of suitable passive power components: specific properties, parasitic components, tolerances, high frequency losses, thermal considerations and safety, reliability. Static and dynamic characteristics of power semiconductors. Optimized design of the EMI filter. Thermal characterization of the converter, optimized heat sink design. Additional circuitry: gate driver, measurement, control. Converter start up: typical sequence of events, circuitry required. Overall system optimization: identifying couplings between different components of the considered power electronic system, optimization targets and issues.

Lecture notes

Lecture notes and complementary exercises including correct answers.

Prerequisites / notice

Prerequisites: Introductory course on power electronics.

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed

Decision-making assessed

Problem-solving assessed

Personal Competencies

Adaptability and Flexibility fostered

Creative Thinking fostered

Critical Thinking fostered

227-0617-00L Solar Cells W 4 credits 3G Y. Romanyuk, R. Carron

Abstract

Physics, technology, characteristics and applications of photovoltaic solar cells and systems.

Objective

The students will appreciate the potential of solar radiation and photovoltaics, will learn the physics and technology of various solar cells, and will get to know the design basics of PV modules and systems including system components such as inverters and controllers, engineering procedures with software demonstration, integration in buildings and other specific examples such concentrated photovoltaics and power generation for space applications.

Content

The theoretical part covers the basic techniques and procedures for characterization, modeling and built-in reliability of modern power semiconductor devices. This knowledge is intended to provide the future engineer with the theoretical background and tools for the design of dependable power devices and systems.

Lecture notes

Lecture slides (PDF files in English) will be available on Moodle and lecture recordings will be available on the ETH video portal.

Prerequisites / notice

Prerequisites: Basic knowledge of semiconductors.

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies assessed

227-0618-00L Modeling, Characterization and Reliability of Power Semiconductors

Does not take place this semester.

Abstract

This lecture provides theoretical and experimental knowledge on the techniques for the characterization and numerical modeling of power semiconductors, as well as on the related built-in reliability strategies.

Objective

The students shall get acquainted with the most important concepts and techniques for characterization, numerical modeling and built-in reliability of modern power semiconductor devices. This knowledge is intended to provide the future engineer with the theoretical background and tools for the design of dependable power devices and systems.

Content

This lecture consists of a theoretical part (50%) and of laboratory exercises and demonstrations (50%). The theoretical part covers the basic techniques and procedures for characterization, modeling and built-in reliability of modern power semiconductor devices with special attention to MOS and IGBT. The starting part on technology provides an overview on the main device families and includes a review of the most relevant application-oriented aspects of the device physics, thermal management, and packaging. The second section deals with the basic experimental characterization techniques for the definition of the semiconductor material properties, electrical characteristics, safe operating area, and junction temperature of the devices. The following section introduces the basic principles for electrical, thermal, and electro-thermal simulation of power semiconductors by Technology Computed Aided Design (TCAD) and compact modeling. Finally, procedures are methods are presented to implement efficient built-in reliability programs targeted on power semiconductors. They include failure physics, dedicated failure analysis techniques, accelerated testing, defect screening, and lifetime modeling.

During the laboratory activities, selections of the experimental techniques presented in the lecture are demonstrated on the base of realistic examples. Furthermore, schematic power devices will be simulated by the students with advanced TCAD tools and circuit simulators.

Lecture notes

Handouts to the lecture (approx. 250 pp.)

Literature

Eiichi Ohno: "Introduction to Power Electronics"
B. Murari et al.: "Smart Power ICs"
B. J. Baliga: "Physics Modern Power Devices"
S. K. Ghandi: "Semiconductor Power Devices"

227-0619-00L Charge Transport in Energy Conversion and Storage W 6 credits 2V+2U C. Battaglia, A. Senocrate

Abstract

The students will be introduced to the fundamental concepts of charge transport in solar cells, batteries, and electrolyzers. Emphasizing analogies between semiconductor physics and electrochemistry, this course is designed to provide a unified modern perspective of energy conversion and storage concepts for students in electrical engineering, materials science, physics, and chemistry.

Objective

By the end of this course, the students will (1) understand the fundamentals of electronic and ionic charge transport, (2) understand the operational principles of solar cells, batteries, and electrolyzers, and (3) understand fundamental limits for each device type. In addition, the students will learn how to simulate these devices during guided exercise sessions and develop an intuitive understanding on how to interpret the most important device characteristics.

Literature

R. Huggins, Advanced Batteries, DOI:10.1007/9780387764245
Introduction to process automation: system architecture, data handling, communication (fieldbuses), process visualization, and 3G.

Concepts and Theories

References will be given at the end of individual lectures.

Assessed

Industrial Process Control

General understanding of industrial automation systems in different industries. Purpose, architecture, technologies, application examples, current and future trends.

Automation Engineering: Application programming in IEC 61131-3 (ladder diagrams, function blocks, sequence control, structured text); PLC programming and simulation, process visualization and operation; engineering integration from sensors, cabling, topology design, function, visualization, diagnosis, to documentation; Industry standards (e.g. OPC, Profinet); Ergonomic design, safety (IEC61508) and availability, supervision and diagnosis.

Automation standards: Communication, Architecture, Engineering, dependable systems, functional safety, automation security. Extensive practical examples from different process industries, power generation, gas compressor control, and automotive manufacturing.

Prerequisites / notice

Students are required to bring a windows-compatible computer with a common data analysis software to the exercises. Apps for simulating devices under different operating conditions will be made available to the students.

Competencies

Subject-specific Competencies

Concepts and Theories

assessed
### Core Courses

These core courses are particularly recommended for the field of “Systems and Control”. You may choose core courses form other fields in agreement with your tutor.

### Foundation Core Courses

- **Fundamentals at bachelor level, for master students who need to strengthen or refresh their background in the area.**

<table>
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### Advanced Core Courses

- **Fundamentals at bachelor level, for master students who need to strengthen or refresh their background in the area.**

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<tr>
<td>227-0225-00L</td>
<td>Linear System Theory</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>J. Lygeros, A. Tsiimas</td>
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<tr>
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<td>The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.</td>
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<td></td>
<td>Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.</td>
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<td></td>
<td>- Proof techniques and practices.</td>
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<td></td>
<td>- Linear spaces, normed linear spaces and Hilbert spaces.</td>
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<td></td>
<td>- Ordinary differential equations, existence and uniqueness of solutions.</td>
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<td></td>
<td>- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.</td>
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<td>- Controllability and observability, duality. Time invariant systems treated as a special case.</td>
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<td></td>
<td>- Stability and stabilization, observers, state and output feedback, separation principle.</td>
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<td></td>
<td>Lecture notes: Available on the course Moodle platform.</td>
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<td>Prerequisites / notice</td>
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<td>Sufficient mathematical maturity, in particular in linear algebra, analysis.</td>
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<td>Competencies</td>
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<td></td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<td></td>
<td>Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<td>Analytical Competencies</td>
<td>assessed</td>
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<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<td></td>
<td>Creative Thinking</td>
<td>fostered</td>
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<td>Critical Thinking</td>
<td>fostered</td>
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<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<td>227-0697-00L</td>
<td>Industrial Process Control</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>A. Horch, L. Dominguez Palomeque</td>
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<td></td>
<td>Introduction to industrial automation systems with application to the process industry, power generation as well as discrete manufacturing. General understanding of industrial automation systems in different industries. Purpose, architecture, technologies, application examples, current and future trends.</td>
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Content
Introduction to process automation: system architecture, data handling, communication (fieldbuses), process visualization, and engineering. Differences and characteristics of discrete and process industries.
Analysis and design of open loop control problems: discrete automata, finite state machines, decision tables, and petri-nets. Practical analysis and design of closed-loop control for the process industry.
Automation Engineering: Application programming in IEC 61131-3 (ladder diagrams, function blocks, sequence control, structured text); PLC programming and simulation, process visualization and operation; engineering integration from sensors, cabling, topology design, function, visualization, diagnosis, to documentation; Industry standards (e.g. OPC, Profinbus); Ergonomic design, safety (IEC61508) and availability, supervision and diagnosis.

Lecture notes
Slides will be available as .PDF documents, see "Learning materials" (for registered students only)

Literature
References will be given at the end of individual lectures.

Prerequisites / notice
Exercises: Tuesdays after the lecture (applies not to all lectures)
Practical exercises will illustrate some topics, e.g. some control software coding using industry standard programming tools based on IEC61131-3.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed
assessed

151-0371-00L Advanced Model Predictive Control
Number of participants limited to 60.

W 4 credits 2V+1U M. Zeilinger, A. Carron, L. Hewing, J. Köhler

Abstract
Model predictive control (MPC) has established itself as a powerful control technique for complex systems under state and input constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

Objective
Design, implement and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.

Content
Topics include
- Nominal MPC for uncertain systems (nominal robustness)
- Robust MPC
- Stochastic MPC
- Review of regression methods
- Set-membership identification and robust data-driven MPC
- Bayesian regression and stochastic data-driven MPC
- MPC as safety filter for reinforcement learning

Lecture notes
Lecture notes will be provided.

Prerequisites / notice
Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control in Spring Semester) strongly recommended.
Background in linear algebra and stochastic systems recommended.

151-0563-01L Dynamic Programming and Optimal Control

W 4 credits 2V+1U R. D'Andrea

Abstract
Introduction to Dynamic Programming and Optimal Control.

Objective
Covers the fundamental concepts of Dynamic Programming & Optimal Control.

Content
Dynamic Programming and Optimization: Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

Literature

Prerequisites / notice
Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

Specialisation Courses
These specialisation courses are particularly recommended for the area of "Systems and Control", but you are free to choose courses from any other field in agreement with your tutor.

A minimum of 40 credits must be obtained from specialisation courses during the Master's Programme.

Number Title Type ECTS Hours Lecturers
227-0102-00L Discrete Event Systems W 6 credits 4G L. Josipovic, L. Vanbever, R. Wattenhofer

Abstract
Introduction to discrete event systems. We start out by studying popular models of discrete event systems. Then we analyze discrete event systems from an average-case and from a worst-case perspective, and study verification. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Petri Nets.

Objective
Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by exploring the limits of what is computable and what is not. In doing so, we will consider three distinct models of computation which are often used to model discrete event systems: finite automata, push-down automata and Turing machines (ranked in terms of expressiveness power). In the second part of the course we analyze discrete event systems. We first examine discrete event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply continuous time markov chains and queueing theory for an understanding of the typical behavior of a system. Then we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queuing. In the last part of the course we introduce methods that allow to formally verify certain properties of Finite Automata and Petri Nets. These are some typical analysis questions we will look at: Do two given systems behave the same? Does a given system behave as intended? Does the system eventually enter a dangerous state?
Abstract

Objective
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.
Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Media and Digital Technologies fostered
Problem-solving assessed

Personal Competencies

Critical Thinking fostered

227-0689-00L System Identification W 4 credits 2V+1U R. Smith

Abstract

Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.

Objective

To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.

Content

Introduction to modeling: Black-box and grey-box models; Parametric and non-parametric models; ARX, ARMAX (etc.) models.
Predictive, open-loop, black-box identification methods. Time and frequency domain methods. Subspace identification methods.
Optimal experimental design, Cramer-Rao bounds, input signal design.
Parametric identification methods. On-line and batch approaches.
Closed-loop identification strategies. Trade-off between controller performance and information available for identification.

Literature


Prerequisites / notice

- Prerequisites: Control systems (227-0216-00L) or equivalent.

151-0532-00L Nonlinear Dynamics and Chaos I W 4 credits 4G G. Haller

Abstract

Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

Objective

This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.

Content

(1) Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
(2) Near equilibrium dynamics: Linear and Lyapunov stability
(3) Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations
(4) Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
(5) Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

Lecture notes

The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

Prerequisites / notice

- Prerequisites: Analysis, linear algebra and a basic course in differential equations.

151-0563-01L Dynamic Programming and Optimal Control W 4 credits 2V+1U R. D’Andrea

Abstract

Introduction to Dynamic Programming and Optimal Control.

Objective

Covers the fundamental concepts of Dynamic Programming & Optimal Control.

Content

Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

Literature


Prerequisites / notice

Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

376-1219-00L Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions W 3 credits 2V R. Riener, O. Lambercy

Abstract

Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

Objective

Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.
Content

- Introduction, problem definition, overview
- Rehabilitation of visual function
  - Anatomy and physiology of the visual sense
  - Technical aids (glasses, sensor substitution)
  - Retina and cortex implants
- Rehabilitation of hearing function
  - Anatomy and physiology of the auditory sense
  - Hearing aids
  - Cochlea Implants
- Rehabilitation and use of kinesthetic and tactile function
  - Anatomy and physiology of the kinesthetic and tactile sense
  - Tactile/haptic displays for motion therapy (incl. electrical stimulation)
  - Role of displays in motor learning
  - Brain stimulation and recording
  - Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces
- Rehabilitation of vestibular function
  - Anatomy and physiology of the vestibular sense
  - Rehabilitation strategies and devices (e.g. BrainPort)
- Rehabilitation of vegetative Functions
  - Cardiac Pacemaker
  - Phrenic stimulation, artificial breathing aids
  - Bladder stimulation, artificial sphincter

Literature


Selected Journal Articles and Web Links:


Prerequisites / notice

Target Group:

- Students of higher semesters and PhD students of
  - D-MAVT, D-ITET, D-INFK, D-HEST
  - Biomedical Engineering, Robotics, Systems and Control
  - Medical Faculty, University of Zurich

Students of other departments, faculties, courses are also welcome

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

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The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.

Key topics include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modeling with mathematical optimization: applications of mathematical programming in engineering.

Information about relevant literature will be given in the lecture.

This course is meant for students who did not already attend the course "Mathematical Optimization", which is a more advance lecture covering similar topics. Compared to "Mathematical Optimization", this course has a stronger focus on modeling and applications.

Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Solid background in linear algebra.

Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

Mathematical treatment of optimization techniques for linear and combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.

Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Solid background in linear algebra.

Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Lecture notes Lecture notes will be made available via Moodle.

Prerequisites / notice Students are expected to have a mathematical background and should be able to write rigorous proofs.

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**Game Theory and Control**

**W** 4 credits 2V+2U S. Bolognani

**Abstract**

Game Theory is the study of strategic decision making, and was originally used to solve problems in economics. We study concepts and methods in non-cooperative game theory and show how these can be used to solve control design problems, emphasizing their possible use in control, robotics, and engineering applications.

**Objective**

Recognize control problems that can be formalized as noncooperative dynamic games, analyze these games to compute their Nash equilibria and to identify their most important properties.

**Content**

Introduction to game theory, mathematical tools including convex optimization and dynamic programming, zero sum games in matrix and extensive form, pure and mixed strategies, nonzero sum games in normal and extensive form, numerical computation of mixed equilibrium strategies, Nash and Stackelberg equilibria, potential games, convex games, multi-stage games, behavioral strategies and informational properties for dynamic games, auction and VCG mechanisms, evolutionary games.

**Lecture notes**

Lecture notes will be made available via Moodle.

**Literature**


Both books are available online and can be a useful reference during the course, but will not be strictly followed.

**Prerequisites / notice**

Control Systems I (or equivalent). Necessary methods and concepts from optimization will be covered in the course.

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**Track: Signal Processing and Machine Learning**

The core courses and specialisation courses below are a selection for students who wish to specialise in the area of "Signal Processing and Machine Learning", see https://www.ee.ethz.ch/studies/main-master/areas-of-specialisation.html.

The individual study plan is subject to the tutor's approval.

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### Core Courses

These core courses are particularly recommended for the field of "Signal Processing and Machine Learning". You may choose core courses form other fields in agreement with your tutor.

A minimum of 24 credits must be obtained from core courses during the MSc EEIT.

#### Foundation Core Courses

Fundamentals at bachelor level, for master students who need to strengthen or refresh their background in the area.

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0101-00L</td>
<td>Discrete-Time and Statistical Signal Processing</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The course is about some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The course is about some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust &quot;inversion&quot; of a linear filter.</td>
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<tr>
<td><strong>Content</strong></td>
<td>1. Discrete-time linear systems and filters: state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion. 2. The discrete Fourier transform and its use for digital filtering. 3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
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<tbody>
<tr>
<td>227-0105-00L</td>
<td>Introduction to Estimation and Machine Learning</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Mathematical basics of estimation and machine learning, with a view towards applications in signal processing.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Students master the basic mathematical concepts and algorithms of estimation and machine learning.</td>
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<td><strong>Content</strong></td>
<td>Review of probability theory; basics of statistical estimation; least squares and linear learning; Hilbert spaces; singular-value decomposition; kernel methods, neural networks, and more</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Lecture notes will be handed out as the course progresses.</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>solid basics in linear algebra and probability theory</td>
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### Advanced Core Courses

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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0423-00L</td>
<td>Neural Network Theory</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>H. Bölcskei</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation theorems, capacity of separating surfaces, generalization, fundamental limits of deep neural network learning, VC dimension.</td>
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<td><strong>Objective</strong></td>
<td>After attending this lecture, participating in the exercise sessions, and working on the homework problem sets, students will have acquired a working knowledge of the mathematical foundations of neural networks.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Detailed lecture notes are available on the course web page <a href="https://www.mins.ee.ethz.ch/teaching/int/">https://www.mins.ee.ethz.ch/teaching/int/</a></td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.</td>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0447-00L</td>
<td>Image Analysis and Computer Vision</td>
<td>W</td>
<td>6 credits</td>
<td>3V+1U</td>
<td>E. Konukoglu, E. Erdil, F. Yu</td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical and computational programming exercises.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.</td>
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This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. The interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes

Course material Script, computer demonstrations, exercises and problem solutions

Prerequisites / notice

Prerequisites:
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux.

The course language is English.

252-0535-00L Advanced Machine Learning W 10 credits 3V+2U+4A C. Cotrini Jimenez

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
What is data?
Bayesian Learning
Computational learning theory

Supervised learning:
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks

Unsupervised learning:
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation
Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

263-3210-00L Deep Learning W 8 credits 3V+2U+2A T. Hofmann

Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning  
https://ml2.inf.ethz.ch/courses/aml/  

Computational Intelligence Lab  
http://da.inf.ethz.ch/teaching/2019/CIL/  

Introduction to Machine Learning  
https://las.inf.ethz.ch/teaching/introml-S19  

Statistical Learning Theory  
http://ml2.inf.ethz.ch/courses/slt/  

Computational Statistics  
https://stat.ethz.ch/lectures/ss19/comp-stats.php  

Probabilistic Artificial Intelligence  
https://las.inf.ethz.ch/teaching/pai-f18  

401-4944-20L  Mathematics of Data Science  
W  8 credits  3V+2U  A. Bandeira  

Abstract  Mostly self-contained, but fast-paced, introductory masters level course on various theoretical aspects of algorithms that aim to extract information from data.  

Objective  Introduction to various mathematical aspects of Data Science.  

Content  These topics lie in overlaps of Mathematics with: Computer Science, Electrical Engineering, Statistics, and/or Operations Research. Most lectures will feature Mathematical Open Problems. The main mathematical tools used will be Probability and Linear Algebra, and a basic familiarity with these subjects is required. There will also be some (although knowledge of these tools is not assumed) Graph Theory, Representation Theory, Applied Harmonic Analysis, among others. The topics treated will include Dimension reduction, Manifold learning, Sparse recovery, Random Matrices, Approximation Algorithms, Community detection in graphs, and several others.  


Prerequisites / notice  The main mathematical tools used will be Probability, Linear Algebra (and real analysis), and a working knowledge of these subjects is required. In addition to these prerequisites, this class requires a certain degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.  

We encourage students who are interested in mathematical data science to take both this course and "227-0434-10L Mathematics of Information" taught by Prof. H. Bölcskei. The two courses are designed to be complementary.  

A. Bandeira and H. Bölcskei  

Competencies  

Subject-specific Competencies  
Concepts and Theories  assessed  
Techniques and Technologies  assessed  

Method-specific Competencies  
Analytical Competencies  assessed  
Decision-making  assessed  
Media and Digital Technologies  fostered  
Problem-solving  assessed  

Social Competencies  
Communication  fostered  
Cooperation and Teamwork  fostered  
Sensitivity to Diversity  fostered  

Personal Competencies  
Creative Thinking  assessed  
Critical Thinking  assessed  
Integrity and Work Ethics  fostered  
Self-awareness and Self-reflection  fostered  
Self-direction and Self-management  fostered  

Specialisation Courses  

These specialisation courses are particularly recommended for the area of "Signal Processing and Machine Learning", but you are free to choose courses from any other field in agreement with your tutor.  

A minimum of 40 credits must be obtained from specialisation courses during the MSc EEIT.  

Number  Title  Type  ECTS  Hours  Lecturers  
227-0116-00L  VLSI 1: HDL Based Design for FPGAs  W  6 credits  5G  F. K. Gürkaynak  

Abstract  This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.  

Objective  Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:

- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.

SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Abstract
- After attending the lectures, participating in the exercise sessions, and working on the homework problems (which include MATLAB coding assignments), the students will be able to:
  - understand the fundamentals of digital communication systems
  - explain the principles of modulation, demodulation, detection, and error correction
  - analyze error rates of simple digital communication systems
  - implement simple MATLAB simulations to calculate error rates
  - build simple MATLAB systems to calculate error rates

Objective
- The course teaches the fundamentals of digital communication systems. The main topics are analog and digital modulation, signals and linear time-invariant systems, baseband and passband representations, continuous-time and discrete-time channels, noise, inter-symbol interference, detection theory, as well as the basics of forward error correction and information theory.

Content
- Building digital communication systems
-机票 and digital modulation
- baseband and passband representation; up- and down-conversion
- communication channels as LTI systems
- discrete-time communication systems; sampling and quantization
- noise, signal-to-noise ratio (SNR), and interference
- detection theory and error rates
- basics of forward error correction
- basics of information theory
- orthogonal frequency-division multiplexing (OFDM)
- building blocks of modern communication systems

Lecture notes
- Textbook and all further documents in English.

Literature

Prerequisites / notice
- Basics of digital circuits.
- Examination:
  - In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English or German.
  - Further details: https://iis-students.ee.ethz.ch/lectures/vlsi-i/

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Component</th>
<th>Instructor</th>
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<tr>
<td>227-0121-00L</td>
<td>Communication Systems</td>
<td>6</td>
<td>4G</td>
<td>C. Studer, S. M. Moser</td>
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**Objective**
The course teaches the fundamentals of digital communication systems. The main topics are analog and digital modulation, signals and linear time-invariant systems, baseband and passband representations, continuous-time and discrete-time channels, noise, inter-symbol interference, detection theory, as well as the basics of forward error correction and information theory.

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- noise, signal-to-noise ratio (SNR), and interference
- detection theory and error rates
- basics of forward error correction
- basics of information theory
- orthogonal frequency-division multiplexing (OFDM)
- building blocks of modern communication systems

**Lecture notes**
Lecture notes will be distributed electronically at the beginning of the semester.

**Literature**

**Prerequisites**
Subject-specific Competencies
- Concepts and Theories

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Personal Competencies
- Critical Thinking
- Integrity and Work Ethics

**227-0155-00L**
**Machine Learning on Microcontrollers**

**Registration in this class requires the permission of the instructors. Preference is given to students in the MSc EEIT.**

**Abstract**
Machine Learning (ML) and artificial intelligence are pervading the digital society. Today, even low power embedded systems are incorporating ML, becoming increasingly "smart". This lecture gives an overview of ML methods and algorithms to process and extract useful near-sensor information in end-nodes of the "internet-of-things", using low-power microcontrollers/processors (ARM-Cortex-M; RISC-V).

**Objective**
Learn how to process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ExG bio-signals, cameras...). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers.

**Content**
- Machine Learning on Microcontrollers
- Implementing machine learning on low-power microcontrollers
- Problem-solving techniques for machine learning on microcontrollers
- Case studies of machine learning applications on microcontrollers

**Lecture notes**
Lecture notes will be distributed electronically at the beginning of the semester.

**Literature**

**Prerequisites**
- Basics of digital circuits.

**Examination**
In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English or German.

Further details: https://iis-students.ee.ethz.ch/lectures/vlsi-i/
Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

Information Theory I

The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.

Typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.

Lecture notes
Available on the course Moodle platform.

Prerequisites
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Problem-solving

Personal Competencies
Creative Thinking
Critical Thinking
Integrity and Work Ethics

The course will cover the basic physics of ultrasound (acoustic waves at frequencies higher than the audible range) in biological tissues as well as the instrumentation required to generate and detect these waves. Imaging methods will extensively be described in the course.

Specifically, standard and ultra-fast ultrasound imaging approaches will be covered along with new optoacoustic and transmission ultrasound imaging methods. The course will also describe mathematical modelling approaches and numerical methods as well as signal and image processing tools applicable in ultrasound-based imaging. Other topics include ultrasound sensors, laser ultrasound, therapeutic effects, or biomedical applications and contrast agents. The course will conclude with current and future research directions in the field of ultrasound in biomedicine.

- Stability and stabilization, observers, state and output feedback, separation principle.

Lecture notes
The laboratory exercised will show how to address concrete design problems, like motion, gesture recognition, emotion detection, image and sound classification, using real sensors data and real MCU boards.

Presentations from Ph.D. students and the visit to the Digital Circuits and Systems Group will introduce current research topics and international research projects.

Prerequisites / notice
Sufficient mathematical maturity, in particular in linear algebra, analysis.


Ultrasound waves are non-ionizing and thus provide a safe means to interrogate and treat biological tissues. Advantages such as real-time operation, low cost, and portability have led to ultrasound systems becoming standard tools in hospitals and research laboratories.

Applications in biology and medicine include ultrasound and optoacoustic imaging, thermal therapy, or pulse stimulation.

The course will cover the basic physics of ultrasound (acoustic waves at frequencies higher than the audible range) in biological tissues as well as the instrumentation required to generate and detect these waves. Imaging methods will extensively be described in the course.

Specifically, standard and ultra-fast ultrasound imaging approaches will be covered along with new optoacoustic and transmission ultrasound imaging methods. The course will also describe mathematical modelling approaches and numerical methods as well as signal and image processing tools applicable in ultrasound-based imaging. Other topics include ultrasound sensors, laser ultrasound, therapeutic effects, or biomedical applications and contrast agents. The course will conclude with current and future research directions in the field of ultrasound in biomedicine.

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Presentations from Ph.D. students and the visit to the Digital Circuits and Systems Group will introduce current research topics and international research projects.

Prerequisites / notice
Sufficient mathematical maturity, in particular in linear algebra, analysis.

Objective

The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today’s neuroscience papers.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today’s neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to ‘error backpropagation’ in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

Content

Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al, 2015, Silver et al., 2018), ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

Lecture notes

The lecture slides will be provided as a PDF after each lecture.

Prerequisites / notice

This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:
1) The number of participants is limited to 120 students (MSc and PhDs).
2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

227-0477-00L Acoustics I

Abstract

Introduction to the fundamentals of acoustics in the field of sound field calculations, measurement of acoustical events, outdoor sound propagation and room acoustics of large and small enclosures.

Objective

Understanding of the basic acoustical concepts and methods. Ability to understand the technical and scientific literature. Confidence in the use of measuring instruments.

Content

Fundamentals of acoustics, calculation of sound fields, measurement and analysis of acoustical events, anatomy and properties of the ear, outdoor sound propagation, absorption and transmission of sound, room acoustics of large and small enclosures, noise and noise control.

Lecture notes

yes

Competencies

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Problem-solving

Social Competencies
Communication

Personal Competencies
Creative Thinking
Critical Thinking
Self-direction and Self-management

227-0560-00L Computer Vision and Artificial Intelligence for Autonomous Cars

Autumn Semester 2024

Up until FS2022 offered as Deep Learning for Autonomous Driving

Abstract

This course introduces the core computer vision techniques and algorithms that autonomous cars use to perceive the semantics and geometry of their driving environment, localize themselves in it, and predict its dynamic evolution. Emphasis is placed on techniques tailored for real-world settings, such as multi-modal fusion, domain-adaptive and outlier-aware architectures, and multi-agent methods.

Objective

Students will learn about the fundamentals of autonomous cars and of the computer vision models and methods these cars use to analyze their environment and navigate themselves in it. Students will be presented with state-of-the-art representations and algorithms for semantic, geometric and temporal visual reasoning in automated driving and will gain hands-on experience in developing computer vision algorithms and architectures for solving such tasks.

After completing this course, students will be able to:
1. understand the operating principles of visual sensors in autonomous cars
2. differentiate between the core architectural paradigms and components of modern visual perception models and describe their logic and the role of their parameters
3. systematically categorize the main visual tasks related to automated driving and understand the primary representations and algorithms which are used for solving them
4. critically analyze and evaluate current research in the area of computer vision for autonomous cars
5. practically reproduce state-of-the-art computer vision methods in automated driving
6. independently develop new models for visual perception
Content

The content of the lectures consists in the following topics:

1. Fundamentals
   (a) Fundamentals of autonomous cars and their visual sensors
   (b) Fundamental computer vision architectures and algorithms for autonomous cars

2. Semantic perception
   (a) Semantic segmentation
   (b) Object detection
   (c) Instance segmentation and panoptic segmentation

3. Geometric perception and localization
   (a) Depth estimation
   (b) 3D reconstruction
   (c) Visual localization
   (d) Unimodal visual/lidar 3D object detection

4. Robust perception: multi-modal, multi-domain and multi-agent methods
   (a) Multi-modal 2D and 3D object detection
   (b) Visual grounding and verbo-visual fusion
   (c) Domain-adaptive and outlier-aware semantic perception
   (d) Vehicle-to-vehicle communication for perception

5. Temporal perception
   (a) Multiple object tracking
   (b) Motion prediction

The practical projects involve implementing complex computer vision architectures and algorithms and applying them to real-world, multi-modal driving datasets. In particular, students will develop models and algorithms for:

1. Semantic segmentation and depth estimation
2. Sensor calibration for multi-modal 3D driving datasets
3. 3D object detection using lidars

Lecture notes
Lecture slides are provided in PDF format.

Prerequisites / notice
Students are expected to have a solid basic knowledge of linear algebra, multivariate calculus, and probability theory, and a basic background in computer vision and machine learning. All practical projects will require solid background in programming and will be based on Python and libraries of it such as PyTorch.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

263-5210-00L Probabilistic Artificial Intelligence

Abstract
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit “intelligent” behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice
Solid basic knowledge in statistics, algorithms and programming.

The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered

263-5300-00L Guarantees for Machine Learning

Abstract
This course is aimed at advanced master and doctorate students who want to conduct independent research on theory for modern machine learning (ML). It teaches standard methods in statistical learning theory commonly used to prove theoretical guarantees for ML algorithms. The knowledge is then applied in independent project work to understand and follow-up on recent theoretical ML results.
This course provides a gentle introduction to the Probabilistic Method, with an emphasis on methodology. We will try to illustrate the main

By the end of the semester students should be able to

- outline a possible approach to prove a conjectured theorem by e.g. reducing to more solvable subproblems. This will be practiced in in-person exercises, homeworks and potentially in the final project

- effectively communicate and present the problem motivation, new insights and results to a technical audience. This will be primarily learned via the final presentation and report as well as during peer-grading of peer talks.

Content

This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning algorithms. It touches on the following topics
- concentration bounds
- uniform convergence and empirical process theory
- regularization for non-parametric statistics (e.g., in RKHS, neural networks)
- high-dimensional learning
- computational and statistical learnability (information-theoretic, PAC, SQ)
- overparameterized models, implicit bias and regularization

The project work focuses on current theoretical ML research that aims to understand modern phenomena in machine learning, including but not limited to
- how overparameterized models generalize (statistically) and converge (computationally)
- complexity measures and approximation theoretic properties of randomly initialized and trained neural networks
- generalization of robust learning (adversarial or distribution-shift robustness)
- private and fair learning

Prerequisites / notice

Students should have a very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as "Introduction to Machine Learning", "Regression" / "Statistical Modelling". In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed

401-3054-14L Probabilistic Methods in Combinatorics

Abstract

This course provides a gentle introduction to the Probabilistic Method, with an emphasis on methodology. We will try to illustrate the main ideas by showing the application of probabilistic reasoning to various combinatorial problems.

Content

The topics covered in the class will include (but are not limited to): linearity of expectation, the second moment method, the local lemma, correlation inequalities, martingales, large deviation inequalities, Janson and Talagrand inequalities and pseudo-randomness.

Literature

- Graph Coloring and the Probabilistic Method, by M. Molloy and B. Reed, Springer, 2002.

401-3055-64L Algebraic Methods in Combinatorics

Does not take place this semester.

Abstract

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic Methods, illustrated by examples and focusing on basic ideas to other areas.

Objective

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

Content

Combinatorics is a fundamental discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic Methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

Lecture notes

The course website can be found at https://moodle-app2.iwitc.ethz.ch/course/view.php?id=15757

Lecture notes

Lectures will be on the blackboard only, but there will be a set of typed lecture notes which follow the class closely.

Prerequisites / notice

Students are expected to have a mathematical background and should be able to write rigorous proofs.

401-3621-00L Fundamentals of Mathematical Statistics

Abstract

This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning algorithms. It touches on the following topics
- concentration bounds
- uniform convergence and empirical process theory
- regularization for non-parametric statistics (e.g., in RKHS, neural networks)
- high-dimensional learning
- computational and statistical learnability (information-theoretic, PAC, SQ)
- overparameterized models, implicit bias and regularization

The project work focuses on current theoretical ML research that aims to understand modern phenomena in machine learning, including but not limited to
- how overparameterized models generalize (statistically) and converge (computationally)
- complexity measures and approximation theoretic properties of randomly initialized and trained neural networks
- generalization of robust learning (adversarial or distribution-shift robustness)
- private and fair learning

Prerequisites / notice

Students should have a very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as "Introduction to Machine Learning", "Regression" / "Statistical Modelling". In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed

401-3054-14L Probabilistic Methods in Combinatorics

Abstract

This course provides a gentle introduction to the Probabilistic Method, with an emphasis on methodology. We will try to illustrate the main ideas by showing the application of probabilistic reasoning to various combinatorial problems.

Content

The topics covered in the class will include (but are not limited to): linearity of expectation, the second moment method, the local lemma, correlation inequalities, martingales, large deviation inequalities, Janson and Talagrand inequalities and pseudo-randomness.

Literature

- Graph Coloring and the Probabilistic Method, by M. Molloy and B. Reed, Springer, 2002.

401-3055-64L Algebraic Methods in Combinatorics

Does not take place this semester.

Abstract

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic Methods, illustrated by examples and focusing on basic ideas to other areas.

Objective

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

Content

Combinatorics is a fundamental discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic Methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

Lecture notes

The course website can be found at https://moodle-app2.iwitc.ethz.ch/course/view.php?id=15757

Lecture notes

Lectures will be on the blackboard only, but there will be a set of typed lecture notes which follow the class closely.

Prerequisites / notice

Students are expected to have a mathematical background and should be able to write rigorous proofs.
Abstract
In this course we study the basics of theoretical statistics. The course includes methods for designing estimators, confidence intervals and tests, and various ways to evaluate the accuracy of estimators, confidence intervals and tests. We consider optimality criteria such as admissibility and minimaxity, as well as Bayesian criteria. We will also present the asymptotic point of view.

Objective
The aim of this course is to gain insight into the main statistical ideas and concepts. The course considers classical low-dimensional models, with pointers towards today's highly complex models.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Problem-solving
- Creative Thinking

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Personal Competencies
- Creative Thinking

401-3901-00L Linear & Combinatorial Optimization
W 10 credits 4V+2U R. Zenklusen

Abstract
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

Objective
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Content
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Literature

Prerequisites / notice
Solid background in linear algebra.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Problem-solving

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Social Competencies
- Communication

Personal Competencies
- Creativity

Tracks (all): Electives
This is only a short selection. Other courses from the ETH course catalogue may be chosen in agreement with your tutor.

As an alternative to the elective courses, students may do a second semester project or an internship in industry. Please consult your tutor.

Number Title Type ECTS Hours Lecturers
151-0371-00L Advanced Model Predictive Control W 4 credits 2V+1U M. Zeilinger, A. Carron, L. Hewing, J. Köhler

Abstract
Model predictive control (MPC) has established itself as a powerful control technique for complex systems under state and input constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

Objective
Design, implement and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.

Content
- Nominal MPC for uncertain systems (nominal robustness)
- Robust MPC
- Stochastic MPC
- Review of regression methods
- Set-membership Identification and robust data-driven MPC
- Bayesian regression and stochastic data-driven MPC
- MPC as safety filter for reinforcement learning

Lecture notes
Lecture notes will be provided.

Prerequisites / notice
Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control in Spring Semester) strongly recommended. Background in linear algebra and stochastic systems recommended.

351-0511-00L Managerial Economics W 4 credits 3V O. Krebs, P. Egger, M. Köthenbürger

Abstract
"Managerial Economics" provides an introduction to the theories and methods from Economics and Management Science to analyze economic decision-making in the context of markets. The course targets students with no prior knowledge in Economics and Management.
Objective

The objective of this course is to provide an introduction to microeconomic thinking. Based on the fundamental principles of economic analysis (optimization and equilibrium), the focus lies on understanding key economic concepts relevant for understanding and analyzing economic behavior of firms and consumers in the context of markets. Market demand and supply are derived from the individual decision-making of economic agents and market outcomes under different assumptions about the market structure and market power (perfect competition, monopoly, oligopoly, game theory) are studied. This introductory course aims at providing essential knowledge from the fields of Economics and Management relevant for economic decision-making in the context of both the private and public sector.

Literature


Prerequisites / notice

The course targets both Bachelor and Master students. No prior knowledge in the areas of Economics and Management is required.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Critical Thinking</th>
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<tr>
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<tr>
<td>Personal Competencies</td>
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</table>

351-0778-00L Discovering Management

Does not take place this semester.

Entry level course in management for BSc, MSc and PHD students at all levels not belonging to D-MTEC. This course can be complemented with Discovering Management (Exercises) 351-0778-01.

Abstract

Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

Objective

The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:

(1) broaden understanding of management principles and frameworks
(2) advance insights into the sources of corporate and entrepreneurial success
(3) develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

Content

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. The theory sessions will be assessed via a multiple choice exam.

Lecture notes

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

351-0778-01L Discovering Management (Pitch)

Does not take place this semester.

Complementary exercises for the module Discovering Management.

Prerequisite: Participation and successful completion of the module Discovering Management (351-0778-00L) is mandatory.

Abstract

This course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

Objective

The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.

Content

The exercise consists of delivering and submitting a "pitch" with a clear recommendation for one of the selected cases amongst those seen in Discovering Management, using your insights from Discovering Management, and an extra session on pitching.

Students have the option to either do this alone or in a group of two students.

Literature

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. Students following this course should also be enrolled for course 351-0778-00L, "Discovering Management".
Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies fostered

Method-specific Competencies
- Analytical Competencies assessed
- Media and Digital Technologies fostered
- Problem-solving assessed

Social Competencies
- Communication assessed

Personal Competencies
- Creative Thinking assessed
- Critical Thinking assessed
- Self-direction and Self-management fostered

Techniques and Technologies fostered

363-0790-00L Technology Entrepreneurship
W 2 credits 2V F. Hacklin

Abstract
Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding.
This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are success factors in the creation of new firms, including founding, financing and growing a venture.

Objective
This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures. A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases.

Content
Weekly sessions - recorded.
10+ sessions carried out by guest lecturers: experts in the broad field of technology entrepreneurship (e.g., serial entrepreneurs, venture capitalists, (E)MBA professors, company builders, patent experts, scale-up executives, …). Final session: multiple choice semester assignment (100% of grade).

Typical lecture format (2h):
15': Introduction
60': Guest testimonial
15': Discussion related to topic (in groups)
10': Plenary discussion
20': Q&A with (guest) lecturer

Lecture notes
Lecture slides and case material

Competencies

Subject-specific Competencies
- Concepts and Theories assessed

Method-specific Competencies
- Analytical Competencies assessed
- Problem-solving assessed

Social Competencies
- Communication fostered

Personal Competencies
- Critical Thinking assessed

363-1082-00L Enabling Entrepreneurship: From Science to Startup
W 3 credits 2V R. De Cock

Abstract
This elective is relevant for students who have developed a technology and are keen to evaluate the steps in starting a startup. This is also relevant for students who would like to start a startup but do not have a technology, but are clear on a specific market and the impact they would like to create.

Objective
Students have technology competence or an idea that they would like to convert into a startup. They are now in the process of evaluating the steps necessary to do so. In summary:

1. Students want to become entrepreneurs.
2. The students can be from business or science & technology.
3. The course will enable the students to identify the relevance of their technology or idea from the market relevance perspective and thereby create a business case to take it to market.
4. The students will have exposure to investors and entrepreneurs (with a focus on ETH spin-offs) through the course, to gain insight to commercialise their idea.

Students should provide a brief overview (unto 1 page) of their business ideas that they would like to commercialise through the course. If they do not have an idea, they are required to provide a motivation letter stating why they would like to do this elective. If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

The total number of students will be limited to 50.

The students should submit the necessary information until 25 September 2024 and apply to Robin De Cock: Robin.DeCock@uantwerpen.be.
The class introduces students into basic features of the legal system. Fundamental issues of constitutional law, administrative law, private law and the law of the EU are covered. The focus is on legal problems related to space. Active participation is expected in short interactive sequences.

Students are able to identify basic structures of the legal system. They understand selected topics of public and private law. They are able to apply the fundamentals in more advanced law classes and to recognize the relevance of law in their own field.

This course will revolve around the ideas of the students, the notes will be for the sole purpose of providing guidance to the students to help convert their technologies or ideas into business cases for the purpose of forming startups. Theoretical subject matter will be kept to a minimum and is not the focus of the course.

The students shall obtain a basic knowledge about the legal environment of entrepreneurs. They shall be able to recognize and evaluate legal issues connected to an entrepreneurial activity and suggest possible solutions.

The seminar includes talks from invited investors, entrepreneurs and legal experts regarding the importance of the various elements being covered in content, workshops and teamwork. There is a particular emphasis on market validation on each step of the journey, to ensure relevance.

If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.
The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture addresses students in the fields of engineering, science and other related technical fields.

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

The students will gain insights into the concept and mechanics of Creative Thinking. They will trace the historical roots of creativity and its contemporary significance, explore how Creative Thinking intersects with modern innovations and technologies.

In the business world Creative Thinking is considered to be one of the “top ten skills” or “most In-Demand skill” in 2024. With Creative Thinking innovative solutions to problems are developed and not only a large number of ideas but also a variety and range of them are brainstormed. It seems that in today’s dynamic world, creativity isn’t just an asset – but actually necessity.

But what exactly is Creative Thinking? In the above mentioned business context it is assumed everybody knows. And what is creativity? And how can we use it. Or not. Originally, connected to artistic practice, creativity is nowadays a skill and practice that can be found in all work areas, especially in innovation and maybe even in technological applications themselves. Today, not only because of creative economy, creative cities or innovation, but also because of generative AI creativity has gained new and broad attention. In the seminar we go back in history to the invention of the genius and look at different social subsystems like art, psychology, economy as well as field as fashion, advertisement and arts and crafts, how our understanding of creativity has emerged till today.

Internship in Industry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>227-1550-10L</td>
<td>Internship in Industry</td>
<td>W</td>
<td>12</td>
<td></td>
<td>external organisers</td>
</tr>
</tbody>
</table>

Abstract

The main objective of the 12-week internship (full-time) is to expose master's students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.

Objective

see above

Master Studies (Programme Regulations 2008)

Major Courses

A total of 42 CP must be achieved during the Master Programme. The individual study plan is subject to the tutor's approval.

Communication

Core Subjects

These core subjects are particularly recommended for the field of "Communication".
1. Regular Languages

Information Theory I

The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

Objective

An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the important elements will be passed on. Students attending the lecture will further get engaged in critical discussion on societal, economical and environmental aspects related to the on-going exponential growth in the field of communications.

Content

* Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.


  * Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.

  * Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.

  * Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.

  * Chapter 7: Optical Amplifiers: Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

Lecture notes

Lecture notes are handed out.

Literature

Govind P. Agrawal; "Fiber-Optic Communication Systems"; Wiley, 2010

Prerequisites / notice


227-0102-00L Information Theory I W 6 credits 4G A. Lapidoth

Abstract

This course covers the basic concepts of information theory and communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equipartition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

Objective

The entropy rate of a source, Typical sequences, the asymptotic equipartition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

Content

The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

Literature

T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

Recommended Subjects

These courses are recommended, but you are free to choose courses from any other special field. Please consult your tutor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
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<tr>
<td>227-0102-00L</td>
<td>Discrete Event Systems</td>
<td>W</td>
<td>6</td>
<td>4</td>
<td>L. Josipovic, L. Vanbever, R. Wattenhofer</td>
</tr>
</tbody>
</table>

Abstract

Introduction to discrete event systems. We start out by studying popular models of discrete event systems. Then we analyze discrete event systems from an average-case and from a worst-case perspective, and study verification. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Petri Nets.

Objective

Over the past decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by exploring the limits of what is computable and what is not. In doing so, we will consider three distinct models of computation which are often used to model discrete event systems: finite automata, push-down automata and Turing machines (ranked in terms of expressiveness power). In the second part of the course we analyze discrete event systems. We first examine discrete event systems from an average-case perspective; we model discrete events as stochastic processes, and then apply continuous time markov chains and queueing theory for an understanding of the typical behavior of a system. Then we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queueing. In the last part of the course we introduce methods that allow to formally verify certain properties of Finite Automata and Petri Nets. These are some typical analysis questions we will look at: Do two given systems behave the same? Does a given system behave as intended? Does the system eventually enter a dangerous state?

Content

1. Regular Languages
2. Non-Regular Languages
3. Markov Chains
4. Stochastic Discrete Event Systems
5. Worst-Case Event Systems
6. Verification of Finite Automata
7. Petri Nets

Lecture notes

Available at https://disco.ethz.ch/courses/des/
Literature

[bertsekas] Data Networks
Dimitri Bertsekas, Robert Gallager

[borodin] Online Computation and Competitive Analysis
Allan Borodin, Ran El-Yaniv.
Cambridge University Press, 1998

[burch] Symbolic Model Checking
Inf. Comput. 98, 2 (June 1992), pp. 142-170

[boudec] Network Calculus
J.-Y. Le Boudec, P. Thiran
Springer, 2001

[cassandras] Introduction to Discrete Event Systems
Christos Cassandras, Stéphane Lafortune.

[fiat] Online Algorithms: The State of the Art
A. Fiat and G. Woeginger

D. Hochbaum

[murata] Petri Nets: Properties, Analysis and Applications
Tadao Murata

[schickinger] Diskrete Strukturen (Band 2: Wahrscheinlichkeitstheorie und Statistik)
T. Schickinger, A. Steger
Springer, Berlin, 2001

[sipser] Introduction to the Theory of Computation
Michael Sipser.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Social Competencies
Communication assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed

227-0103-00L Control Systems W 6 credits 2V+2U F. Dörfler

Abstract
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Objective
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Content

Literature

Prerequisites / notice
Prerequisites: Signal and Systems Theory II.

MATLAB is used for system analysis and simulation.

227-0116-00L VLSI 1: HDL Based Design for FPGAs W 6 credits 5G F. K. Gürkaynak

Abstract
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with deising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Objective
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conceptions to gate-level netlists. How to model digital circuits with SystemVerilog, How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:

- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.

- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Textbook and all further documents in English.

**Literature**


**Prerequisites / notice**

Basics of digital circuits.

**Lecture notes**

Textbook and handouts of presented slides. No script but an accompanying textbook is recommended.

**Examination:**

Written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English or German.

Further details: [https://iis-students.ee.ethz.ch/lectures/vlsi-i/](https://iis-students.ee.ethz.ch/lectures/vlsi-i/)

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**227-0166-00L Analog Integrated Circuits**

**Objective**

This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies.

Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.

**Content**

Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors.

The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.

**Literature**


**Lecture notes**

Handouts of presented slides. No script but an accompanying textbook is recommended.

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**227-0301-00L Optical Communication Fundamentals**

**Objective**

The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the important elements will be passed on. Students attending the lecture will further get engaged in critical discussion on societal, economical and environmental aspects related to the on-going exponential growth in the field of communications.

**Content**

* Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.
* Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.
* Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.
* Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.
* Chapter 7: Optical Amplifiers : Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

**Literature**


**Lecture notes**

Lecture notes are handed out.
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

### Content
1. Universal approximation with single- and multi-layer networks
2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory
3. Fundamental limits of deep neural network learning
4. Geometry of decision surfaces
5. Separating capacity of nonlinear decision surfaces
6. Vapnik-Chervonenkis (VC) dimension
7. VC dimension of neural networks
8. Generalization error in neural network learning

### Lecture notes
Detailed lecture notes are available on the course web page [https://www.mins.ee.ethz.ch/teaching/nnnt/](https://www.mins.ee.ethz.ch/teaching/nnnt/)

### Prerequisites / notice
This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

### 227-0447-00L Image Analysis and Computer Vision
- **Abstract**
- **Objective**
  - Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.
- **Content**
  - The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

### Lecture notes
Course material, script, computer demonstrations, exercises and problem solutions

### Prerequisites / notice
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

### 227-0468-00L Analog Signal Processing and Filtering
- **Abstract**
  - This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers.
- **Objective**
  - This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers. The way the exam is done allows for the different interests of the two groups.
- **Content**
  - At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during the whole course for analog filters. The course treats analog filters, analog discrete-time, mixed-signal and digital) and understand how signals propagate through them. The theory and CMOS implementation of active filters is then discussed in detail using the example of Gm-C filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators follows. The link to the practical design of circuits and systems is done with an overview over different quality measures and figures of merit used in scientific literature and datasheets. Finally, an introduction to discrete-time and mixed-domain filters and circuits is given, including sensor read-out amplifiers, correlated double sampling, and chopping, and an introduction to sigma-delta A/D and D/A conversion on a system level. The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

### Lecture notes
The base for these lecture notes are two or three published scientific papers. From these papers we will together develop the technical content.

### Prerequisites / notice
Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.
Acoustics I

**W 3 credits 2G R. Pieren**

**Abstract**
Introduction to the fundamentals of acoustics in the field of sound field calculations, measurement of acoustical events, outdoor sound propagation and room acoustics of large and small enclosures.

**Objective**
Understanding of the basic acoustical concepts and methods. Ability to understand the technical and scientific literature. Confidence in the use of measuring instruments.

**Content**
Fundamentals of acoustics, calculation of sound fields, measurement and analysis of acoustical events, anatomy and properties of the ear, outdoor sound propagation, absorption and transmission of sound, room acoustics of large and small enclosures, noise and noise control.

**Lecture notes**
yes

**Competencies**

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

Advanced Machine Learning

**W 10 credits 3V+2U+4A C. Cotrini Jimenez**

**Abstract**
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

**Content**
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

**Topics covered in the lecture include:**

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

**Lecture notes**
No lecture notes, but slides will be made available on the course webpage.

**Literature**
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least “Introduction to Machine Learning” or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

263-4640-00L Network Security W 8 credits 2V+2U+3A P. De Vaere, S. Frei, K. Paterson, A. Perrig

Abstract
Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems.

This course provides an in-depth study of network attack techniques and methods to defend against them.

Objective
- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

Content
The course will cover topics spanning four broad themes with a focus on the first two themes:
(1) network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
(2) network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
(3) analysis and inference topics such as traffic monitoring and network forensics; and
(4) new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

Prerequisites / notice
This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L.

Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

Cost
401-3055-64L Algebraic Methods in Combinatorics W 5 credits 2V+1U not available

Abstract
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

Objective
The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

Content
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, spaces of polynomials and tensor product methods.
- Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem.
- Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lecture notes
Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Prerequisites / notice
Students are expected to have a mathematical background and should be able to write rigorous proofs.

The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack towards logic gates and increasingly complex digital circuit structures. The topics of this course include:

- Nanometer MOSFETs
- Static and dynamic behavior of complementary MOS (CMOS) inverters
- CMOS gate design, sizing, and timing
- Full-custom standard-cell design
- Wire models and parasitics
- Latch and flip-flop circuits
- Gate-level timing analysis and optimization
- Static and dynamic power consumption; low-power techniques
- Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
- Arithmetic and logic circuits
- Fixed-point and floating-point arithmetic
- Synchronous and asynchronous design principles
- Memory circuits (ROM, SRAM, and DRAM)
- In- and near-memory processing architectures
- Full-custom accelerator circuits for machine learning

The exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

N. H. E. Weste and D. M Harris, CMOS VLSI Design: A Circuits and Systems Perspective (4th Ed.), Addison-Wesley


See https://safari.ethz.ch/architecture for past examples.
Objective

The goals of this course is to provide students with a deeper understanding of the existing and upcoming Internet technologies used in large-scale computer networks such as Internet Service Providers (e.g., Swisscom or Deutsche Telekom), Content Delivery Networks (e.g., Netflix) and Data Centers (e.g., Google). Besides covering the fundamentals, the course will be "hands-on" and will enable students to play with the technologies in realistic network environments.

Content

In 2023, the course will cover advanced topics in communication networks such as:
- Advanced Internet routing (convergence, optimality, scalability, flexibility);
- Network programmability (OpenFlow, P4);
- Traffic engineering / Load Balancing;
- Network verification and synthesis;
- Network measurements;
- Network security;
- Upcoming transport protocols and technologies;
- Adaptive video streaming; and
- Network sustainability.

The course will be composed of lectures and practical exercises (some of which including labs).

Lecture notes

Lecture notes and material will be made available before each course on the course website.

Slides, relevant literature and manuals will be made available during the course.

Method-specific Competencies

- System Security

Abstract

This course covers the security of commodity computer hardware (e.g., CPU, DRAM, etc.) with a special focus on cutting-edge hands-on research. The aim of the course is familiarizing the students with hardware security and more specifically microarchitectural and circuit-level attacks and defenses through lectures and implementing some of these advanced attacks.

Objective

By the end of the course, the students will be familiar with the state of the art in commodity computer hardware attacks and defenses. More specifically, the students will learn about:
- security problems of commodity hardware that we use everyday and how you can defend against them.
- relevant computer architecture and operating system aspects of these issues.
- hands-on techniques for performing hardware attacks.

This is the course where you get credit points by building some of the most advanced exploits on the planet! The luckiest team will collect a Best Demo Award at the end of the course.

Literature

Relevant references will be made available through the course website.

Prerequisites / notice

Prerequisites: Communication Networks (227-0120-00L) or equivalents / programming skills (in any language) are expected (some of the exercises will involve coding).

Competencies

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<tr>
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227-0579-00L Hardware Security

W 8 credits 2V+2U+2A K. Razavi

Abstract

This course covers the security of commodity computer hardware (e.g., CPU, DRAM, etc.) with a special focus on cutting-edge hands-on research. The aim of the course is familiarizing the students with hardware security and more specifically microarchitectural and circuit-level attacks and defenses through lectures and implementing some of these advanced attacks.

Objective

By the end of the course, the students will be familiar with the state of the art in commodity computer hardware attacks and defenses. More specifically, the students will learn about:
- security problems of commodity hardware that we use everyday and how you can defend against them.
- relevant computer architecture and operating system aspects of these issues.
- hands-on techniques for performing hardware attacks.

This is the course where you get credit points by building some of the most advanced exploits on the planet! The luckiest team will collect a Best Demo Award at the end of the course.

Literature

Relevant references will be made available through the course website.

Prerequisites / notice

Experience with Linux, low-level systems programming and computer architecture.

Competencies

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252-1414-00L System Security

W 7 credits 2V+2U+2A S. Capkun, S. Shinde

Abstract

The first part of the course covers general security concepts and hardware-based support for security. In the second part, the focus is on system design and methodologies for building secure systems.

Objective

In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

Content

The first part of the lecture covers hardware-based security concepts. Topics include the concept of physical and software-based side channel attacks on hardware resources, architectural support for security (e.g., memory management and permissions, disk encryption), and trusted execution environments (Intel SGX, ARM TrustZone, AMD SEV, and RISC- V Keystone).

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: common software faults (e.g., buffer overflows, etc.), bug- detection, writing secure software (design, architecture, QA, testing), compiler- supported security (e.g., control- flow integrity), and language- supported security (e.g., memory safety).

Along the lectures, model cases will be elaborated and evaluated in the exercises.
Students are familiar with fundamental network-security concepts.

Adaptability and Flexibility

- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

The course will cover topics spanning four broad themes with a focus on the first two themes:

1. Discrete-time linear systems and filters:
   - Type
   - assessed
   - Techniques and Technologies
   - assessed

2. The discrete Fourier transform and its use for digital filtering.
   - The course is about some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.
   - The main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of estimation theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust "inversion" of a linear filter.

3. The statistical perspective:
   - Students have an in-depth understanding of a range of important state-of-the-art security technologies.
   - Students can implement network-security protocols based on cryptographic libraries.

   - Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems.

   - This course provides an in-depth study of network attack techniques and methods to defend against them.

   - The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

   - The course will cover topics spanning four broad themes with a focus on the first two themes:
     1. Network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
     2. Network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
     3. Analysis and inference topics such as traffic monitoring and network forensics; and

   - In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

   - This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L, or 263-4680-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

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     3. Analysis and inference topics such as traffic monitoring and network forensics; and

   - In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

   - This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L, or 263-4680-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

   - The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.
Understanding the physics of failures and failure mechanisms enables reliability analysis and serves as a practical guide for electronic devices design, integration, systems development and manufacturing. The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.

The first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:

- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.

Textbook and all further documents in English.

Further details: https://isis-students.ee.ethz.ch/lectures/vlsi-1/
Objective
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes
Course material Script, computer demonstrations, exercises and problem solutions

Prerequisites / notice
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

227-0555-00L Distributed Systems W 4 credits 3G+1A R. Wattenhofer
Enrolled students will be notified by e-mail about the notice

Abstract
This course introduces the fundamentals of distributed systems. We study different protocols and algorithms that allow for fault-tolerant operation, and discuss practical systems that implement these techniques.

Objective
The objective of the course is for students to understand the theoretical principles and practical considerations of distributed systems. This includes the main models of fault-tolerant distributed systems (crash failures, byzantine failures, and selfishness), and the most important algorithms, protocols and impossibility results. By the end of the course, students should be able to reason about various concepts such as consistency, durability, availability, fault tolerance, and replication.

Content
We discuss the following concepts related to fault-tolerant distributed systems: client-server, serialization, two-phase protocols, three-phase protocols, Paxos, two generals problem, crash failures, impossibility of consensus, byzantine failures, agreement, termination, validity, Byzantine agreement, king algorithm, asynchronous Byzantine agreement, authentication, signatures, reliable and atomic broadcast, eventual consistency, blockchain, cryptocurrencies such as bitcoin and Ethereum, proof-of-work, proof-of-, smart contracts, quorum systems, fault-tolerant protocols such as pChain or pbft, distributed storage, distributed hash tables, physical and logical clocks, causality, selfishness, game theoretic models, mechanism design.

227-2210-00L Computer Architecture W 8 credits 6G+1A S. Sadrosadati, O. Mutlu

Abstract
Computer architecture is the science & art of designing and optimizing hardware components and the hardware/software interface to create a computer that meets design goals. This course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.

Objective
We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), new paradigms like processing-in-memory, parallel computing systems (including multicore processors, coherence and consistency, GPUs), heterogeneous computing, interconnection networks, specialized systems for major data-intensive workloads (e.g. graph analytics, bioinformatics, machine learning), etc. We will focus on fundamentals as well as cutting-edge research. Significant attention will be given to real-life examples and tradeoffs, as well as critical analysis of modern computing systems.

Content
The principles presented in the lecture are reinforced in the laboratory through 1) the design and implementation of a cycle-accurate simulator, where we will explore different components of a modern computing system (e.g., pipeline, memory hierarchy, branch prediction, prefetching, caches, multithreading), and 2) the extension of state-of-the-art research simulators (e.g., Ramulator) for more in-depth understanding of specific system components (e.g., memory scheduling, prefetching).

Lecture notes
All the materials (including lecture slides) will be provided on the course website: https://safari.ethz.ch/architecture/

The video recordings of the lectures are expected to be made available after lectures.

Literature
See https://safari.ethz.ch/architecture for past examples.

Prerequisites / notice

151-0593-00L Embedded Control Systems W 4 credits 6G C. Onder, M. Schmid Daners

Abstract
This course provides a comprehensive overview of embedded control systems. The concepts introduced are implemented and verified on a microprocessor-controlled haptic device.

Objective
Familiarize students with main architectural principles and concepts of embedded control systems.
This course discusses physical layer aspects of wireless communication and a wide range of security-related topics in the domain of wireless technologies. It mainly targets computer science students. Though useful, a background in signal processing or physical layer concepts is not required. A basic understanding of security (e.g. as taught in 252-0211.00L Information Security) is recommended.

After this course, students should be able to describe and classify security goals of and attacks on various wireless networks and technologies, with an emphasis on physical layer aspects.

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Objectives:
- Security aspects of cellular networks, WiFi, and Bluetooth Low Energy (BLE)
- Secure ranging with Ultra-Wide Band (UWB)
- Spreading techniques and their application in jamming-resilient communication and Global Navigation Satellite Systems (GNSSs)
- Physical layer security schemes

Methods and Techniques:
- Introduction to wireless communication
- Physical layer security schemes
- Spreading techniques and their application in jamming-resistant communication and Global Navigation Satellite Systems (GNSSs)
- Secure ranging with Ultra-Wide Band (UWB)
- Security aspects of cellular networks, WiFi, and Bluetooth Low Energy (BLE)

Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, lower bounds for the chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows: In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Waring theorem.
- Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Students are expected to have a mathematical background and should be able to write rigorous proofs.

**Electronics and Photonics**

**Core Subjects**

These core subjects are particularly recommended for the field of “Electronics and Photonics”.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>227-0146-00L</td>
<td>Data Conversion System Design</td>
<td>W</td>
<td>6 credits</td>
<td>2V+2U</td>
<td>T. Burger, G. Cervelli, R. Reutemann</td>
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</table>

This course provides a thorough treatment of integrated data conversion systems from system level specifications and trade-offs, over architecture choice down to circuit implementation.
Data conversion systems are substantial sub-parts of many electronic systems, e.g. the audio conversion system of a home-cinema systems or the base-band front-end of a wireless modem. Data conversion systems usually determine the performance of the overall system in terms of dynamic range and linearity. Students will learn the underlying principles of data conversion and be introduced to the different methods and circuit architectures to implement such a conversion. The conversion methods such as successive approximation or algorithmic conversion are explained based on their operation principle accompanied with the appropriate mathematical calculations, including effects of non-idealities in some cases. After successful completion of the course students should understand the concept of an ideal ADC, know all major converter architectures, their principle of operation and what governs their performance.

Content
- Introduction: examples of data conversion architectures; information representation; abstraction, categorization and symbolic representation; basic conversion algorithms; data converter application; tradeoffs among key parameters; ADC taxonomy.
- Dual-slope & successive approximation register (SAR) converters: dual slope principle & converter; SAR ADC operating principle; SAR implementation with a capacitive array; range extension with segmented array.
- Algorithmic & pipelined A/D converters: algorithmic conversion principle; sample & hold stage; pipe-lined converter; multiplying DAC; flash sub-ADC and n-bit MDAC; redundancy for correction of non-idealities, error correction.
- Performance metrics and non-linearity: ideal ADC; offset; gain error, differential and integral non-linearities; capacitor mismatch; impact of capacitor mismatch on SAR ADC's performance.
- Flash, folding an interpolating analog-to-digital converters: flash ADC principle, thermometer to binary coding, sparkle correlation; limitations of flash converters: the folding principle, residue extraction; folding amplifiers; cascaded folding; interpolation for folding converters; cascaded folding and interpolation.
- Noise in analog-to-digital converters: types of noise; noise calculation in electronic circuit, KTC-noise, sampled noise; noise analysis in switched-capacitor circuits; aperture time uncertainty and sampling jitter.
- Delta-sigma A/D-converters: linearity and resolution; from delta-modulation to delta-sigma modulation; first-order delta-sigma modulation, circuit level implementation; clock-jitter & SNR in delta-sigma modulators; second-order delta-sigma modulation, higher-order modulation, design procedure for a single-loop modulator.

Lecture notes
Slides are available online under https://iis-students.ee.ethz.ch/lectures/analog-to-digital-converters/

Abstract
This third course in our VLSI series is concerned with full-custom digital integrated circuits. The goals include learning the design of digital circuits on the schematic, layout, gate, and register-transfer levels. The use of state-of-the-art CAD software (Cadence Virtuoso) in order to simulate, optimize, and characterize digital circuits is another important topic of this course.

Objective
At the end of this course, you will
- understand the design of the main building blocks of state-of-the-art digital integrated circuits
- be able to design and optimize digital integrated circuits on the schematic, layout, and gate levels
- be able to use standard industry software (Cadence Virtuoso) for drawing, simulating, and characterizing digital circuits
- understand the performance trade-offs between delay, area, and power consumption

Content
The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack towards logic gates and increasingly complex digital circuit structures. The topics of this course include:
- Nanometer MOSFETs
- Static and dynamic behavior of complementary MOS (CMOS) inverters
- CMOS gate design, sizing, and timing
- Full-custom standard-cell design
- Wire models and parasitics
- Latch and flip-flop circuits
- Gate-level timing analysis and optimization
- Static and dynamic power consumption; low-power techniques
- Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
- Arithmetic and logic circuits
- Fixed-point and floating-point arithmetic
- Synchronous and asynchronous design principles
- Memory circuits (ROM, SRAM, and DRAM)
- In- and near-memory processing architectures
- Full-custom accelerator circuits for machine learning

The exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

Literature
- N. H. E. Weste and D. M Harris, CMOS VLSI Design: A Circuits and Systems Perspective (4th Ed.), Addison-Wesley

Prerequisites / notice
It is highly recommended to attend the course "Analog Integrated Circuits" of Prof. T. Jang as a preparation for this course.

Competencies
Subject-specific Competencies
- assessed
- assessed

Method-specific Competencies
- Analytical Competencies
- fostered

227-0147-10L
VLSI 3: Full-Custom Digital Circuit Design

W 6 credits 2V+3U C. Studer, O. Cañada Fernández

Abstract
This third course in our VLSI series is concerned with full-custom digital integrated circuits. The goals include learning the design of digital circuits on the schematic, layout, gate, and register-transfer levels. The use of state-of-the-art CAD software (Cadence Virtuoso) in order to simulate, optimize, and characterize digital circuits is another important topic of this course.

Objective
At the end of this course, you will
- understand the design of the main building blocks of state-of-the-art digital integrated circuits
- be able to design and optimize digital integrated circuits on the schematic, layout, and gate levels
- be able to use standard industry software (Cadence Virtuoso) for drawing, simulating, and characterizing digital circuits
- understand the performance trade-offs between delay, area, and power consumption

Content
The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack towards logic gates and increasingly complex digital circuit structures. The topics of this course include:
- Nanometer MOSFETs
- Static and dynamic behavior of complementary MOS (CMOS) inverters
- CMOS gate design, sizing, and timing
- Full-custom standard-cell design
- Wire models and parasitics
- Latch and flip-flop circuits
- Gate-level timing analysis and optimization
- Static and dynamic power consumption; low-power techniques
- Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
- Arithmetic and logic circuits
- Fixed-point and floating-point arithmetic
- Synchronous and asynchronous design principles
- Memory circuits (ROM, SRAM, and DRAM)
- In- and near-memory processing architectures
- Full-custom accelerator circuits for machine learning

The exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

Literature
- N. H. E. Weste and D. M Harris, CMOS VLSI Design: A Circuits and Systems Perspective (4th Ed.), Addison-Wesley

Prerequisites / notice
VLSI 3 can be taken in parallel with “VLSI 1: HDL-based design for FPGAs” and is designed to complement the topics of this course. Basic analog circuit knowledge is required.

Competencies
Subject-specific Competencies
- assessed
- assessed

Method-specific Competencies
- Analytical Competencies
- fostered

227-0301-00L
Optical Communication Fundamentals

W 6 credits 2V+1U+1P J. Leuthold

Abstract
The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

Objective
An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the important elements will be passed on. Students attending the lecture will further get engaged in critical discussion on societal, economical and environmental aspects related to the on-going exponential growth in the field of communications.
Understanding concepts of light localization and light-matter interactions on the sub-wavelength scale.

Lecture notes are handed out.

2V+2U

This course introduces to different electric machine concepts and provides a deeper understanding of their detailed operating principles.

D. Bortis, S. We start with the angular spectrum representation of fields to understand the classical resolution limit. We continue with the theory of

Subject-specific Competencies

assessed

Analytical Competencies fostered

Method-specific Competencies

assessed

Decision-making fostered

Problem-solving fostered

Lecture notes


227-0517-10L Fundamentals of Electric Machines W 6 credits 4G D. Bortis

Abstract

This course introduces to different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.

Objective

The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are research enabled by the rapid advance of nanotechnology. Nano-optics embraces topics such as plasmonics, optical antennas, optical trapping and manipulation, and high/ super-resolution imaging and spectroscopy.

Content

- Fundamentals in magnetic circuits and electromechanical energy conversion
- Force and torque calculation
- Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine)
- Complex space vector notation, rotating coordinate system (dq-transformation)
- Loss components in electric machines, scaling laws of electromechanical actuators
- Mechanical and thermal modelling.

Lecture notes

Lecture notes and associated exercises including correct answers

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies fostered

Method-specific Competencies

Analytical Competencies assessed

Decision-making fostered

Problem-solving fostered

227-0663-00L Nano-Optics W 6 credits 2V+2U M. Frimmer

Abstract

Nano-Optics is the study of light-matter interaction at the sub-wavelength scale. It is an flourishing field of fundamental and applied research enabled by the rapid advance of nanotechnology. Nano-optics embraces topics such as plasmonics, optical antennas, optical trapping and manipulation, and high/super-resolution imaging and spectroscopy.

Objective

Understanding the concepts of light localization and light-matter interactions on the sub-wavelength scale.

Content

We start with the angular spectrum representation of fields to understand the classical resolution limit. We continue with the theory of strongly focused light, the point spread function, and resolution criteria of conventional microscopy, before turning to super-resolution techniques and, based on near- and far-fields. We introduce the local density of states and approaches to control spontaneous emission rates in inhomogeneous environments, including optical antennas. Finally, we touch upon optical forces and their applications in optical tweezers.

Prerequisites / notice

- Electromagnetic fields and waves (or equivalent)
- Physics I+II

227-1033-00L Neuromorphic Engineering I W 6 credits 2V+3U T. Delbrück, G. Indiveri, S.-C. Liu, M. Payvand

Abstract

This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Objective

Understanding of the characteristics of neuromorphic circuit elements.
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Literature
S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

Prerequisites
Particular: The course is highly recommended for those who intend to take the spring semester course ‘Neuromorphic Engineering II’, that teaches the conception, simulation, and physical layout of such circuits with chip design tools.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

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<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0111-01L</td>
<td>Communication Electronics II</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>H. Wang</td>
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<tr>
<td>Abstract</td>
<td>This course focuses on the advanced concepts and designs of wireless circuits and systems. The first half introduces key building blocks and popular topologies of low noise amplifiers, power amplifiers, T/R switches, phase shifters, variable gain amplifiers, and combiners/splitters. The second half will cover advanced phased array systems for 5G/6G, satellite communication (SATCOM), and radars.</td>
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<td>Objective</td>
<td>After attending the lectures, participating in the exercise sessions, and working on the homework problems (which include MATLAB coding assignments), the students will be able to:</td>
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<td>- understand the fundamentals of digital communication systems</td>
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<td>- explain the principles of modulation, demodulation, detection, and error correction</td>
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<td>- analyze error rates of simple digital communication systems</td>
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<td>- implement simple MATLAB simulations to calculate error rates</td>
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<td>Content</td>
<td>The course focuses on the fundamentals of digital communication systems. The course starts with analog modulation and discusses the main building blocks of modern digital communication systems. The topics include:</td>
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<td>- analog and digital modulation</td>
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<td>- baseband and passband representation; up- and down-conversion</td>
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<td>- communication channels as LTI systems</td>
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<td>- discretizing communication systems; sampling and quantization</td>
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<td>- noise, signal-to-noise ratio (SNR), and interference</td>
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<td>- detection theory and error rates</td>
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<td>- basics of forward error correction</td>
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<td>- orthogonal frequency-division multiplexing (OFDM)</td>
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<td>- building blocks of modern communication systems</td>
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<td>Literature</td>
<td>Lecture notes will be distributed electronically at the beginning of the semester.</td>
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<td>Competencies</td>
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| 227-0121-00L| Communication Systems                        | W    | 6    | 4G    | C. Studer, S. M. Moser |
| Abstract    | The course teaches the fundamentals of digital communication systems. The main topics are analog and digital modulation, signals and linear time-invariant systems, baseband and passband representations, continuous-time and discrete-time channels, noise, inter-symbol interference, detection theory, as well as the basics of forward error correction and information theory. |
| Objective   | After attending the lectures, participating in the exercise sessions, and working on the homework problems (which include MATLAB coding assignments), the students will be able to: |
|             | - understand the fundamentals of digital communication systems |
|             | - explain the principles of modulation, demodulation, detection, and error correction |
|             | - analyze error rates of simple digital communication systems |
|             | - implement simple MATLAB simulations to calculate error rates |
| Content     | The course focuses on the fundamentals of digital communication systems. The course starts with analog modulation and discusses the main building blocks of modern digital communication systems. The topics include: |
|             | - essential components of digital communication systems |
|             | - analog and digital modulation |
|             | - baseband and passband representation; up- and down-conversion |
|             | - communication channels as LTI systems |
|             | - discretizing communication systems; sampling and quantization |
|             | - noise, signal-to-noise ratio (SNR), and interference |
|             | - detection theory and error rates |
|             | - basics of forward error correction |
|             | - basics of information theory |
|             | - orthogonal frequency-division multiplexing (OFDM) |
|             | - building blocks of modern communication systems |
| Literature  | Lecture notes will be distributed electronically at the beginning of the semester. |
| Competencies| Subject-specific Competencies                |      |      |       |               |
|             | Concepts and Theories                        |      |      |       | assessed      |
|             | Techniques and Technologies                 |      |      |       | assessed      |
|             | Method-specific Competencies                 |      |      |       | assessed      |
|             | Analytical Competencies                      |      |      |       | assessed      |
|             | Problem-solving                             |      |      |       | assessed      |
|             | Personal Competencies                        |      |      |       | fostered      |
|             | Critical Thinking                            |      |      |       | fostered      |
|             | Integrity and Work Ethics                   |      |      |       |               |

| 227-0155-00L| Machine Learning on Microcontrollers         | W    | 6    | 4G    | M. Magno      |
| Abstract    | Machine Learning (ML) and artificial intelligence are pervading the digital society. Today, even low power embedded systems are incorporating ML, becoming increasingly “smart”. This lecture gives an overview of ML methods and algorithms to process and extract useful near-sensor information in end-nodes of the “internet-of-things”, using low-power microcontrollers/ processors (ARM-Cortex-M; RISC-V) |
| Objective   | Learn how to Process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ECG bio-signals, cameras…). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers. |
The final goal of the course is a deep understanding of machine learning and its practical implementation on single- and multi-core microcontrollers, coupled with performance and energy efficiency analysis and optimization. The main topics of the course include:

- Sensors and sensor data acquisition with low power embedded systems
- Machine Learning: Overview of supervised and unsupervised learning and in particular supervised learning (Bayes Decision Theory, Decision Trees, Random Forests, kNN-Methods, Support Vector Machines, Convolutional Networks and Deep Learning)
- Low-power embedded systems and their architecture. Low Power microcontrollers (ARM-Cortex M) and RISC-V-based Parallel Ultra Low Power (PULP) systems-on-chip.
- Low power smart sensor system design: hardware-software tradeoffs, analysis, and optimization. Implementation and performance evaluation of ML in battery-operated embedded systems.

The laboratory exercises will show how to address concrete design problems, like motion, gesture recognition, emotion detection, image and sound classification, using real sensors data and real MCU boards.

Presentations from Ph.D. students and the visit to the Digital Circuits and Systems Group will introduce current research topics and international research projects.

<table>
<thead>
<tr>
<th>Lecture notes</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Script and exercise sheets. Books will be suggested during the course.</td>
<td>Prerequisites: C language programming. Basics of Digital Signal Processing. Basics of processor and computer architecture. Some exposure to machine learning concepts is also desirable</td>
</tr>
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<table>
<thead>
<tr>
<th>227-0157-00L</th>
<th>Semiconductor Devices: Physical Bases and Simulation</th>
<th>W</th>
<th>4 credits</th>
<th>3G</th>
<th>A. Schenk, C. I. Roman</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>The course addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical simulation. Necessary basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided. Computer simulations of the most important devices and of interesting physical effects supplement the lectures.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The course aims at the understanding of semiconductor devices, of the foundations in the physical modeling of transport and its numerical simulation. During the course also basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided.</td>
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<tr>
<td><strong>Content</strong></td>
<td>The main topics are: transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model, hydrodynamic model), physical characterization of silicon (intrinsic properties, scattering processes), mobility of cold and hot carriers, recombination (Shockley-Read-Hall statistics, Auger recombination), impact ionization, metal-semiconductor contact, metal-insulator-semiconductor structure, and heterojunctions. The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>The script (in book style) can be downloaded from: <a href="https://iis-students.ee.ethz.ch/lectures/">https://iis-students.ee.ethz.ch/lectures/</a></td>
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<tr>
<td><strong>Literature</strong></td>
<td>The script (in book style) is sufficient. Further reading will be recommended in the lecture.</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Qualifications: Physics I-II, Semiconductor devices (4. semester).</td>
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<tr>
<th>227-0166-00L</th>
<th>Analog Integrated Circuits</th>
<th>W</th>
<th>6 credits</th>
<th>4G</th>
<th>T. Jang</th>
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<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.</td>
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<tr>
<td><strong>Content</strong></td>
<td>The basic elements, design issues and techniques for analog integrated circuits will be taught in this course. Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors. The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Handsouts of presented slides. No script but an accompanying textbook is recommended.</td>
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<tr>
<th>227-0377-10L</th>
<th>Physics of Failure and Reliability of Electronic Devices and Systems</th>
<th>W</th>
<th>3 credits</th>
<th>2V</th>
<th>I. Shorubalko, M. Held</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Understanding the physics of failures and failure mechanisms enables reliability analysis and serves as a practical guide for electronic devices design, integration, systems development and manufacturing. The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.</td>
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<td><strong>Objective</strong></td>
<td>Provide an understanding of the physics of failure and reliability. Introduce the degradation and failure mechanisms, basics of failure analysis, methods and tools of reliability testing.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Summary of reliability and failure analysis terminology; physics of failure: materials properties, physical processes and failure mechanisms; failure analysis; basics and properties of instruments; quality assurance of technical systems (introduction); introduction to stochastic processes; reliability analysis; component selection and qualification; maintainability analysis (introduction); design rules for reliability, maintainability, reliability tests (introduction).</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Comprehensive copy of transparencies</td>
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<tr>
<th>227-0443-00L</th>
<th>Space Communications</th>
<th>W</th>
<th>4 credits</th>
<th>2V+2U</th>
<th>J. Smajic, R. Muff</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>The course has the following main goals: (a) to give a comprehensive overview of challenges on communication equipment imposed by space flight missions, (b) to present the theoretical fundamentals and existing practical solutions of communication technology for space missions, and (c) to review existing and future communication technologies for inter-satellite links, inter-spacecraft links, as well as satellite communications links.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>After completing this course, a student will understand the challenges of space flight imposed on communication components and systems, the available existing solutions of those problems, the main components of communications systems suitable for a spacecraft, and future technologies capable of enabling ultra-fast RF/mm-Wave, THz, and Laser communication links.</td>
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</table>
Analog Signal Processing and Filtering

- Space missions: scenarios and challenges on flight equipment
- Space communications: architectures, assets, payload, link budgets, and use cases.
- Electromagnetic waves: radiation, operating principles of antennas, antenna types, and antenna parameters.
- RF electronics and antenna arrays architecture for SATCOM: low-noise amplifiers, beam forming, spatial filtering, and design examples.
- Microwave photonics for space applications: analog photonic links, optical generation and distribution of RF signals, and advanced RF filtering using photonic techniques.
- Communication channels: channel modeling, incl. atmospheric effects, Doppler, synchronization tracking, beam forming, tracking and finding.
- Signal modulation: modulation formats, adaptive optics, phase noise, and quantum key distribution (QKD).
- Outlook for emerging use-cases (ranging, time-, nav- and position-transfer (PNT))

Lecture notes
Lecture notes, Matlab programs, exercises and their solutions will be handed out.

At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during:

- Space missions: scenarios and challenges on flight equipment
- Communication channels: channel modeling, incl. atmospheric effects, Doppler, synchronization tracking, beam forming, tracking and finding.

Lecture notes
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- Communication channels: channel modeling, incl. atmospheric effects, Doppler, synchronization tracking, beam forming, tracking and finding.
- Signal modulation: modulation formats, adaptive optics, phase noise, and quantum key distribution (QKD).
- Outlook for emerging use-cases (ranging, time-, nav- and position-transfer (PNT))

Prerequisites / notice
Bachelor Studies of Electrical Engineering or Physics.

227-0468-00L Analog Signal Processing and Filtering

W 6 credits 2V+2U H. Schmid
Suitable for Master Students as well as Doctoral Students.

Abstract
This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers.

Objective
This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers. The way the exam is done allows for the different interests of the two groups.

Content
At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during the whole term to analyze circuits on a system level (analog continuous-time, analog discrete-time, mixed-signal and digital) and understand how signals propagate through them. The theory and CMOS implementation of active Filters is then discussed in detail using the example of Gm-C filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators follows. The link to the practical design of circuits and systems is done with an overview over different quality measures and figures of merit used in scientific literature and datasheets. Finally, an introduction to discrete-time and mixed-domain filters and circuits is given, including sensor read-out amplifiers, correlated double sampling, and chopping, and an introduction to sigma-delta A/D and D/A conversion on a system level.

This lecture does not go down to the details of transistor implementations. The lecture "227-0166-00L Analog Integrated Circuits" complements this lecture very well in that respect.

Lecture notes
The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the technical content.

Details: https://people.ee.ethz.ch/~haschmid/asfwiki/

The graph methods are also supported with teaching videos: https://tube.switch.ch/channels/d206c96c?order=episodes, and a Python-based open-source tool to manipulate graphs is available on https://github.com/hanspi42/signalflowgrapher

Some material is protected by password; students from ETHZ who are interested can write to haschmid@ethz.ch to ask for the password even if they do not attend the lecture.

Prerequisites / notice
Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.

Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria ...) and of the main properties of linear systems is necessary.
Analytical Competencies

- Fostered
- Assessed

Adaptability and Flexibility

- Fostered
- Assessed

Social Competencies

- Communication
  - Fostered
- Cooperation and Teamwork
  - Fostered
- Customer Orientation
  - Fostered
- Leadership and Responsibility
  - Fostered
- Self-presentation and Social Influence
  - Fostered
- Sensitivity to Diversity
  - Fostered
- Negotiation
  - Fostered

Personal Competencies

- Adaptability and Flexibility
  - Fostered
- Creative Thinking
  - Fostered
- Critical Thinking
  - Assessed
- Integrity and Work Ethics
  - Fostered
- Self-awareness and Self-reflection
  - Fostered
- Self-direction and Self-management
  - Fostered

227-0615-00L Simulation of Photovoltaic Devices - From Materials to W 3 credits 2G U. Aeberhard

Abstract
The lecture provides an introduction to the theoretical foundations and numerical approaches for the simulation of photovoltaic power conversion, from the microscopic description of component materials to macroscopic continuum modelling of solar cells and network simulation or effective models for performance prediction of entire solar modules.

Objective
- Get an overview of the current status of photovoltaic technology. Understand the physics of photovoltaic energy conversion and solar cell device operation. Know how to obtain and assess by simulation the key material properties and device parameters. Be able to use standard device simulation tools to analyze, optimize, and predict the performance of solar cells and modules.

Content
Photovoltaic technology: history and overview; The solar spectrum; Thermodynamics of solar energy conversion; Detailed balance models and efficiency limit; Microscopic rates of charge carrier generation and recombination; Optical simulation of solar cells; Models for charge transport in semiconductor devices; High-efficiency wafer-based (silicon) photovoltaics; Thin film photovoltaics based on disordered materials (amorphous silicon, organic PV); High-efficiency thin film photovoltaics (CIGS, CdTe, metal-halide perovskites); PV beyond the single junction detailed balance (Shockley-Queisser) limit; Simulation of photovoltaic modules; Energy yield and performance modelling for PV systems; Quantum simulation of nanostructure-based solar cell devices (bonus lecture).

Literature
- M. A. Green, „Solar cells: operating principles, technology, and system applications“, Prentice Hall, 1982.

Prerequisites / notice
- Undergraduate physics (including basic quantum mechanics), mathematics, semiconductor devices, optics. Knowledge of some scripting language (e.g. python) is of advantage.

Competencies

- Subject-specific Competencies
  - Assessed
  - Fostered

227-0617-00L Solar Cells W 4 credits 3G Y. Romanyuk, R. Carron

Abstract
Physics, technology, characteristics and applications of photovoltaic solar cells and systems.

Objective
The students will appreciate the potential of solar radiation and photovoltaics, will learn the physics and technology of various solar cells, and will get to know the design basics of PV modules and systems for different applications.

Content
Introduction to photovoltaics and economic aspects, solar radiation, semiconductor physics and operation of solar cells, technology of wafer-based (Si, GaAs, multi-junction) and thin-film (CIGS, CdTe, perovskite) solar cells, emerging technologies, design of PV modules, systems and plants including system components such as inverters and controllers, engineering procedures with software demonstration, integration in buildings and other specific examples such concentrated photovoltaics and power generation for space applications.

Lecture notes
- Lecture slides (PDF files in English) will be available on Moodle and lecture recordings will be available on the ETH video portal.

Prerequisites / notice
- Prerequisites: Basic knowledge of semiconductors.

Competencies

- Subject-specific Competencies
  - Assessed
  - Fostered

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### 227-0619-00L Charge Transport in Energy Conversion and Storage Devices

**W 6 credits 2V+2U C. Battaglia, A. Senocrate**

**Abstract**
The students will be introduced to the fundamental concepts of charge transport in solar cells, batteries, and electrolysers. Emphasizing analogies between semiconductor physics and electrochemistry, this course is designed to provide a unified modern perspective of energy conversion and storage concepts for students in electrical engineering, materials science, physics, and chemistry.

**Objective**
By the end of the course, the students will (1) understand the fundamentals of electronic and ionic charge transport, (2) understand the operational principles of solar cells, batteries, and electrolysers, and (3) understand fundamental limits for each device type. In addition, the students will learn how to simulate these devices during guided exercise sessions and develop an intuitive understanding on how to interpret the most important device characteristics.

**Literature**
R. Huggins, Advanced Batteries, DOI:10.1007/9780387764245

**Prerequisites / notice**
Be motivated to change the world to renewable energies!

This course is taught simultaneously at ETH Zurich and EPFL. All lectures will be recorded by zoom and made available to the students. Lectures will be streamed live from ETH Zurich with four lectures taught onsite at EPFL Lausanne.

A visit to Empa's Energy Conversion and Storage Labs will be organized during the semester. Possibility to interact and meet your classmates from EPFL via online lecture platform and during two special lectures with guest lecturers from industry (one guest lecture by ABB at ETH Zurich, one guest lecture by Northvolt at EPFL). Travel expenses for students will be covered.

Elements of calculus will be reviewed during the lectures, where necessary, but we leave the hard work of solving coupled differential charge transport equations to the computer and focus on developing a strong intuition. Prior knowledge in semiconductor physics or electrochemistry is an advantage, but not a prerequisite.

Students are required to bring a windows-compatible computer with a common data analysis software to the exercises. Apps for simulating devices under different operating conditions will be made available to the students.

**Competencies**
- Subject-specific Competencies
- Concepts and Theories

**227-0653-00L Quantum Measurements and Optomechanics**

- **W 4 credits 2V+1U M. Frimmer**

**Abstract**
The measurement process is at the heart of both science and engineering. The limitations of measurement precision is ultimately dictated by the laws of quantum mechanics. This course provides the knowledge necessary to understand current state-of-the-art quantum measurement systems operating at their fundamental limits with a particular focus on optomechanical implementations.

**Objective**
The goal of this course is to understand both the standard and the ultimate quantum limits of measurement precision.

**Content**
The lecture starts with summarizing the relevant fundamentals of the treatment of noisy signals. We familiarize ourselves with the concept of measurement imprecision in light-based measurement systems. To this end, we consider the process of photodetection and discuss the statistical fluctuations arising from the quantization of the electromagnetic field into photons. We exemplify our insights at hand of concrete examples, such as homodyne and heterodyne photodetection. Furthermore, we focus on the process of measurement backaction, the inevitable result of the interaction of the probe with the system under investigation. We discuss the “standard quantum limit” as it arises from the balance of measurement imprecision and backaction, before turning to approaches to overcome it and reach the fundamental “Heisenberg limit”. The course emphasizes the connection between the taught concepts and current state-of-the-art research carried out in the field of optomechanics. Exercises serve to consolidate our understanding and insight.

**Prerequisites / notice**
1. Electrodynamics
2. Physics 1.2
3. Introduction to quantum mechanics

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**Competencies**

<table>
<thead>
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<th>Subject-specific Competencies</th>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Social Competencies</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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**227-0654-00L  Carbon-based Nanoelectronics**

**Abstract**

This course explores the exciting realm of carbon-based nanoelectronics, where the remarkable quantum properties of materials like graphene, carbon nanotubes, graphene nanoribbons, and single molecules are used for building electronic devices.

**Objective**

The objective of this course is to understand how the electronic properties of carbon-based materials can be exploited for fabricating quantum devices. We will delve into both the theoretical and experimental aspects, discussing how these materials' unique properties can be translated into device functionality.

On the theoretical side, we'll cover how the chemical structure of the material and its dimensionality, ranging from 0D to 2D, affects the electronic properties. We'll also discuss how charge carriers flow through the devices and what charge transport mechanisms are at play.

On the experimental side, we'll cover how such devices are fabricated, including how the materials are synthesized. We'll also discuss how to characterize the devices and assess their performance.

**Content**

The course will cover the following carbon-based materials:
- Single-molecule
- Graphene (single layer, bilayer, twisted bilayer)
- Graphene nanoribbons
- Carbon nanotubes

For each material, we will discuss:
- Electronic structure and charge transport properties
- Material synthesis and characterization
- Device integration and characterization

The course also includes a presentation by each student in which a related scientific publication is discussed. This presentation is compulsory and accounts for 50% of the grade.

**Lecture notes**

Lecture slides are distributed every week. In addition, relevant scientific articles and book chapters will be provided for self-study.

**Literature**

In addition to the slides, the following supplementary books can be recommended:


**Prerequisites / notice**

A basic knowledge of solid-state physics and quantum mechanics is required. The course is taught in English.

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**Competencies**

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- Graphene (single layer, bilayer, twisted bilayer)
- Graphene nanoribbons
- Carbon nanotubes

For each material, we will discuss:
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- Device integration and characterization

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**Lecture notes**

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**Literature**

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**Prerequisites / notice**

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<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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**227-0659-00L  Integrated Systems Seminar**

**Abstract**

In the "Fachseminar IIS" the students learn to communicate topics, ideas or problems of scientific research by listening to more experienced authors and by presenting scientific work in a conference-like situation for a specific audience.

**Objective**

The seminar aims at instructing graduate and PhD students in the basics of presentation techniques, i.e. "how to give a professional talk". Attendees have the possibility to become acquainted with a current topic by a literature study, and to present the results thereof in a 20 minutes talk in English. The participation at the seminar gives also an overview on current problems in modern nano- and opto-electronics.

**Content**

The seminar topics' are simulation of nanoelectronic processes and devices, and the optical as well as electronic simulation of optoelectronic devices as lasers, photodiodes, etc.

The students learn how to find the right literature for a certain topic quickly, as well as how to prepare a talk for a scientific conference, i.e. presentation techniques.

**Lecture notes**

Presentation material

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**227-0671-00L  Nanodevices and Circuits for the Beyond-Moore Era**

**Abstract**

Big Data, AI and the Internet of Things demand new hardware which overcomes the limitations of von Neumann architectures. The lecture gives an insight into how the fundamental physics and the resulting complex functionalities of nanodevices and circuits offer viable alternatives. Their increased computational power and energy efficiency are demonstrated through neuromorphic computing applications.

**Objective**

The students will gain a firm understanding in the theory and pioneering experiments of electronic and heat transport at atomic-to-nanometer length-scales. Advanced device functionalities enabled by recently discovered material systems will be covered. The students will learn how to exploit such phenomena for designing nanodevices and circuits to energy-efficiently implement neuromorphic algorithms for a sustainable future of information technologies.

**Lecture notes**

The presentation slides and further material will be provided every week.

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**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>assessed</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
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<tr>
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<td>Self-direction and Self-management</td>
<td>fostered</td>
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</table>
With guidance from a tutor, the individual silicon microsystem process steps that are required for the fabrication of an accelerometer are fostered. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

Content
The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetics, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or chose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

## 227-2037-00L Physical Modelling and Simulation

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>Competencies</th>
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</thead>
<tbody>
<tr>
<td>Basic knowledge of solid state physics and semiconductors.</td>
<td>Subject-specific Competencies</td>
</tr>
<tr>
<td></td>
<td>Concepts and Theories</td>
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<tr>
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<td>Techniques and Technologies</td>
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<td></td>
<td>Method-specific Competencies</td>
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<td>Analytical Competencies</td>
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<td>Problem-solving</td>
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<td>Communication</td>
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<td>Personal Competencies</td>
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<td>Critical Thinking</td>
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</tbody>
</table>

### Content
This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics, and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.

### Objective
Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

### 151-0620-00L Embedded MEMS Lab

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>Competencies</th>
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</thead>
<tbody>
<tr>
<td>151-0621-00L Microsystems Technology, registration to this practicum at previous semester, and by drawing lots.</td>
<td>Embedded MEMS Lab</td>
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<tr>
<td></td>
<td>Practical course: Students are introduced to the process steps required for the fabrication of MEMS (Micro Electro Mechanical System) and carry out the fabrication and testing steps in the clean rooms by themselves. Additionally, they learn the requirements for working in clean rooms. Processing and characterization will be documented and analyzed in a final report.</td>
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<tr>
<td></td>
<td>Students learn the individual process steps that are required to make a MEMS (Micro Electro Mechanical System). Students carry out the process steps themselves in laboratories and clean rooms. Furthermore, participants become familiar with the special requirements (cleanliness, safety, operation of equipment and handling hazardous chemicals) of working in the clean rooms and laboratories. The entire production, processing, and characterization of the MEMS is documented and evaluated in a final report.</td>
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<tr>
<td></td>
<td>With guidance from a tutor, the individual silicon microsystem process steps that are required for the fabrication of an accelerometer are carried out:</td>
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<td>- Photolithography, dry etching, wet etching, sacrificial layer etching, various cleaning procedures</td>
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<td>- Packaging and electrical connection of a MEMS device</td>
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<td></td>
<td>- Testing and characterization of the MEMS device</td>
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<td></td>
<td>- Written documentation and evaluation of the entire production, processing and characterization</td>
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</tbody>
</table>

### Literature
The document provides sufficient information for the participants to successfully participate in the course.

### Prerequisites / notice
Participating students are required to attend all scheduled lectures and meetings of the course.

For safety and efficiency reasons the number of participating students is limited. We regret to restrict access to this course by the following rules:

- **Priority 1:** all master students of the master's program in "Micro and Nanosystems".
- **Priority 2:** master students of the Master's program in "Mechanical Engineering" with a specialization in Microsystems and Nanoscale Engineering (MAYT-tutors Pros Daraio, Dual, Hierold, Koumoutsakos, Nelson, Norris, Poulilakkos, Pratsinis, Stemmer), who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.
- **Priority 3:** master students, who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.
- **Priority 4:** all other students (PhD, bachelor, master) with a background in silicon or microsystems process technology.

If there are more students in one of these priority groups than places available, we will decide by (in following order) best achieved grade from 151-0621-00L Microsystems Technology, registration to this practicum at previous semester, and by drawing lots.

Students will be notified at the first lecture of the course (introductory lecture) as to whether they are able to participate.

The course is offered in autumn and spring semester.

### 363-0389-00L Technology and Innovation Management

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>Competencies</th>
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</thead>
<tbody>
<tr>
<td>Basic knowledge of solid state physics and semiconductors.</td>
<td>Technology and Innovation Management</td>
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<tr>
<td></td>
<td>This course focuses on the sources of innovation (with a specific focus on digital technologies), the tools and techniques that organizations deploy to innovate routinely, and the strategic implications of technical change at different levels of analysis: individuals, firms and whole ecosystems.</td>
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<tr>
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<td>This course intends to enable all students to:</td>
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<td>- Acquire and understand the basic jargon, concepts and methods necessary to discuss, in a precise and concise manner, innovation processes and their outcomes at different levels of analysis</td>
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<td></td>
<td>- Analyze the differences between individual and organizational decision processes and their innovative outcomes</td>
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<td></td>
<td>- Evaluate critically the potential of different (digital) technologies to impact business organizations.</td>
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<tr>
<td></td>
<td>Organizations and people are faced with a fundamental decision: they have to allocate resources between well-known tasks that reliably generate positive results; or explore new ways of doing things, new technologies, products and services. The latter is a high risk choice. Its rewards can be high, but the chances of success are small. How do firms organize to take these decisions? What kind of management skills are necessary to take them? What kind of tools and methods are deployed to sustain managerial decision-making in highly volatile environments? These are the central questions on which this course focuses, relying on a combination of lectures, case-based discussion, and guest speakers.</td>
</tr>
</tbody>
</table>

### Objective
This course focuses on the sources of innovation (with a specific focus on digital technologies), the tools and techniques that organizations deploy to innovate routinely, and the strategic implications of technical change at different levels of analysis: individuals, firms and whole ecosystems.
Algebraic Methods in Combinatorics

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Leadership and Responsibility
- Sensitivity to Diversity

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

401-3055-64L Algebraic Methods in Combinatorics

W 5 credits 2V+1U not available

Abstract
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

Objective
The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

Content
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lecture notes
Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

402-0475-00L Terahertz Science and Applications

W 5 credits 2V+1U E. Abreu

Abstract
The Terahertz (THz) range (0.1 – 10 THz), lies between the infrared and microwave spectral regions and has become accessible in the past few years. This new capability has had great impact in scientific research, and has led to technological advances and to the development of a variety of applications and devices. This course provides an introduction to THz science, technology and applications.

Objective
The goal of this course is to enable students to determine whether a THz solution can be applied to a particular scientific or technological problem. Armed with the fundamentals of THz science and of current THz technologies, covered in this introductory course, students will be able to weigh the capabilities, advantages and limitations of THz tools to address topics ranging from phonons in solid state systems and molecular vibrations in solutions to medical imaging and wireless communications.

Lecture notes
Will be distributed via moodle.

Literature
Yun-Shik Lee, Principles of Terahertz Science and Technology, Springer 2009
Additional references distributed via moodle.

Prerequisites / notice
Basic knowledge in physics, especially in electromagnetism, is required. No formal prerequisites.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Energy and Power Electronics
Basics of the switching behavior and gate drive circuits of power semiconductor devices and auxiliary circuits for minimizing the switching losses of power semiconductors are discussed. Soft-switching and resonant switching of three-phase PWM converters systems in the lecture Power Electronic Systems II.

The students know the fundamental phenomena and principles associated with the occurrence of high electric field strengths. They understand the different mechanisms leading to the failure of insulation systems and are able to apply failure criteria on the dimensioning of high voltage components. They have the ability to identify and demonstrate weak spots in insulation systems and to propose options for improvement.

Further, they know the different insulation systems and their dimensioning in practice.

- discussion of the field equations relevant for high voltage engineering.
- analytical and numerical solutions/solving of these equations, as well as the derivation of the important equivalent circuits for the description of the fields and losses in insulations.
- introduction to kinetic gas theory
- mechanisms of the breakdown in gaseous, liquid and solid insulations, as well as insulation systems
- methods for the mathematical determination of the electric withstand of gaseous, liquid and solid insulations
- application of the expertise on high voltage components
- excursions to manufacturers of high voltage components

The goal of this course is understanding the stationary dependencies in electrical power systems and the application of analysis tools in these stationary but also in faulty state.

Stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large systems. Furthermore, the course should convey knowledge on the switching frequency related losses of power semiconductors and voltage switching and zero current switching non-isolated and isolated DC/DC converter systems and three-phase voltage DC link inverter systems. Furthermore, the course should convey knowledge on the switching frequency related losses of power semiconductors and inductive power components and introduce the concept of space vector calculus which provides a basis for the comprehensive discussion of three-phase PWM converters systems in the lecture Power Electronic Systems II.

The operating behavior of isolated full-bridge DC/DC converters is detailed for different secondary side rectifier topologies; high frequency loss mechanisms of magnetic components of converter circuits are explained and approximate calculation methods are presented; the concept of space vector calculus for analyzing three-phase systems is introduced; finally, phase-oriented and space vector modulation of three-phase inverter systems are discussed related to voltage DC link inverter systems and the design of the main power components based on analytical calculations is explained.

- application of the expertise on high voltage components
- methods for the mathematical determination of the electric withstand of gaseous, liquid and solid insulations
- mechanisms of the breakdown in gaseous, liquid and solid insulations, as well as insulation systems
- methods for the mathematical determination of the electric withstand of gaseous, liquid and solid insulations
- application of the expertise on high voltage components
- excursions to manufacturers of high voltage components

The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power networks. Approaches such as the Newton-Raphson algorithm applied to power flow equations, superposition technique for short-circuit analysis and symmetrical components are discussed as well as power flow computation techniques for distribution grids and state estimation.
The course is about some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.

**Objectives**
The course is about some fundamental topics of digital signal processing with a bias towards applications in communications. The main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust "inversion" of a linear filter.

1. Discrete-time linear systems and filters:
   - state-space realizations, z-transform and spectrum,
   - decimation and interpolation, digital filter design,
   - stable realizations and robust inversion.

2. The discrete Fourier transform and its use for digital filtering,

3. The statistical perspective:
   - probability, random variables, discrete-time stochastic processes;
   - detection and estimation: MAP, ML, Bayesian MMSE, LMMSE;
   - Wiener filter, LMS adaptive filter, Viterbi algorithm.

**Lecture notes**
Lecture Notes

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0101-00L</td>
<td>Discrete-Time and Statistical Signal Processing</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>H. - A. Loeliger</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course is about some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.</td>
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</tr>
<tr>
<td>Content</td>
<td>1. Discrete-time linear systems and filters: state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.</td>
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</tr>
</thead>
<tbody>
<tr>
<td>227-0121-00L</td>
<td>Communication Systems</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>C. Studer, S. M. Moser</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course teaches the fundamentals of digital communication systems. The main topics are analog and digital modulation, signals and linear time-invariant systems, baseband and passband representations, continuous-time and discrete-time channels, noise, inter-symbol interference, detection theory, as well as the basics of forward error correction and information theory.</td>
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<tr>
<td>Content</td>
<td>The course focuses on the fundamentals of digital communication systems. The course starts with analog modulation and discusses the main building blocks of modern digital communication systems. The topics include:</td>
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</table>

**Lecture notes**
Lecture notes will be distributed electronically at the beginning of the semester.

**Literature**

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Media and Digital Technologies
  - Problem-solving
- Personal Competencies
  - Critical Thinking

**Prerequisites / notice**
Sufficient mathematical maturity, in particular in linear algebra, analysis.

**Recommended Subjects**
These courses are recommended, but you are free to choose courses from any other special field. Please consult your tutor.
COMPETENCIES

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

227-0523-00L Railway Systems I

Abstract
Basic characteristics of railway vehicles and their interfaces with the railway infrastructure:
- Transportation tasks and vehicle types
- Running dynamics
- Mechanical part of rail vehicles
- Brakes
- Traction chain and auxiliary supply
- Railway power supply
- Signalling systems
- Standards
- Availability and safety
- Traffic control and maintenance

Objective
- Overview of the technical characteristics of railway systems
- Know-how about the design and construction principles of rail vehicles
- Interrelationship between different fields of engineering sciences (mechanics, electro and information technology, transport systems)
- Understanding tasks and opportunities of engineers working in an environment which has strong economical and political boundaries
- Insight into the activities of the railway vehicle industry and railway operators in Switzerland
- Motivation of young engineers to start a career in the railway industry or with railway operators

Content
EST I (Herbstsemester) - Begriffen, Grundlagen, Merkmale

Lecture notes
Abgabe der Unterlagen (gegen eine Schutzgebühr) zu Beginn des Semesters. Rechtzeitig eingeschriebene Teilnehmer können die Unterlagen auf Wunsch und gegen eine Zusatzgebühr auch in Farbe beziehen.

Prerequisites / notice
Dozent:
Dr. Markus Meyer, Emkamatik GmbH

Voraussichtlich ein oder zwei Gastvorträge von anderen Referenten.

EST I (Herbstsemester) kann als in sich geschlossene einsemestrige Vorlesung besucht werden. EST II (Frühjahrssemester) dient der weiteren Vertiefung der Fahrzeugtechnik und der Integration in die Bahnhinfrastuktur.

227-0536-00L Multiphysics Simulations for Power Systems

Abstract
The goals of this course are a) understanding the fundamentals of the electromagnetic, thermal, mechanical, and coupled field simulations and b) performing effective simulations of primary equipment of electric power systems. The course is understood complementary to 227-0537-00L "Technology of Electric Power System Components", but can also be taken separately.

Objective
The student should learn the fundamentals of the electromagnetic, thermal, mechanical, and coupled fields simulations necessary for modern product development and research based on virtual prototyping. She / he should also learn the theoretical background of the finite element method (FEM) and its application to low- and high-frequency electromagnetic field simulation problems. The practical exercises of the course should be done by using one of the commercially available field simulation software (Infolytica, ANSYS, and / or COMSOL). After completing the course the student should be able to properly and efficiently use the software to simulate practical design problems and to understand and interpret the obtained results.

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Complete design process: from given specifications to a complete power electronic system; selection / design of suitable passive power components; static and dynamic properties of power semiconductors; optimized EMI filter design; heat sink optimization; additional circuitry, e.g. gate driver; system optimization.

Prerequisites: Introductory course on power electronics.

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered

Does not take place this semester.

Abstract
This lecture provides theoretical and experimental knowledge on the techniques for the characterization and numerical modeling of power semiconductors, as well as on the related built-in reliability strategies.

Objective
The students shall get acquainted with the most important concepts and techniques for characterization, numerical modeling and built-in reliability of modern power electronic devices. This knowledge is intended to provide the future engineer with the theoretical background and tools for the design of dependable power devices and systems.

Content
This lecture consists of a theoretical part (50%) and of laboratory exercises and demonstrations (50%). The theoretical part covers the basic techniques and procedures for characterization, modeling and built-in reliability of modern power semiconductor devices with special attention to MOS and IGBT. The starting part on technology provides an overview on the main device families and includes a review of the most relevant application-oriented aspects of the device physics, thermal management, and packaging. The second section deals with the basic experimental characterization techniques for the definition of the semiconductor material properties, electrical characteristics, safe operating area, and junction temperature of the devices. The following section introduces the basic principles for electrical, thermal, and electro-thermal simulation of power semiconductor devices. Technology Computed Aided Design (TCAD) and compact modeling. Finally, procedures are methods are presented to implement efficient built-in reliability programs targeted on power semiconductors. They include failure physics, dedicated failure analysis techniques, accelerated testing, defect screening, and lifetime modeling.

During the laboratory activities, selections of the experimental techniques presented in the lecture are demonstrated on the base of realistic examples. Furthermore, schematic power devices will be simulated by the students with advanced TCAD tools and circuit simulators.
### 227-0619-00L Charge Transport in Energy Conversion and Storage

**W 6 credits 2V+2U**  
C. Battaglia, A. Senocrate

**Abstract**  
The students will be introduced to the fundamental concepts of charge transport in solar cells, batteries, and electrolysers. Emphasizing analogies between semiconductor physics and electrochemistry, this course is designed to provide a unified modern perspective of energy conversion and storage concepts for students in electrical engineering, materials science, physics, and chemistry.

**Objective**  
By the end of this course, the students will (1) understand the fundamentals of electronic and ionic charge transport, (2) understand the operational principles of solar cells, batteries, and electrolysers, and (3) understand fundamental limits for each device type. In addition, the students will learn how to simulate these devices during guided exercise sessions and develop an intuitive understanding on how to interpret the most important device characteristics.

**Literature**  
R. Huggins, Advanced Batteries, DOI:10.1007/9780387764245

**Prerequisites / notice**  
Be motivated to change the world to renewable energies!

This course is taught simultaneously at ETH Zurich and EPFL. All lectures will be recorded by zoom and made available to the students. Lectures will be streamed live from ETH Zurich with four lectures taught onsite at EPFL Lausanne.

A visit to Empa's Energy Conversion and Storage Labs will be organized during the semester. Possibility to interact and meet your classmates from EPF's via online lecture platform and during two special lectures with guest lecturers from industry (one guest lecture by ABB at ETH Zurich, one guest lecture by Northvolt at EPFL). Travel expenses for students will be covered.

Elements of calculus will be reviewed during the lectures, where necessary, but we leave the hard work of solving coupled differential charge transport equations to the computer and focus on developing a strong intuition. Prior knowledge in semiconductor physics or electrochemistry is an advantage, but not a prerequisite.

Students are required to bring a windows-compatible computer with a common data analysis software to the exercises. Apps for simulating devices under different operating conditions will be made available to the students.

**Competencies**  
Subject-specific Competencies  
Concepts and Theories  
assessed

<table>
<thead>
<tr>
<th>227-0697-00L Industrial Process Control</th>
<th>W 4 credits 3G</th>
<th>A. Horch, L. Dominguez Palomeque</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Introduction to industrial automation systems with application to the process industry, power generation as well as discrete manufacturing.</td>
<td></td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>General understanding of industrial automation systems in different industries. Purpose, architecture, technologies, application examples, current and future trends.</td>
<td></td>
</tr>
<tr>
<td><strong>Content</strong></td>
<td>Introduction to process automation: system architecture, data handling, communication (fieldbuses), process visualization, and engineering. Differences and characteristics of discrete and process industries. Analysis and design of open loop control problems: discrete automata, finite state machines, decision tables, and petri-nets. Practical analysis and design of closed-loop control for the process industry. Automation Engineering; Application programming in IEC 61131-3 (ladder diagrams, function blocks, sequence control, structured text); PLC programming and simulation, process visualization and operation; engineering integration from sensors, cables, topology design, function, visualization, diagnosis, to documentation; Industry standards (e.g. OPC, Profibus); Ergonomic design, safety (IEC61508) and availability, supervision and diagnosis. Automation standards: Communication, Architecture, Engineering, dependable systems, functional safety, automation security. Extensive practical examples from different process industries, power generation, gas compressor control, and automotive manufacturing.</td>
<td></td>
</tr>
<tr>
<td><strong>Lecture notes Literature</strong></td>
<td>Slides will be available as .PDF documents, see &quot;Learning materials&quot; (for registered students only)</td>
<td></td>
</tr>
<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>References will be given at the end of individual lectures.</td>
<td></td>
</tr>
<tr>
<td><strong>Exercises</strong></td>
<td>Tuesdays after the lecture (applies not to all lectures)</td>
<td></td>
</tr>
</tbody>
</table>
| **Competencies**                      | Subject-specific Competencies  
Concepts and Theories  
assessed  
Techniques and Technologies  
assessed |

<table>
<thead>
<tr>
<th>227-0731-00L Power Market I - Portfolio and Risk Management</th>
<th>W 6 credits 4G</th>
<th>D. Reichelt, G. A. Koeppe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Portfolio and risk management in the electrical power business, Pan-European power market trading, futures and forward contracts, hedging, options and derivatives, performance indicators for the risk management, modelling of physical assets, cross-border trading, ancillary services, balancing power market, Swiss market model.</td>
<td></td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>Knowledge on the worldwide liberalisation of electricity markets, pan-european power trading and the role of power exchanges. Understand financial products (derivatives) based on power. Management of a portfolio containing physical production, contracts and derivatives. Evaluate trading and hedging strategies. Apply methods and tools of risk management.</td>
<td></td>
</tr>
</tbody>
</table>

**Discussion**  
This course is designed to provide a unified modern perspective of energy conversion and storage concepts for students in electrical engineering, materials science, physics, and chemistry.
1. Pan-European power market and trading
   1.1. Power trading
   1.2. Development of the European power markets
   1.3. Energy economics
   1.4. Spot and OTC trading
   1.5. European energy exchange EEX

2. Market model
   2.1. Market place and organisation
   2.2. Balance groups / balancing energy
   2.3. Ancillary services
   2.4. Market for ancillary services
   2.5. Cross-border trading
   2.6. Capacity auctions

3. Portfolio and Risk management
   3.1. Portfolio management 1 (introduction)
   3.2. Forward and futures contracts
   3.3. Risk management 1 (m2m, VaR, hpfC, volatility, cVaR)
   3.4. Risk management 2 (PaR)
   3.5. Contract valuation (HPFC)
   3.6. Portfolio management 2

2.8. Risk Management 3 (enterprise wide)

4. Energy & Finance I
   4.1. Options 1 basics
   4.2. Options 2 hedging with options
   4.3. Introduction to derivatives (swaps, cap, floor, collar)
   4.4. Financial modelling of physical assets
   4.5. Trading and hydro power
   4.6. Incentive regulation

Lecture notes
Handouts of the lecture
Prerequisites / notice
Case studies and ML exercise for Power Market can give bonus points for the exam. Guest speakers for specific topics.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Method-specific Competencies
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management assessed
Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered

Core Subjects
These core subjects are particularly recommended for the field of "Systems and Control".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0225-00L</td>
<td>Linear System Theory</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>J. Lygeros, A. Tsiamis</td>
</tr>
</tbody>
</table>

Abstract
The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.

Objective
Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

Lecture notes
Available on the course Moodle platform.

Sufficient mathematical maturity, in particular in linear algebra, analysis.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tr>
<td>227-0697-00L</td>
<td>Industrial Process Control</td>
<td>W</td>
<td>4</td>
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Abstract
Introduction to industrial automation systems with application to the process industry, power generation as well as discrete manufacturing.

Objective
General understanding of industrial automation systems in different industries. Purpose, architecture, technologies, application examples, current and future trends.
Content
Introduction to process automation: system architecture, data handling, communication (fieldbuses), process visualization, and engineering. Differences and characteristics of discrete and process industries. Analysis and design of open loop control problems: discrete automata, finite state machines, decision tables, and petri-nets. Practical analysis and design of closed-loop control for the process industry. Automation Engineering: Application programming in IEC 61131-3 (ladder diagrams, function blocks, sequence control, structured text); PLC programming and simulation, process visualization and operation; engineering integration from sensors, cabling, topology design, function, visualization, diagnosis, to documentation; Industry standards (e.g. OPC, Profibus); Ergonomic design, safety (IEC61508) and availability, supervision and diagnosis. Automation standards: Communication, Architecture, Engineering, dependable systems, functional safety, automation security. Extensive practical examples from different process industries, power generation, gas compressor control, and automotive manufacturing.

Lecture notes
Slides will be available as .PDF documents, see "Learning materials" (for registered students only)

Literature
References will be given at the end of individual lectures.

Prerequisites
Exercises: Tuesdays after the lecture (applies not to all lectures)

Competencies
Practical exercises will illustrate some topics, e.g. some control software coding using industry standard programming tools based on IEC61131-3.

151-0563-01L Dynamic Programming and Optimal Control W 4 credits 2V+1U R. D'Andrea
Abstract Introduction to Dynamic Programming and Optimal Control.
Objective Covers the fundamental concepts of Dynamic Programming & Optimal Control.
Content Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

151-0563-02L Discrete Event Systems W 6 credits 4G L. Josipovic, L. Vanbever, R. Wattenhofer
Abstract Introduction to discrete event systems. We start out by studying popular models of discrete event systems. Then we analyze discrete event systems from an average-case and from a worst-case perspective, and study verification. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Petri Nets.
Objective Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).
Content 1. Regular Languages
2. Non-Regular Languages
3. Markov Chains
4. Stochastic Discrete Event Systems
5. Worst-Case Event Systems
6. Verification of Finite Automata
7. Petri Nets
Lecture notes Available at https://disco.ethz.ch/courses/des/
Literature

[bertsekas] Data Networks
Dimitri Bertsekas, Robert Gallager

[borodin] Online Computation and Competitive Analysis
Allan Borodin, Ran El-Yaniv.
Cambridge University Press, 1998

[burch] Symbolic Model Checking
Inf. Comput. 98, 2 (June 1992), pp. 142-170

[boudec] Network Calculus
J.-Y. Le Boudec, P. Thiran
Springer, 2001

[cassandras] Introduction to Discrete Event Systems
Christos Cassandras, Stéphane Lafortune.

[fiat] Online Algorithms: The State of the Art
A. Fiat and G. Woeginger

D. Hochbaum

[murata] Petri Nets: Properties, Analysis and Applications
Tadao Murata

[schickinger] Diskrete Strukturen (Band 2: Wahrscheinlichkeitstheorie und Statistik)
T. Schickinger, A. Steger
Springer, Berlin, 2001

[sipser] Introduction to the Theory of Computation
Michael Sipser.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking

227-0447-00L Image Analysis and Computer Vision W 6 credits 3V+1U E. Konukoglu, E. Erdil, F. Yu

Abstract

Objective
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes
Course material Script, computer demonstrations, exercises and problem solutions

Prerequisites / notice
Course material Script, computer demonstrations, exercises and problem solutions
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

227-0526-00L Power System Analysis W 6 credits 4G G. Hug

Abstract
The goal of this course is understanding the stationary dependencies in electrical power systems. The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power networks.

Objective
The goal of this course is understanding the stationary dependencies in electrical power systems and the application of analysis tools in normal but also in faulty state.

Content
The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power grids. Approaches such as the Newton-Raphson algorithm applied to power flow equations, superposition technique for short-circuit analysis and symmetrical components are discussed as well as power flow computation techniques for distribution grids and state estimation.

Lecture notes
Lecture notes.
System Identification

**Abstract**
Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.

**Objective**
To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.

**Content**
- Predictive, open-loop, black-box identification methods. Time and frequency domain methods. Subspace identification methods.
- Optimal experimental design, Cramer-Rao bounds, input signal design.
- Parametric identification methods. On-line and batch approaches.

**Literature**

**Prerequisites / notice**
Control systems (227-0216-00L) or equivalent.

Nonlinear Dynamics and Chaos I

**Abstract**
Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

**Objective**
This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.

**Content**
1. Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
2. Near equilibrium dynamics: Linear and Lyapunov stability
3. Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations
4. Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
5. Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

**Lecture notes**
The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

**Prerequisites / notice**
- Prerequisites: Analysis, linear algebra and a basic course in differential equations.

Dynamic Programming and Optimal Control

**Abstract**
Introduction to Dynamic Programming and Optimal Control.

**Objective**
Covers the fundamental concepts of Dynamic Programming & Optimal Control.

**Content**
Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

**Literature**

**Prerequisites / notice**
Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions

**Abstract**
Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reinteegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

**Objective**
Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.
Content

Introduction, problem definition, overview
Rehabilitation of visual function
- Anatomy and physiology of the visual sense
- Technical aids (glasses, sensor substitution)
- Retina and cortex implants
Rehabilitation of hearing function
- Anatomy and physiology of the auditory sense
- Hearing aids
- Cochlea Implants
Rehabilitation and use of kinesthetic and tactile function
- Anatomy and physiology of the kinesthetic and tactile sense
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
Rehabilitation of vestibular function
- Anatomy and physiology of the vestibular sense
- Rehabilitation strategies and devices (e.g. BrainPort)
Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter
Brain stimulation and recording
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces

Literature

Introductory Books:


Selected Journal Articles and Web Links:

Prerequisites / notice

Target Group:
Students of higher semesters and PhD students of
- D-MAVT, D-ITET, D-INFK, D-HEST
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich
Students of other departments, faculties, courses are also welcome
This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1065 of 2653
The goal of this course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.

Topics covered in this course include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.

Information about relevant literature will be given in the lecture.

401-3901-00L  Linear & Combinatorial Optimization  W  10 credits  4V+2U  R. Zenklusen

Abstract
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

Objective
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Content
Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Literature

Prerequisites / notice
Solid background in linear algebra.

636-0007-00L  Computational Systems Biology  W  6 credits  3V+2U  J. Stelling

Abstract
Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

Objective
The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

Content
Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

Lecture notes
http://www.csb.ethz.ch/education/lectures.html
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lecture notes
Prerequisites / notice
Students are expected to have a mathematical background and should be able to write rigorous proofs.

#### Signal Processing and Machine Learning
#### Core Subjects

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0105-00L</td>
<td>Introduction to Estimation and Machine Learning</td>
<td>W</td>
<td>6</td>
<td>G</td>
<td>H.-A. Loeliger</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Mathematical basics of estimation and machine learning, with a view towards applications in signal processing.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Students master the basic mathematical concepts and algorithms of estimation and machine learning.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Review of probability theory; basics of statistical estimation; least squares and linear learning; Hilbert spaces; singular-value decomposition; kernel methods, neural networks, and more</td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Lecture notes will be handed out as the course progresses.</td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>solid basics in linear algebra and probability theory</td>
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</tbody>
</table>

| 227-0423-00L | Neural Network Theory | W    | 4    | 2V+1U | H. Bölcskei        |
| **Abstract** | Does not take place this semester. |
| **Objective** | The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation theorems, capacity of separating surfaces, generalization, fundamental limits of deep neural network learning, VC dimension. |
| **Content** | 1. Universal approximation with single- and multi-layer networks |
|  | 2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory |
|  | 3. Fundamental limits of deep neural network learning |
|  | 4. Geometry of decision surfaces |
|  | 5. Separating capacity of nonlinear decision surfaces |
|  | 6. Vapnik-Chervonenkis (VC) dimension |
|  | 7. VC dimension of neural networks |
| Lecture notes | Detailed lecture notes are available on the course web page https://www.mins.ese.ethz.ch/teaching/nnt/ |
| Prerequisites / notice | This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular. |

| 227-0447-00L | Image Analysis and Computer Vision | W    | 6    | 3V+1U | E. Konukoglu, E. Erdil, F. Yu |

Data: 15.06.2024 12:39 Autumn Semester 2024
Objective
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part will start with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Prerequisites
Course material Script, computer demonstrations, exercises and problem solutions

Literature


Prerequisites:
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux.

The course language is English.

227-0101-00L

Discrete-Time and Statistical Signal Processing

The course is about some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.

Objective
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

Recommended Subjects

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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</tr>
</thead>
<tbody>
<tr>
<td>227-0101-00L</td>
<td>Discrete-Time and Statistical Signal Processing</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
</tbody>
</table>

The course is about some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust "inversion" of a linear filter.
Content
1. Discrete-time linear systems and filters:
   - state-space realizations, z-transform and spectrum,
   - decimation and interpolation, digital filter design,
   - stable realizations and robust inversion.

2. The discrete Fourier transform and its use for digital filtering.

3. The statistical perspective:
   - probability, random variables, discrete-time stochastic processes;
   - detection and estimation: MAP, ML, Bayesian MMSE, LMMSE;
   - Wiener filter, LMS adaptive filter, Viterbi algorithm.

Lecture notes
Lecture Notes

227-0116-00L
VLSI 1: HDL Based Design for FPGAs
W 6 credits 5G F. K. Gürkaynak

Abstract
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front-end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Objective
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conceptions to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

Content
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICS compared to microprocessors, DSPs, and FPGAs.

Lecture notes
Lecture Notes

227-0121-00L
Communication Systems
W 6 credits 4G C. Studer, S. M. Moser

Abstract
The course teaches the fundamentals of digital communication systems. The main topics are analog and digital modulation, signals and linear time-invariant systems, baseband and passband representations, continuous-time and discrete-time channels, noise, inter-symbol interference, detection theory, as well as the basics of forward error correction and information theory.

Objective
After attending the lectures, participating in the exercise sessions, and working on the homework problems (which include MATLAB coding assignments), the students will be able to:
- understand the fundamentals of digital communication systems
- explain the principles of modulation, demodulation, detection, and error correction
- analyze error rates of simple digital communication systems
- implement simple MATLAB simulations to calculate error rates

Content
The course focuses on the fundamentals of digital communication systems. The course starts with analog modulation and discusses the main building blocks of modern digital communication systems. The topics include:
- essential components of digital communication systems
- analog and digital modulation
- baseband and passband representation; up- and down-conversion
- communication channels as LTI systems
- discretizing communication systems; sampling and quantization
- noise, signal-to-noise ratio (SNR), and interference
- detection theory and error rates
- basics of forward error correction
- basics of information theory
- orthogonal frequency-division multiplexing (OFDM)
- building blocks of modern communication systems

The exercises cover theoretical aspects as well as the basics of software-based communication-system modeling in MATLAB.

Lecture notes
Lecture notes will be distributed electronically at the beginning of the semester.

Literature
Machine Learning on Microcontrollers

Registration in this class requires the permission of the instructors.
Preference is given to students in the MSc EEIT.

Abstract
Machine Learning (ML) and artificial intelligence are pervading the digital society. Today, even low power embedded systems are incorporating ML, becoming increasingly “smart”. This lecture gives an overview of ML methods and algorithms to process and extract useful near-sensor information in end-nodes of the “internet-of-things”, using low-power microcontrollers/processors (ARM-Cortex-M; RISC-V).

Objective
Learn how to process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ExG bio-signals, cameras…). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers.

Content
The final goal of the course is a deep understanding of machine learning and its practical implementation on single- and multi-core microcontrollers, coupled with performance and energy efficiency analysis and optimization. The main topics of the course include:

- Sensors and sensor data acquisition with low power embedded systems
- Machine Learning: Overview of supervised and unsupervised learning and in particular supervised learning (Bayes Decision Theory, Decision Trees, Random Forests, kNN-Methods, Support Vector Machines, Convolutional Networks and Deep Learning)
- Low-power embedded systems and their architecture. Low Power microcontrollers (ARM-Cortex M) and RISC-V-based Parallel Ultra Low Power (PULP) systems-on-chip.
- Low power smart sensor system design: hardware-software tradeoffs, analysis, and optimization. Implementation and performance evaluation of ML in battery-operated embedded systems.

The laboratory exercises will show how to address concrete design problems, like motion, gesture recognition, emotion detection, image and sound classification, using real sensors data and real MCU boards.

Presentations from Ph.D. students and the visit to the Digital Circuits and Systems Group will introduce current research topics and international research projects.

Lecture notes
Script and exercise sheets. Books will be suggested during the course.

Prerequisites / notice
The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today’s neuroscience papers.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today's neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to 'error backpropagation' in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minih et al, 2015, Silver et al., 2018), ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

The lecture slides will be provided as a PDF after each lecture.

This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:

1) The number of participants is limited to 120 students (MSc and PhDs).
2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

Objectives
- Integrity and Work Ethics
- Critical Thinking
- Project Management
- Media and Digital Technologies
- Decision-making
- Techniques and Technologies
- Problem-solving
- Critical Thinking
- Self-direction and Self-management
- Emotion
- Communication
- Professional Competencies
- Social Competencies
- Personal Competencies
- Problem-solving
- Project Management
- Communication
- Cooperation and Teamwork
- Critical Thinking
- Integrity and Work Ethics

Content
- Probabilistic Artificial Intelligence
- Machine Learning
- Guarantees for Machine Learning

Prerequisites / notice
- The material covered in the course “Introduction to Machine Learning” is considered as a prerequisite.

Competencies
- Subject-specific Competencies
- Method-specific Competencies
- Social Competencies
- Personal Competencies

Lecture notes
- The lecture slides will be provided as a PDF after each lecture.

Prerequisites
- The number of participants is limited to 120 students (MSc and PhDs).
- Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Problem-solving
- Communication
- Critical Thinking
- Self-direction and Self-management

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management
- Cooperation and Teamwork

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Critical Thinking
- Integrity and Work Ethics

Guarantees for Machine Learning
- 7 credits
- 3V+1U+2A
- F. Yang
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

Abstract

This course provides a gentle introduction to the Probabilistic Method, with an emphasis on methodology. We will try to illustrate the main ideas by showing the application of probabilistic reasoning to various combinatorial problems.

Content

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Abstract

This course provides a gentle introduction to the Probabilistic Method, with an emphasis on methodology. We will try to illustrate the main ideas by showing the application of probabilistic reasoning to various combinatorial problems.

Content

This course provides a gentle introduction to the Probabilistic Method, with an emphasis on methodology. We will try to illustrate the main ideas by showing the application of probabilistic reasoning to various combinatorial problems.
The aim of this course is to gain insight into the main statistical ideas and concepts. The course considers classical low-dimensional models, with pointers towards today's highly complex models.

### Prerequisites
Students are expected to have a mathematical background and should be able to write rigorous proofs.

#### 401-3621-00L Fundamentals of Mathematical Statistics

<table>
<thead>
<tr>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>9</td>
<td>4V+1U</td>
<td>J. Ziegel</td>
</tr>
</tbody>
</table>

**Abstract**
In this course we study the basics of theoretical statistics. The course includes methods for designing estimators, confidence intervals and tests, and various ways to evaluate the accuracy of estimators, confidence intervals and tests. We consider optimality criteria such as admissibility and minimaxity, as well as Bayesian criteria. We will also present the asymptotic point of view.

**Objective**

The course includes methods for designing estimators, confidence intervals and tests, and various ways to evaluate the accuracy of estimators, confidence intervals and tests. We consider optimality criteria such as admissibility and minimaxity, as well as Bayesian criteria. We will also present the asymptotic point of view.

**Competencies**

Subject-specific Competencies: Concepts and Theories

Method-specific Competencies: Analytical Competencies

Personal Competencies: Creative Thinking

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#### 401-3901-00L Linear & Combinatorial Optimization

<table>
<thead>
<tr>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>10</td>
<td>4V+2U</td>
<td>R. Zenklusen</td>
</tr>
</tbody>
</table>

**Abstract**

Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

**Objective**

The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

**Content**

Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

**Literature**


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### Subjects of General Interest

These courses are suitable for several special fields. Please consult your tutor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0377-10L</td>
<td>Physics of Failure and Reliability of Electronic Devices and Systems</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>I. Shorubalko, M. Held</td>
</tr>
</tbody>
</table>

**Abstract**

Understanding the physics of failures and failure mechanisms enables reliability analysis and serves as a practical guide for electronic devices design, integration, systems development and manufacturing. The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.

**Objective**

Provide an understanding of the physics of failure and reliability. Introduce the degradation and failure mechanisms, basics of failure analysis, methods and tools of reliability testing.

**Content**

Summary of reliability and failure analysis terminology; physics of failure: materials properties, physical processes and failure mechanisms; failure analysis; basics and properties of instruments; quality assurance of technical systems (introduction); introduction to stochastic processes; reliability analysis; component selection and qualification; maintainability analysis (introduction); design rules for reliability, maintainability, reliability tests (introduction).

**Lecture notes**

Comprehensive copy of transparencies

**Literature**


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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0790-00L</td>
<td>Technology Entrepreneurship</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>F. Hacklin</td>
</tr>
</tbody>
</table>

**Abstract**

Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding.

This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are success factors in the creation of new firms, including founding, financing and growing a venture.

**Objective**

This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures. A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases.
Content
Weekly sessions - recorded.
10+ sessions carried out by guest lecturers: experts in the broad field of technology entrepreneurship (e.g., serial entrepreneurs, venture capitalists, (E)MBA professors, company builders, patent experts, scale-up executives, ...). Final session: multiple choice semester assignment (100% of grade).

Typical lecture format (2h):
15': Introduction
60': Guest testimonial
15': Discussion related to topic (in groups)
10': Plenary discussion
20': Q&A with (guest) lecturer

Lecture notes
Lecture slides and case material

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Sensitivity to Diversity fostered

Personal Competencies
Critical Thinking assessed

151-0317-00L Visualization, Simulation and Interaction - Virtual Reality II
W 4 credits 3G A. Kunz

Abstract
This lecture provides deeper knowledge on the possible applications of virtual reality, its basic technology, and future research fields. The goal is to provide a strong knowledge on Virtual Reality for a possible future use in business processes.

Objective
Virtual Reality can not only be used for the visualization of 3D objects, but also offers a wide application field for small and medium enterprises (SME). This could be for instance an enabling technology for net-based collaboration, the transmission of images and other data, the interaction of the human user with the digital environment, or the use of augmented reality systems.
The goal of the lecture is to provide a deeper knowledge of today’s VR environments that are used in business processes. The technical background, the algorithms, and the applied methods are explained more in detail. Finally, future tasks of VR will be discussed and an outlook on ongoing international research is given.

Content
Introduction into Virtual Reality; basics of augmented reality; interaction with digital data, tangible user interfaces (TUI); basics of simulation; compression procedures of image-, audio-, and video signals; new materials for force feedback devices; introduction into data security; cryptography; definition of free-form surfaces; digital factory; new research fields of virtual reality

Lecture notes
The handout is available in German and English.

Prerequisites / notice
Prerequisites:
"Visualization, Simulation and Interaction - Virtual Reality I" is recommended, but not mandatory.

Didactical concept:
The course consists of lectures and exercises.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies assessed
Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

Internship in Industry

Number Title Type ECTS Hours Lecturers
227-1550-00L Internship in Industry Z 0 credits external organisers

Abstract
The main objective of the 12-week internship (full-time) is to expose master's students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.

Objective
siehe oben

Semester Projects

Number Title Type ECTS Hours Lecturers
227-1101-00L How to Write Scientific Texts E- 0 credits U. Koch

Abstract
This four-hour course covers the basics of writing and presenting scientific work. The focus lies on the structure and the main elements of a scientific text. Formatting guidelines, citation rules, good practice of scientific writing and hints to convince the audience are part of the course.

Objective
- You can write scientific texts using the correct structure
- You can convincingly present scientific work
- You can differentiate the scientific style from novels and news
- You can adhere to citation rules and scientific integrity

Content
The block course covers the following topics:
- Structure of Scientific Texts
- Structure of Scientific Presentations
- Formatting of Scientific Elements (figures, equations, tables)
- Citation Rules and Scientific Integrity

The lecture will be given in two parts on two afternoons. Some exercises will be built into the lecture.

Literature
Scientific Integrity, see https://ethz.ch/en/research/ethics-and-animal-welfare/research-integrity.html

Prerequisites / notice
You should be writing either a bachelor/semester/master thesis or a scientific publication in the immediate future.
Semester Project (Nr 1)  ■  227-1572-01L
Registration in myStudies required!
Supervisor must be a professor at D-ITET or associated, see https://ee.ethz.ch/studies/master-s-programmes/main-master/projects-and-master-thesis.html

The first semester project is compulsory both for students enrolled in the MSc EEIT under the 2008 regulations and for students enrolled under the 2018 regulations.

Abstract
Semester projects are designed to train the students for independent scientific work. A project uses the student’s technical and social skills acquired during the master's program. The semester project comprises 280 hours of work and is supervised by a professor.

Objective
see above

Prerequisites / notice
Supervisor must be a professor at D-ITET or associated, see https://www.ee.ethz.ch/studies/main-master/projects-and-master-thesis.html

Semester Project (Nr 2)  ■  227-1572-02L
Registration in myStudies required!
Supervisor must be a professor at D-ITET or associated, see https://ee.ethz.ch/studies/master-s-programmes/main-master/projects-and-master-thesis.html

The second semester project is compulsory for students enrolled in the MSc EEIT under the 2008 regulations, it is optional for students enrolled under the 2018 regulations.

Abstract
Semester projects are designed to train the students for independent scientific work. A project uses the student’s technical and social skills acquired during the master's program. The semester project comprises 280 hours of work and is supervised by a professor.

Objective
see above

Prerequisites / notice
Supervisor must be a professor at D-ITET or associated, see https://www.ee.ethz.ch/studies/main-master/projects-and-master-thesis.html

Science in Perspective
Only courses offered under “GESS Science in Perspective” count in this category. See “Offered in” tab in course view. For more information, please refer to https://gess.ethz.ch/en/studies/science-in-perspective/SiP-FAQs.html

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-ITET

Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1101-00L</td>
<td>How to Write Scientific Texts</td>
<td>Strongly recommended prerequisite for Semester Projects and Theses at D-ITET (MSc BME, MSc EEIT, MSc EST)</td>
<td>E-</td>
<td>0 credits</td>
<td>U. Koch</td>
</tr>
</tbody>
</table>

Abstract
This four-hour course covers the basics of writing and presenting scientific work. The focus lies on the structure and the main elements of a scientific text. Formatting guidelines, citation rules, good practice of scientific writing and hints to convince the audience are part of the course.

Objective
- You can write scientific texts using the correct structure
- You can convincingly present scientific work
- You can differentiate the scientific style from novels and news
- You can adhere to citation rules and scientific integrity

Content
The block course covers the following topics:
- Structure of Scientific Texts
- Structure of Scientific Presentations
- Formatting of Scientific Elements (figures, equations, tables)
- Citation Rules and Scientific Integrity

The lecture will be given in two parts on two afternoons. Some exercises will be built into the lecture.

Literature
Scientific Integrity, see https://ethz.ch/en/research/ethics-and-animal-welfare/research-integrity.html

Prerequisites / notice
You should be writing either a bachelor/semester/master thesis or a scientific publication in the immediate future.

Competencies
Subject-specific Competencies: Assessed
Method-specific Competencies: Fostered
Social Competencies: Fostered
Personal Competencies: Assessed
Self-awareness and Self-reflection: Fostered

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1501-00L</td>
<td>Master's Thesis</td>
<td></td>
<td>30 credits</td>
<td>68D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>
Admission only if ALL of the following apply:

a) bachelor program successfully completed
b) (if applicable) acquired all credits from additional requirements for admission to msc program
c) (2018 regulations): acquired the minimum number of credits in the 'core courses' category
d) successfully completed the semester project(s)

Registration in mystudies required!
Supervisor must be a professor at D-ITET or associated, see https://ee.ethz.ch/studies/master-5-programmes/main-master/projects-and-master-thesis.html

Abstract
The Master Program finishes with a 6-months Master Thesis which is directed by a Professor of the Department or a Professor of another Department who is associated with the D-ITET. Students gain the ability to conduct independent scientific research on a specific research problem.

Objective
see above

Prerequisites / notice
Supervisor must be a professor at D-ITET or associated, see https://www.ee.ethz.ch/studies/main-master/projects-and-master-thesis.html

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### Generally Accessible Seminars and Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0919-00L</td>
<td>Knowledge-Based Image Interpretation</td>
<td>Z</td>
<td>0</td>
<td>2S</td>
<td>E. Konukoglu, F. Yu</td>
</tr>
<tr>
<td>Abstract</td>
<td>With the lecture series on special topics of Knowledge based image interpretation we sporadically offer special talks.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>To become acquainted with selected, recent results in image analysis and interpretation.</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>227-0955-00L</td>
<td>Seminar in Electromagnetics, Photonics and Terahertz</td>
<td>Z</td>
<td>3</td>
<td>2S</td>
<td>J. Leuthold</td>
</tr>
<tr>
<td>Abstract</td>
<td>Selected topics of the current research activities at the IEF and closely related institutions are discussed.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Have an overview on the research activities of the IEF institute.</td>
<td></td>
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</tr>
<tr>
<td>227-0980-00L</td>
<td>Seminar on Biomedical Magnetic Resonance</td>
<td>Z</td>
<td>0</td>
<td>1S</td>
<td>K. P. Prüssmann, S. Kozerke, M. Weiger Senften</td>
</tr>
<tr>
<td>Abstract</td>
<td>Current developments and problems of magnetic resonance imaging (MRI)</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Getting insight into advanced topics in magnetic resonance imaging</td>
<td></td>
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</tr>
<tr>
<td>401-5680-00L</td>
<td>Foundations of Data Science Seminar</td>
<td>Z</td>
<td>0</td>
<td>1S</td>
<td>A. Bandeira, H. Bölcskei, J. Peters, F. Yang</td>
</tr>
<tr>
<td>Abstract</td>
<td>Research colloquium</td>
<td></td>
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</tr>
</tbody>
</table>

### Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0101-AAL</td>
<td>Discrete-Time and Statistical Signal Processing</td>
<td>E-</td>
<td>6</td>
<td>8R</td>
<td>H.-A. Loeliger</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.</td>
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<tr>
<td>Objective</td>
<td>The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust &quot;inversion&quot; of a linear filter.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>1. Discrete-time linear filters and filters: state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.</td>
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<tr>
<td></td>
<td>2. The discrete Fourier transform and its use for digital filtering.</td>
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<tr>
<td></td>
<td>3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.</td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Lecture Notes.</td>
<td></td>
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</tr>
<tr>
<td>227-0103-AAL</td>
<td>Control Systems</td>
<td>E-</td>
<td>6</td>
<td>8R</td>
<td>F. Dörfler</td>
</tr>
<tr>
<td>Abstract</td>
<td>Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.</td>
<td></td>
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</tr>
</tbody>
</table>
This course provides a foundation in analog integrated circuit design based on CMOS technologies. Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

### Objective
Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

### Content
- Review of bipolar and MOS devices and their small-signal equivalent circuit models.
- Building blocks in analog circuits such as diffenential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors.
- Basic elements, design issues and techniques for analog integrated circuits will be taught in this course.
- The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.
- MATLAB is used for system analysis and simulation.
- The students know the different insulation systems and their dimensioning in practice.
- Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.
- Further they know the different insulation systems and their dimensioning in practice.
- The students know the fundamental phenomena and principles connected with the occurrence of extensive electric field strengths. They comprehend the different mechanisms leading to the failure of insulation systems and are able to apply failure criteria on the dimensioning of high voltage components. They have the ability to identify of weak spots in insulation systems and to name possibilities for improvement.
- The students know the fundamental phenomena and principles connected with the occurrence of extensive electric field strengths. They comprehend the different mechanisms leading to the failure of insulation systems and are able to apply failure criteria on the dimensioning of high voltage components. They have the ability to identify of weak spots in insulation systems and to name possibilities for improvement.
- This knowledge is applied to the dimensioning of high-voltage equipment. Methods of computer-modeling in use today are presented and applied within a workshop in the framework of the exercises.
- The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.
- The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.
- Methods of computer-modeling in use today are presented and applied within a workshop in the framework of the exercises.
- MATLAB is used for system analysis and simulation.
-principles connected with the occurrence of extensive electric field strengths. They comprehend the different mechanisms leading to the failure of insulation systems and are able to apply failure criteria on the dimensioning of high voltage components. They have the ability to identify of weak spots in insulation systems and to name possibilities for improvement.
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- MATLAB is used for system analysis and simulation.
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- Methods of computer-modeling in use today are presented and applied within a workshop in the framework of the exercises.
- MATLAB is used for system analysis and simulation.
### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: fostered
- Project Management: fostered

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### Electrical Engineering and Information Technology Master - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Eligibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
</tbody>
</table>

### Key for Hours

<table>
<thead>
<tr>
<th>Letter</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

### ECTS
- European Credit Transfer and Accumulation System
  - Special students and auditors need special permission from the lecturers.
# EMBA ETH HSG (emba X)

## Modules

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>367-0020-00L</td>
<td>Business Model Innovation for Social Impact  ■</td>
<td>O</td>
<td>7.5 credits</td>
<td>4G</td>
<td>S. Brusoni</td>
</tr>
<tr>
<td>367-0021-00L</td>
<td>Global Business  ■</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>F. Schimmelfennig</td>
</tr>
</tbody>
</table>

**Key for Hours**

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
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</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

**Special students and auditors need special permission from the lecturers.**
**Energy Science and Technology Master**

**Core Courses**

At least two core courses must be passed in each area.
All students must participate in the course offered in the area “Interdisciplinary Energy Management”

#### Electrical Power Engineering

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1635-00L</td>
<td>Electric Circuits</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>D. Shchetinin</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Introduction to analysis methods and network theorems to describe operation of electric circuits. Theoretical foundations are essential for the analysis of the electric power transmission and distribution grids as well as many modern technological devices – consumer electronics, control systems, computers and communications.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>At the end of this course, the student will be able to: understand variables in electric circuits, evaluate possible approaches and analyze simple electric circuits with RLC elements at steady state and during transients, apply circuit theorems to simple meshed circuits, analyze AC circuits and understand the connection of the explained principles to the modelling of 3-phase electric power systems.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Content</strong></td>
<td>Course will introduce electric circuits variables, circuit elements (resistive, inductive, capacitive), resistive circuits and theorems (Kirchhoff's laws, Norton and Thevenin equivalents), nodal and mesh analysis, superposition principle; it will continue by discussing the complete response of RL, RC and RLC circuits during transients, sinusoidal analysis – AC steady state (complex power, reactive, active power) and conclude with the introduction to 3-phase analysis; Mathematical foundations of the circuit analysis, such as matrix operations and complex numbers will be briefly reviewed. This course is targeting students who have no prior background in electrical engineering.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Lecture and exercises slides will be distributed after each lecture via Moodle platform; additional materials to be accessed online (wileyplus)</td>
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</tr>
<tr>
<td><strong>Prerequisites notice</strong></td>
<td>This course is primarily intended for students outside of D-ITET. No prior course in electrical engineering is required.</td>
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</tr>
<tr>
<td><strong>Competencies</strong></td>
<td>Subject-specific Competencies: Concepts and Theories assessed</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Method-specific Competencies: Analytical Competencies fostered</td>
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</tbody>
</table>

| 227-0122-00L | Introduction to Electric Power Transmission: System & Technology | W | 4 credits | 4G | C. Franck, G. Hug |
| **Abstract** | Introduction to theory and technology of electric power transmission systems. |
| **Objective** | At the end of this course, the student will be able to: describe the structure of electric power systems, name the most important components and describe what they are needed for, apply models for transformers and overhead power lines, explain the technology of lines, know about electrical safety, calculate electric withstand strength of gas gaps, stationary power flows and other basic parameters in simple power systems. |
| **Content** | Structure of electric power systems, transformer and power line models, analysis of and power flow calculation in basic systems, technology and principle of electric power systems. |
| **Lecture notes** | Lecture script in English, exercises and sample solutions. |
| **Competencies** | Subject-specific Competencies: Concepts and Theories assessed |
| | Method-specific Competencies: Analytical Competencies fostered |

| 227-0526-00L | Power System Analysis | W | 6 credits | 4G | G. Hug |
| **Abstract** | The goal of this course is understanding the stationary dependencies in electrical power systems. The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power networks. |
| **Objective** | The goal of this course is understanding the stationary dependencies in electrical power systems and the application of analysis tools in normal but also in faulty state. |
| **Content** | The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power grids. Approaches such as the Newton-Raphson algorithm applied to power flow equations, superposition technique for short-circuit analysis and symmetrical components are discussed as well as power flow computation techniques for distribution grids and state estimation. |
| **Lecture notes** | Lecture notes. |
Thermodynamics is key to understanding and use of energy conversion processes in Nature and technology. The main objective of this course is to give a compact introduction into basics of Thermodynamics: Thermodynamic states and thermodynamic processes; Work and Heat; First and Second Laws of Thermodynamics. Students shall learn how to use energy balance equation in the analysis of power cycles and shall be able to evaluate efficiency of internal combustion engines, gas turbines and steam power plants. The course shall extensively use thermodynamic charts to building up students’ intuition about opportunities and restrictions to increase useful work output of energy conversion. Thermodynamic functions such as entropy, enthalpy and free enthalpy shall be used to understand chemical and phase equilibrium. The course also gives introduction to refrigeration cycles, combustion and refrigeration. The course compactly covers the standard course of thermodynamics for engineers, with additional topics of a general physics interest (nonideal gas equation of state and Joule-Thomson effect) also included.

In the course “Energy Conversion”, the competencies of process understanding and system understanding are applied and examined and the competencies process understanding and modeling are taught.

### Energy Flows and Processes

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1633-00L</td>
<td>Energy Conversion</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>I. Karlin, G. Sansavini, S. A. Hosseini</td>
</tr>
</tbody>
</table>

This course is intended for students outside of D-MAVT.

**Abstract**

This course provides the students with an introduction to thermodynamics and energy conversion. Students shall gain basic understanding of energy and energy interactions as well as their link to energy conversion technologies.

**Objective**

Thermodynamics is key to understanding and use of energy conversion processes in Nature and technology. Main objective of this course is to give a compact introduction into basics of Thermodynamics: Thermodynamic states and thermodynamic processes; Work and Heat; First and Second Laws of Thermodynamics. Students shall learn how to use energy balance equation in the analysis of power cycles and shall be able to evaluate efficiency of internal combustion engines, gas turbines and steam power plants. The course shall extensively use thermodynamic charts to building up students’ intuition about opportunities and restrictions to increase useful work output of energy conversion. Thermodynamic functions such as entropy, enthalpy and free enthalpy shall be used to understand chemical and phase equilibrium. The course also gives introduction to refrigeration cycles, combustion and refrigeration. The course compactly covers the standard course of thermodynamics for engineers, with additional topics of a general physics interest (nonideal gas equation of state and Joule-Thomson effect) also included.

Content

1. Thermodynamic systems, states and state variables
2. Properties of substances: Water, air and ideal gas
3. Energy conservation in closed and open systems: work, internal energy, heat and enthalpy
4. Second law of thermodynamics and entropy
5. Energy analysis of steam power cycles
6. Energy analysis of gas power cycles
7. Refrigeration and heat pump cycles
8. Nonideal gas equation of state and Joule-Thomson effect
9. Maximal work and exergy
10. Mixtures
11. Chemical reactions and combustion systems; chemical and phase equilibrium

**Lecture notes**

Lecture slides and supplementary documentation will be available online.

**Literature**


**Prerequisites / notice**

This course is intended for students outside of D-MAVT.

Students are assumed to have an adequate background in calculus, physics, and engineering mechanics.
Combustion and Reactive Processes in Energy and Materials Technology

The main learning objectives of this course are: 1. Understand the thermodynamic, fluid-dynamic and chemical kinetics fundamentals of combustion processes. 2. Predict relevant parameters for combustion systems, such as laminar and turbulent flame speeds, adiabatic flame temperature or quenching distance. 3. Understand the causal relations of relevant combustion parameters such as the pressure influence on the laminar flame speed. 4. Analyze the challenges of developing sustainable combustion technologies based on carbon-neutral synthetic fuels.

Methods and Technologies
- Reaction kinetics, fuel oxidation mechanisms, premixed and diffusion laminar flames, two-phase-flows, turbulence and turbulent combustion, pollutant formation, development of sustainable combustion technologies for power generation, shipping and aviation.

Lecture notes
No script available. Instead, material will be provided in lecture slides and the following text book (which can be downloaded for free) will be followed:


Teaching language, assignments and lecture slides in English

Literature


Energy Economics and Policy

The learning objectives of the course are:

1. Students must be able to discuss basic principles, problems and approaches of microeconomics. 2. Students can analyse and explain simple economic principles in a market using supply and demand graphs. 3. Students can contrast different market structures and describe firm and consumer behaviour. 4. Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole. 5. Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics. 6. Students can apply simple mathematical concepts on economic problems.
Content

The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture "Principles of Microeconomics" is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.

Topics covered by the course are:

- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade

Lecture notes

Lecture notes, exercises and reference material can be downloaded from Moodle.

Literature


For students taking only the course 'Principles of Microeconomics' there is a shorter version of the same book:

Prerequisites / notice

GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>fostered</td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Project Management</td>
<td>fostered</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<td>Leadership and Responsibility</td>
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<td>assessed</td>
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<tr>
<td></td>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Negotiation</td>
<td>fostered</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
</tr>
</tbody>
</table>

Number Title Type ECTS Hours Lecturers

Abstract

This course will allow the students to get an interdisciplinary overview of the "Energy" topic. It will explore the challenges to build a sustainable energy system for the future. This will be done through the means of case studies that the students have to work on. These case studies will be provided by industry partners.

Objective

The students will understand the different aspects involved in designing solutions for a sustainable future energy system. They will have experience in collaborating in interdisciplinary teams. They will have an understanding on how industry is approaching new solutions.

Lecture notes

Descriptions of case studies.
### Industrial Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1650-10L</td>
<td>Internship in Industry</td>
<td>O</td>
<td>12</td>
<td>external organisers</td>
<td></td>
</tr>
</tbody>
</table>

**Abstract**

The main objective of the 12-week internship (full-time) is to expose master's students to the industrial work environment. During this period, students have the opportunity to be involved in ongoing projects at the host institution.

**Objective**

- see above

### Semester Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1101-00L</td>
<td>How to Write Scientific Texts</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>U. Koch</td>
</tr>
</tbody>
</table>

**Abstract**

This four-hour course covers the basics of writing and presenting scientific work. The focus lies on the structure and the main elements of a scientific text. Formatting guidelines, citation rules, good practice of scientific writing and hints to convince the audience are part of the course.

**Objective**

- You can write scientific texts using the correct structure
- You can convincingly present scientific work
- You can differentiate the scientific style from novels and news
- You can adhere to citation rules and scientific integrity

**Content**

The block course covers the following topics:

- Structure of Scientific Texts
- Structure of Scientific Presentations
- Formatting of Scientific Elements (figures, equations, tables)
- Citation Rules and Scientific Integrity

The lecture will be given in two parts on two afternoons. Some exercises will be built into the lecture.

**Literature**


**Prerequisites / notice**

You should be writing either a bachelor/semester/master thesis or a scientific publication in the immediate future.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Media and Digital Technologies
  - Communication
  - Critical Thinking
  - Self-awareness and Self-reflection

- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Self-presentation and Social Influence

- Social Competencies
  - Cooperation and Teamwork
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
  - Negotiation

- Personal Competencies
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

### Electives

These courses are particularly recommended, other ETH-courses from the field of Energy Science and Technology at large may be chosen in accordance with your tutor.

### Electrical Power Engineering

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0113-00L</td>
<td>Power Electronics</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>J. Huber</td>
</tr>
</tbody>
</table>

**Abstract**

Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

**Objective**

Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.
Content
Fields of application and application examples of power electronic converters, basic concept of switch-mode voltage and current conversion, pulse-width modulation (PWM); derivation and operating modes (continuous and discontinuous current mode) of DC/DC converter topologies, buck / boost / buck-boost converter; extension to DC/AC conversion using differences of unipolar output voltages varying over time; single-phase diode rectifier; boost-type PWM rectifier featuring sinusoidal input current; tolerance band AC current control and cascaded output voltage control with inner constant switching frequency current control; local and global averaging of switching frequency discontinuous quantities for calculation of component stresses; three-phase AC/DC conversion, center-tap rectifier with impressed output current, thyristor function, thyristor center-tap and full-bridge converter, rectifier and inverter operation, control angle and recovery time, inverter operation limit; basics of inductors and single-phase transformers, design based on scaling laws; isolated DC/DC converter, flyback and forward converter, single-switch and two-switch circuit; single-phase DC/AC conversion, four-quadrant converter, unipolar and bipolar modulation, fundamental frequency model of AC-side operating behaviour; three-phase DC/AC converter with star-connected three-phase load, zero sequence (common-mode) and current forming differential-mode output voltage components, fundamental frequency modulation and PWM with sine triangular carrier and individual carrier signals of the phases.

Lecture notes
Lecture notes and associated exercises including correct answers, simulation program for interactive self-learning including visualization/animation features.

Prerequisites / notice
Prerequisites: Basic knowledge of electrical engineering / electric circuit analysis and signal theory.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
</tr>
<tr>
<td>Analytical Competencies</td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
<td>Critical Thinking</td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>Problem-solving</td>
<td>Customer Orientation</td>
<td>Integrity and Work Ethics</td>
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<tr>
<td>Project Management</td>
<td>Leadership and Responsibility</td>
<td>Self-presentation and Social Influence</td>
<td>Self-awareness and Self-reflection</td>
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<td></td>
<td>Sensitivity to Diversity</td>
<td>Negotiation</td>
<td>Self-direction and Self-management</td>
</tr>
</tbody>
</table>

227-0247-00L Power Electronic Systems I
W 6 credits 4G J. Biela, F. Krämer

Abstract
Basics of the switching behavior, gate drive and snubber circuits of power semiconductors are discussed. Soft-switching and resonant DC/DC converters are analyzed in detail and high frequency loss mechanisms of magnetic components are explained. Space vector modulation of three-phase inverters is introduced and the main power components are designed for typical industry applications.

Objective
Detailed understanding of the principle of operation and modulation of advanced power electronics converter systems, especially of zero voltage switching and zero current switching non-isolated and isolated DC/DC converter systems and three-phase voltage DC link inverter systems. Furthermore, the course should convey knowledge on the switching frequency related losses of power semiconductors and inductive power components and introduce the concept of space vector calculus which provides a basis for the comprehensive discussion of three-phase PWM converters systems in the lecture Power Electronic Systems II.

Content
Basics of the switching behavior and gate drive circuits of power semiconductor devices and auxiliary circuits for minimizing the switching losses are explained. Furthermore, zero voltage switching, zero current switching, and resonant DC/DC converters are discussed in detail; the operating behavior of isolated full-bridge DC/DC converters is detailed for different secondary side rectifier topologies; high frequency loss mechanisms of magnetic components of converter circuits are explained and approximate calculation methods are presented; the concept of space vector calculus for analyzing three-phase systems is introduced; finally, phase-oriented and space vector modulation of three-phase inverter systems are discussed related to voltage DC link inverter systems and the design of the main power components based on analytical calculations is explained.

Lecture notes
Lecture notes and associated exercises including correct answers.

Prerequisites / notice
Prerequisites: Introductory course on power electronics is recommended.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Creative Thinking</td>
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<tr>
<td>Analytical Competencies</td>
<td>Media and Digital Technologies</td>
<td>Critical Thinking</td>
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<tr>
<td>Project Management</td>
<td>Problem-solving</td>
<td>Integrity and Work Ethics</td>
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<td></td>
<td>Systematische Bildung</td>
<td>Self-awareness and Self-reflection</td>
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<td></td>
<td>Leadership and Responsibility</td>
<td>Self-direction and Self-management</td>
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</tbody>
</table>

227-0311-00L Qubits, Electrons, Photons
W 6 credits 3V+2U T. Zambelli

Abstract
In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis).

Objective
Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics.

Starting from the axioms of quantum mechanics, we will derive the fascinating theory describing spin and qubits, electron transitions and transfer, photons and LASER: quantum mechanics is different because it mocks our daily Euclidean intuition!

In this way, students will work out a robust quantum mechanics (theoretical!!!) basis which will help them in their advanced studies of the following masters: EEIT (batteries), Biomedical Engineering (NMR, bioelectronics), Quantum Engineering, Micro- and Nanosystems.

IMPORTANT: "qubits" from the point of view of NMR (and NOT from that of quantum computing!).
Content

• Lagrangian and Hamiltonian: Symmetries and Poisson Brackets
• Postulates of QM: Hilbert Spaces and Operators
• Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator
• Density Operator
• Spin: Qubits, Bloch Equations, and NMR
• Entanglement
• Symmetries and Corresponding Operators
• Schrödinger's Wave Mechanics: Electrons in a Periodic Potential and Energy Bands
• Harmonic Oscillator: Creation and Annihilation Operators
• Identical Particles: Bosons and Fermions
• Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER
• Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener

Lecture notes

No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM, while corresponding videos of the previous years are available in Moodle !!!

Literature

• M. Le Bellac, "Quantum Physics", 2011, Cambridge University Press

Supplementary material will be uploaded in Moodle.

— — — — — — — — — — — — — — — — — — — — — —

+ (as rigorous and profound presentation of the mathematical framework) G. Dell’Antonio, "Lectures on the Mathematics of Quantum Mechanics I", 2015, Springer

+ (as account of those formidable years) G. Gamow, "Thirty Years that Shook Physics", 1985, Dover Publications Inc.

Prerequisites / notice

The course has been intentionally conceived to be self-consistent with respect to QM for those master students not having encountered it in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) QM introduction course like the D-ITET “Physics II”.

A solid base of Analysis I & II as well as of Linear Algebra is really helpful.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Project Management assessed

Social Competencies

Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity assessed
Negotiation fostered

Personal Competencies

Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

227-0523-00L Railway Systems I W 6 credits 4G M. Meyer

Abstract

Basic characteristics of railway vehicles and their interfaces with the railway infrastructure:
- Transportation tasks and vehicle types
- Running dynamics
- Mechanical part of rail vehicles
- Brakes
- Traction chain and auxiliary supply
- Railway power supply
- Signalling systems
- Standards
- Availability and safety
- Traffic control and maintenance

Objective

- Overview of the technical characteristics of railway systems
- Know-how about the design and construction principles of rail vehicles
- Interrelationship between different fields of engineering sciences (mechanics, electro and information technology, transport systems)
- Understanding tasks and opportunities of engineers working in an environment which has strong economical and political boundaries
- Insight into the activities of the railway vehicle industry and railway operators in Switzerland
- Motivation of young engineers to start a career in the railway industry or with railway operators
### Critical Thinking

**Assessed Competencies**

1. Portfolio and risk management in the electrical power business, Pan-European power market and trading, futures and forward contracts, and risk management of financial products (derivatives) based on power. Management of a portfolio containing physical production, contracts and derivatives.

2. Ancillary services, balancing power market, Swiss market model.


**Subject-specific Competencies**

- G. A. Koeppel

**Concepts and Theories**

Knowledge on the worldwide liberalisation of electricity markets, pan-european power trading and the role of power exchanges. Understand financial products (derivatives) based on power. Management of a portfolio containing physical production, contracts and derivatives.

**Method-specific Competencies**

Evaluate trading and hedging strategies. Apply methods and tools of risk management.

**Personal Competencies**

- Dr. Markus Meyer, Emkamatik GmbH

### EST I (Herbstsemester) - Begriffe, Grundlagen, Merkmale

**Objective**

The goals of this course are a) understanding the fundamentals of the electromagnetic, thermal, mechanical, and coupled field simulations necessary for modern product development and research based on virtual prototyping. She / he should also learn the theoretical background of the finite element method (FEM) and its application to low- and high-frequency electromagnetic field simulation problems. The practical exercises of the course should be done by using one of the commercially available field simulation software (Infolytica, ANSYS, and / or COMSOL).

After completing the course the student should be able to properly and efficiently use the software to simulate practical design problems and to understand and interpret the obtained results.

**Content**

1. Electromagnetic Fields and Waves: Simulation Aspects (1 lecture, 2 hours)
   a. Short review of the governing equations
   b. Boundary conditions
   c. Initial conditions
   d. Linear and nonlinear material properties
   e. Coupled fields (electro-mechanical and electro-thermal coupling)

2. Finite Element Method for electromagnetic simulations (5 lectures and 3 exercises, 16 hours)
   a. Scalar-FEM in 2-D (electrostatic, magnetostatic, eddy-currents, etc.)
   b. Vector-FEM in 3-D (3-D eddy-currents, wave propagation, etc.)
   c. Numerical aspects of the analysis (convergence, linear solvers, preconditioning, mesh quality, etc.)
   d. Matlab code for 2-D FEM for learning and experimenting

3. Practical applications (5 lectures and 5 exercises, 20 hours)
   a. Dielectric analysis of high-voltage equipment
   b. Nonlinear quasi-electrostatic analysis of surge arresters
   c. Eddy-currents analysis of power transformers
   d. Electromagnetic analysis of electric machines
   e. Very fast transients in gas insulated switchgears (GIS)
   f. Electromagnetic compatibility (EMC)

**227-0536-00L Multiphysics Simulations for Power Systems**

**Abstract**

The goals of this course are a) understanding the fundamentals of the electromagnetic, thermal, mechanical, and coupled field simulations and b) performing effective simulations of primary equipment of electric power systems. The course is understood complementary to 227-0537-00L “Technology of Electric Power System Components”, but can also be taken separately.

**Objective**

The student should learn the fundamentals of the electromagnetic, thermal, mechanical, and coupled fields simulations necessary for modern product development and research based on virtual prototyping. She / he should also learn the theoretical background of the finite element method (FEM) and its application to low- and high-frequency electromagnetic field simulation problems. The practical exercises of the course should be done by using one of the commercially available field simulation software (Infolytica, ANSYS, and / or COMSOL).

After completing the course the student should be able to properly and efficiently use the software to simulate practical design problems and to understand and interpret the obtained results.

**Content**

1. Electromagnetic Fields and Waves: Simulation Aspects (1 lecture, 2 hours)
   a. Short review of the governing equations
   b. Boundary conditions
   c. Initial conditions
   d. Linear and nonlinear material properties
   e. Coupled fields (electro-mechanical and electro-thermal coupling)

2. Finite Element Method for electromagnetic simulations (5 lectures and 3 exercises, 16 hours)
   a. Scalar-FEM in 2-D (electrostatic, magnetostatic, eddy-currents, etc.)
   b. Vector-FEM in 3-D (3-D eddy-currents, wave propagation, etc.)
   c. Numerical aspects of the analysis (convergence, linear solvers, preconditioning, mesh quality, etc.)
   d. Matlab code for 2-D FEM for learning and experimenting

3. Practical applications (5 lectures and 5 exercises, 20 hours)
   a. Dielectric analysis of high-voltage equipment
   b. Nonlinear quasi-electrostatic analysis of surge arresters
   c. Eddy-currents analysis of power transformers
   d. Electromagnetic analysis of electric machines
   e. Very fast transients in gas insulated switchgears (GIS)
   f. Electromagnetic compatibility (EMC)
1. Pan-European power market and trading
   1.1. Power trading
   1.2. Development of the European power markets
   1.3. Energy economics
   1.4. Spot and OTC trading
   1.5. European energy exchange EEX

2. Market model
   2.1. Market place and organisation
   2.2. Balance groups / balancing energy
   2.3. Ancillary services
   2.4. Market for ancillary services
   2.5. Cross-border trading
   2.6. Capacity auctions

3. Portfolio and Risk management
   3.1. Portfolio management 1 (introduction)
   3.2. Forward and futures contracts
   3.3. Risk management 1 (M2M, VaR, HPFC, volatility, cVaR)
   3.4. Risk management 2 (PaR)
   3.5. Contract valuation (HPFC)
   3.6. Portfolio management 2
   2.8. Risk Management 3 (enterprise wide)

4. Energy & Finance I
   4.1. Options 1 basics
   4.2. Options 2 hedging with options
   4.3. Introduction to derivatives (swaps, cap, floor, collar)
   4.4. Financial modelling of physical assets
   4.5. Trading and hydro power
   4.6. Incentive regulation

Lecture notes
Handouts of the lecture
Prerequisites / notice
Case studies and ML exercise for Power Market can give bonus points for the exam. Guest speakers for specific topics.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Decision-making
Method-specific Competencies
- Media and Digital Technologies
- Problem-solving
- Project Management
Social Competencies
- Communication
- Cooperation and Teamwork
Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking

Simulation of Photovoltaic Devices - From Materials to Modules
3 credits 2G U. Aeberhard

Abstract
The lecture provides an introduction to the theoretical foundations and numerical approaches for the simulation of photovoltaic power conversion, from the microscopic description of component materials to macroscopic continuum modelling of solar cells and network simulation or effective models for performance prediction of entire solar modules.

Objective
Get an overview of the current status of photovoltaic technology. Understand the physics of photovoltaic energy conversion and solar cell device operation. Know how to obtain and assess by simulation the key material properties and device parameters. Be able to use standard device simulation tools to analyze, optimize, and predict the performance of solar cells and modules.

Content
Photovoltaic technology: history and overview; The solar spectrum; Thermodynamics of solar energy conversion; Detailed balance models and efficiency limit; Microscopic rates of charge carrier generation and recombination; Optical simulation of solar cells; Models for charge transport in semiconductor devices; High-efficiency water-based (silicon) photovoltaics; Thin film photovoltaics based on disordered materials (amorphous silicon, organic PV); High-efficiency thin film photovoltaics (CIGS, CdTe, metal-halide perovskites); PV beyond the single junction detailed balance (Shockley-Queisser) limit; Simulation of photovoltaic modules; Energy yield and performance modelling for PV systems; Quantum simulation of nanostructure-based solar cell devices (bonus lecture)

Literature
- M. A. Green, „Solar cells: operating principles, technology, and system applications“, Prentice Hall, 1982.

Prerequisites / notice
Undergraduate physics (including basic quantum mechanics), mathematics, semiconductor devices, optics. Knowledge of some scripting language (e.g. python) is of advantage.
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Solar Cells
227-0617-00L

Abstract
Physics, technology, characteristics and applications of photovoltaic solar cells and systems.

Objective
The students will appreciate the potential of solar radiation and photovoltaics, will learn the physics and technology of various solar cells, and will get to know the design basics of PV modules and systems for different applications.

Content
Introduction to photovoltaics and economic aspects, solar radiation, semiconductor physics and operation of solar cells, technology of wafer-based (Si, GaAs, multi-junction) and thin-film (CIGS, CdTe, perovskite) solar cells, emerging technologies, design of PV modules, systems and plants including system components such as inverters and controllers, engineering procedures with software demonstration, integration in buildings and other specific examples such as concentrated photovoltaics and power generation for space applications.

Lecture notes
Lecture slides (PDF files in English) will be available on Moodle and lecture recordings will be available on the ETH video portal.

Prerequisites / notice
Prerequisites: Basic knowledge of semiconductors.

⬇️ Energy Flows and Processes

Number Title Type ECTS Hours Lecturers
151-0123-00L Experimental Methods for Engineers W 4 credits 2V+2U D. J. Norris, F. Coletti, M. Lukatskaya, A. Manera, O. Supponen, M. Tibbitt

Does not take place this semester.

Abstract
The course presents an overview of measurement tasks in engineering environments. Different concepts for the acquisition and processing of typical measurement quantities are introduced. Following an initial in-class introduction, laboratory exercises from different application areas (especially in thermofluidics, energy, and process engineering) are attended by students in small groups.

Objective
Introduction to various aspects of measurement techniques, with particular emphasis on thermo-fluidic, energy, and process-engineering applications.

Understanding of various sensing technologies and analysis procedures.

Exposure to typical experiments, diagnostics hardware, data acquisition, and processing.

Study of applications in the laboratory. Fundamentals of scientific documentation and reporting.

Content
In-class introduction to representative measurement techniques in the research areas of the participating institutes (fluid dynamics, energy technology, and process engineering).

Student participation in ~6 laboratory experiments (study groups of ~3 students, dependent on the number of course participants and available experiments).

Lecture notes
Lab reports for all attended experiments have to be submitted by the study groups.

Literature

Prerequisites / notice
Basic understanding in the following areas:
- fluid mechanics, thermodynamics, heat and mass transfer
- electrical engineering / electronics
- numerical data analysis and processing (e.g. using MATLAB)

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving fostered
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Leadership and Responsibility fostered

Personal Competencies
Critical Thinking fostered
Self-direction and Self-management fostered
The objective of this course is to introduce the students to the fundamentals, technologies, modern day application, and economics of wind energy. This course introduces the fundamentals of energy system modeling for the analysis and the optimization of the energy system design and operation. An introductory (advanced Bachelor or beginner Master level) course on Energy Systems Analysis, providing an overview of the field and methods. After an introduction to systems thinking and characterisation of technologies, three main blocks cover with Lifecycle Assessment (LCA, 3 units), bottom-up linear optimisation models (5 units) and Multi-Criteria Decision Analysis (MCDAs, 3 units). 

### Nuclear Energy Conversion

**W 4 credits 2V+1U A. Manera**

**Abstract**
Physical fundamentals of the fission reaction and the sustainable chain reaction, thermal design, construction, function and operation of nuclear reactors and power plants, light water reactors and other reactor types, conversion and breeding.

**Objective**
- Students get an overview on energy conversion in nuclear power plants, on construction and function of the most important types of nuclear reactors with special emphasis to light water reactors. They obtain the mathematical/physical basis for quantitative assessments concerning most relevant aspects of design, dynamic behaviour as well as material and energy flows.

**Content**
Nuclear physics of fission and chain reaction. Thermodynamics of nuclear reactors. Design of the reactor core. Introduction into the dynamic behaviour of nuclear reactors. Overview on types of nuclear reactors, difference between thermal reactors and fast breeders. Construction and operation of nuclear power plants with pressurized and boiling water reactors, role and function of the most important safety systems, special features of the energy conversion. Development tendencies of reactor technology.

**Lecture notes**
Hand-outs will be distributed. Additional literature and information on the website of the lab: https://www.ethz.ch/content/specialinterest/mavt/energy-technology/lab-of-nuclear-energy-systems/en/studium/teaching-materials/151-0163-00l-nuclear-energy-conversion.html

**Literature**

R. L. Murray: Nuclear Energy (Sixth Edition), An Introduction to the Concepts, Systems, and Applications of Nuclear Processes, Elsevier

### Wind Energy

**W 4 credits 2V+1U N. Chokani**

**Abstract**
The objective of this course is to introduce the students to the fundamentals, technologies, modern day application, and economics of wind energy. This mechanical engineering course focuses on the technical aspects of wind turbines; non-technical issues are not within the scope of this technically oriented course. On completion of this course, the student shall be able to conduct the preliminary aerodynamic and structural design of the wind turbine blades. The student shall also be more aware of the broad context of drivetrains, dynamics and control, electrical systems, and meteorology, relevant to all types of wind turbines.

**Objective**
The objective of this course is to introduce the students to the fundamentals, technologies, modern day application, and economics of wind energy.

**Content**
This course introduces the fundamentals of energy system modeling for the analysis and the optimization of the energy system design and operations. The students are taught to understand and will be able to apply the basic principles of wind energy generation and conversion, and a detailed description of the broad range of relevant technical, economic and environmental topics.

**Lecture notes**
Lecture slides and supplementary documentation will be available online. Reference to appropriate book chapters and scientific papers will be provided.

### Introduction to Modeling and Optimization of Sustainable Energy Systems

**W 4 credits 4G G. Sansavini, A. Bardow, S. Moret**

**Abstract**
This course introduces the fundamentals of energy system modeling for the analysis and the optimization of the energy system design and operations.

**Objective**
At the end of this course, students will be able to:
- define and quantify the key performance indicators of sustainable energy systems;
- select and apply appropriate models for conversion, storage and transport of energy;
- develop mathematical models for the analysis, design and operations of multi-energy systems and solve them with appropriate mathematical tools;
- select and apply methodologies for the uncertainty analysis on energy systems models;
- apply the acquired knowledge to tackle the challenges of the energy transition.

**Content**
In the course "Introduction to Modeling and Optimization of Sustainable Energy Systems", the competencies of process understanding, system understanding, modeling, concept development, data analysis & interpretation and measurement methods are taught, applied and examined. Programming is applied.

**Lecture notes**
Lecture slides and supplementary documentation will be available online. Reference to appropriate book chapters and scientific papers will be provided.

### Energy Systems Analysis: an Introduction and Overview with Applications

**W 4 credits 2V+2U R. McKenna, P. Burgherr, E. Panos, R. Sacchi**

**Abstract**
Introductory (advanced Bachelor or beginner Master level) course on Energy Systems Analysis, providing an overview of the field and methods. After an introduction to systems thinking and characterisation of technologies, three main blocks cover with Lifecycle Assessment (LCA, 3 units), bottom-up linear optimisation models (5 units) and Multi-Criteria Decision Analysis (MCDAs, 3 units).

**Objective**
- Analyse energy technologies with respect to different criteria/characteristics;
- Discuss and debate the pros and cons of different ESA models/approaches (for specific applications);
- Explain the system-level interdependencies/interconnections within the energy system;
- Evaluate the effect of uncertainties and "the human dimension" on ESA and scenarios.

**Content**
The course provides an introduction and overview to the most well-established models and methods of energy systems analysis, in each case introducing students to the theory and assumptions of the method, strengths and weaknesses of the specific approach, and case studies for exemplary energy technologies and systems. The students are taught to understand and will be able to apply the basic principles of these methods in the context of targeted assignments relating to real-world energy systems.

### Competencies

#### Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: fostered

#### Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed

#### Social Competencies

- Communication: fostered
- Cooperation and Teamwork: fostered
- Sensitivity to Diversity: fostered

#### Personal Competencies

- Negotiation: fostered
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

**Prerequisites / notice**
No specific prerequisites, some background in energy-related topics in the Bachelor would be beneficial.

**Literature**
Will be provided during the course.

**Prerequisites / notice**
No specific prerequisites, some background in energy-related topics in the Bachelor would be beneficial.
151-0251-00L Principles, Efficiency Optimization and Future Applications of IC Engines

Objective
The students get familiar with operating characteristics and efficiency maximization methods for Internal Combustion (IC) engines which are expected to continue to play a very important role in transportation (long-haul heavy duty, marine) and decentralized combined heat and power generation. Following an overview of different applications and powertrains, the course will focus on the following topics: First, a generic overview of the history of IC-Engines is given, and the basic dimensions and specific engine-relevant terminology are introduced. Next, operating maps for different duty cycles are discussed, highlighting the benefits of individual powertrain configurations for different usage scenarios. The high-pressure thermodynamic process and combustion-induced heat release are analyzed in detail and the design of the combustion processes is discussed in view of further optimization of the energy conversion efficiency. The concept of boosting, its challenges and potential are also presented. In addition, flow field characteristics, convective and radiative heat transfer and combustion modes (Otto, Diesel and “multi-mode” cycles) will be discussed along with possible simulation methods. The course consists of lectures combined with exercises. In addition, several invited guest talks will be held by representatives from Swiss industrial companies active in this field. Provided the pandemic measures allow, visits to different engine test facilities are further envisioned.

Literature

Prerequisites / notice
This course provides background for the course 151-0254-00L “Environmental Aspects of Future Mobility” held in the Spring Semester, where the focus is on emission formation and minimization, exhaust gas after treatment systems and potentials of future synthetic/e-fuels in IC engines; all given in the broader context of a future mobility/transportation options (battery electric, hybrids, fuel cells etc.) and transformation pathways towards sustainability.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Transformation pathways towards sustainability.

Method-specific Competencies
Analytical Competencies

151-0567-00L Engine Systems

Objective
Introduction to current and future engine systems and their control systems

Content
Physical description and mathematical models of components and subsystems (mixture formation, load control, supercharging, emissions, drive train components, etc.).

Lecture notes
Introduction to Modeling and Control of Internal Combustion Engine Systems
Guzzella Lino, Onder Christopher H.
ISBN: 978-3-642-10774-0

Prerequisites / notice
Combined homework and testbench exercise (air-to-fuel-ratio control or idle-speed control) in groups

151-0569-00L Vehicle Propulsion Systems

Objective
Introduction to current and future propulsion systems and the electronic control of their longitudinal behavior

Content
Understanding of physical phenomena and mathematical models of components and subsystems (manual, automatic and continuously variable transmissions, energy storage systems, electric drive trains, batteries, hybrid systems, fuel cells, road/wheel interaction, automatic braking systems, etc.).

Lecture notes
Vehicle Propulsion Systems
Introduction to Modeling and Optimization
Guzzella Lino, Sciarretta Antonio
2013, X, 409 p, 202 illus., Geb.
ISBN: 978-3-642-35912-5

Prerequisites / notice
Lectures of Prof. Dr. Ch. Onder and Dr. Ph. Elbert are also possible to be held in German.

529-0613-01L Process Simulation and Flowsheeting

Objective
This course comprises the theoretical principles of chemical process simulation and optimization, as well as its practical application in process analysis. The techniques for simulating stationary and dynamic processes are presented, and illustrated with case studies. Commercial software packages (Aspen) are introduced for solving process flowsheeting and optimization problems.

Abstract
This course aims to develop the competency of chemical engineers in process flowsheeting, process simulation and process optimization. Specifically, students will develop the following skills:
- Deep understanding of chemical engineering fundamentals: the acquisition of new concepts and the application of previous knowledge in the area of chemical process systems and their mechanisms are crucial to intelligently simulate and evaluate processes.
- Modeling of general chemical processes and systems: students should be able to identify the boundaries of the system to be studied and develop the relevant mathematical relations, which describe the process behavior.

Method-specific Competencies
Understanding of physical phenomena and mathematical models of components and subsystems (manual, automatic and continuously variable transmissions, energy storage systems, electric drive trains, batteries, hybrid systems, fuel cells, road/wheel interaction, automatic braking systems, etc.).

Publication
Guzzella Lino, Onder Christopher H.
Case studies of model-based optimal design and control of engine systems with the goal of minimizing fuel consumption and emissions.

Techniques and Technologies
- Process optimization: the students will learn how to formulate optimization problems in mathematical terms, the main type of optimization problems that exist (i.e., LP, NLP, MILP and MINLP) and the fundamentals of the optimization algorithms implemented in commercial solvers.

Method-specific Competencies
- Process optimization: the students will learn how to formulate optimization problems in mathematical terms, the main type of optimization problems that exist (i.e., LP, NLP, MILP and MINLP) and the fundamentals of the optimization algorithms implemented in commercial solvers.

Objective
- Process optimization: the students will learn how to formulate optimization problems in mathematical terms, the main type of optimization problems that exist (i.e., LP, NLP, MILP and MINLP) and the fundamentals of the optimization algorithms implemented in commercial solvers.

Abstract
- Process optimization: the students will learn how to formulate optimization problems in mathematical terms, the main type of optimization problems that exist (i.e., LP, NLP, MILP and MINLP) and the fundamentals of the optimization algorithms implemented in commercial solvers.

González Lino, Gómez Antonio
Presentation of mathematical methods, CAE tools and case studies for the model-based design and control of propulsion systems with the goal of minimizing fuel consumption and emissions.

Techniques and Technologies
- Process optimization: the students will learn how to formulate optimization problems in mathematical terms, the main type of optimization problems that exist (i.e., LP, NLP, MILP and MINLP) and the fundamentals of the optimization algorithms implemented in commercial solvers.
Overview of process simulation and flowsheeting:
- Definition and fundamentals
- Fields of application
- Case studies

Process simulation:
- Modeling strategies of process systems
- Mass and energy balances and degrees of freedom of process units and process systems

Process flowsheeting:
- Flowsheet partitioning and tearing
- Solution methods for process flowsheeting
- Simultaneous methods
- Sequential methods

Process optimization and analysis:
- Classification of optimization problems
- Linear programming, LP
- Non-linear programming, NLP
- Mixed-integer linear programming, MILP
- Mixed-integer nonlinear programming, MINLP

Commercial software for simulation (Aspen Plus):
- Thermodynamic property methods
- Reaction and reactors
- Separation / columns
- Convergence, optimisation & debugging

Literature
An exemplary literature list is provided below:
- Smith, R. Chemical process design and integration, Wiley (2005).

Prerequisites / notice
A basic understanding of material and energy balances, thermodynamic property methods and typical unit operations (e.g., reactors, flash separations, distillation/absorption columns etc.) is required.

Energy Economics and Policy

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0577-00L</td>
<td>An Introduction to Sustainable Development in the Built Environment</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>G. Habert, E. Zea Escamilla</td>
</tr>
</tbody>
</table>

Abstract
In 2015, the UN Conference in Paris shaped future world objectives to tackle climate change. This decarbonization strategy is additional to Sustainable Development goals formulated the same year by the UN general assembly.

What does that mean for the built environment?
This course provides an introduction to the notion of sustainable development when applied to our built environment.

Objective
At the end of the semester, the students have an understanding of the term of sustainable development, its history, the current political and scientific discourses and its relevance for our built environment.

In order to address current challenges of climate change mitigation and resource depletion, students will learn a holistic approach of sustainable development. Ecological, economical and social constraints will be presented and students will learn about methods for argumentation and tools for assessment (i.e. life cycle assessment).

For this purpose an overview of sustainable development is presented with an introduction to the history of sustainability and its today definition as well as the role of cities, urbanisation and material resources (i.e. energy, construction material) in social economic and environmental aspects.

The course aims to promote an integral view and understanding of sustainability and describing different spheres (social/cultural, ecological, economical, and institutional) that influence our built environment.

Students will acquire critical knowledge and understand the role of involved stakeholders, their motivations and constraints, learn how to evaluate challenges, identify deficits and define strategies to promote a more sustainable construction.

After the course students should be able to define the relevance of specific local, regional or territorial aspects to achieve coherent and applicable solutions toward sustainable development.

The course offers an environmental, socio-economic and socio-technical perspective focusing on buildings, cities and their transition to resilience with sustainable development. Students will learn on theory and application of current scientific pathways towards sustainable development.
The following topics give an overview of the themes that are to be worked on during the lecture.

- Overview on the history and emergence of sustainable development
- Overview on the current understanding and definition of sustainable development and beyond

Methods
- Method 1: Life cycle assessment (planning, construction, operation/use, deconstruction)
- Method 2: Life Cycle Costing
- Method 3: Labels and certification
- Method 4: Material Flow Analysis

Main issues:
- Operation energy at building, urban and national scale
- Mobility and density questions
- Embodied energy for developing and developed world

- Synthesis: Transition to sustainable development

Lecture notes
All relevant information will be online available before the lectures. For each lecture slides of the lecture will be provided.

Literature
A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.

Competencies

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**102-0317-00L Advanced Environmental Assessments**

Master students in Environmental Engineering choosing module Ecological Systems Design are not allowed to enrol 102-0317-00 Advanced Environmental Assessments (3KP) as already included in 102-0307-01 Advanced Environmental, Social and Economic Assessments (5KP).

**Abstract**
This course deepens students' knowledge of the environmental assessment methodologies and their various applications.

**Objective**
This course has the aim of deepening students' knowledge of the environmental assessment methodologies and their various applications. In particular, students completing the course should have the

- Ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors
- Knowledge about the current state of the scientific discussion and new research developments
- Ability to properly plan, conduct and interpret environmental assessment studies
- Knowledge of how to use LCA as a decision support tool for companies, public authorities, and consumers

**Content**
- Inventory developments, transparency, data quality, data completeness, and data exchange formats
- Allocation (multiooutput processes and recycling)
- Hybrid LCA methods.
- Consequential and marginal analysis
- Recent development in impact assessment
- Spatial differentiation in Life Cycle Assessment
- Workplace and indoor exposure in Risk and Life Cycle Assessment
- Uncertainty analysis
- Subjectivity in environmental assessments
- Multicriteria analysis
- Case Studies

**Lecture notes**
No script. Lecture slides and literature will be made available on Moodle.

**Literature**
Literature will be made available on Moodle.

**Prerequisites / notice**
Basic knowledge of environmental assessment tools is a prerequisite for this class. Students that have not done classwork in this topic before are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. 2016: Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5.2)).

**Competencies**

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**102-0317-03L Advanced Environmental Assessment (Computer Lab I)**

Different tools and software used for environmental assessments, such as LCA are introduced. The students will have hands-on exercises in the computer rooms and will gain basic knowledge on how to apply the software and other resources in practice

**Objective**
Become acquainted with various software programs for environmental assessment including Life Cycle Assessment, Environmental Risk Assessment, Probabilistic Modeling, Material Flow Analysis.

**Competencies**

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**102-0317-04L Advanced Environmental Assessment (Computer Lab II)**

Not for master students in Environmental Engineering choosing module Ecological System Design as already included in Environment and Computer Laboratory I (Year Course): 102-0527-00 and 102-0528-00.
Abstract

Technical systems are investigated in projects, based on the software and tools introduced in the course 102-0317-03L Advanced Env. Assesment (Computer Lab I). The projects are created around a complete but simplified LCA study, where the students will learn how to answer a given question with target oriented methodologies using various software programs and data sources for env. assessment.

Objective

Become acquainted with utilizing various software programs for environmental assessment to perform a Life Cycle Assessment and learn how to address the challenges when analyzing a complex system with available data and software limitations.

Prerequisites / notice

Prerequisite is enrolment of 102-0317-00 Advanced Environmental Assessments and of 102-0317-03 Advanced Environmental Assessments (Computer Lab I) in parallel or in advance (both courses in HS).

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Project Management fostered

Social Competencies

Communication assessed
Cooperation and Teamwork fostered

Personal Competencies

Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered

102-0327-01L Implementation of Environmental and Other Sustainability Goals

Master students in Environmental Engineering choosing module Ecological Systems Design are not allowed to enrol 102-0327-01 Advanced Environmental Assessments (2KP) as already included in 102-0307-01 Advanced Environmental, Social and Economic Assessments (5KP).

Abstract

This course teaches approaches and methods to identify, assess and manage environmental (mainly) and societal (to some extent) aspects in organisations. The course contains an introduction to the global ISO 14001 standard on environmental management, into the concept of ecobalance of organisations, and supply chain management, and a general view on how such approaches fit into a management system.

Objective

Students will learn to

- describe key sustainability problems of the current economic system and measuring units.
- describe the management system of an organisation and how to develop a sustainability orientation
- discuss approaches to measure environmental performance of an organisation, including ‘organisational LCA’ (Ecobalance)
- explain the pros and cons of single score environmental assessment methods
- apply life cycle costing
- interpret stakeholder relations of an organisation
- (if time allows) describe sustainable supply chain management and stakeholder management

Content

- Sustainability problems of the current economic system and its measuring units;
- The structure of a management system, and elements to integrate environmental management (ISO 14001) and social management (SA8000), especially into strategy development, planning, controlling and communication;
- Sustainability Opportunities and Innovation for companies
- The concept of ‘continuous Improvement’, and its application to environmental management
- Life Cycle Costing, as part of Life Cycle Management
- environmental performance measurement of an organisation, including ‘organisational LCA’ (Ecobalance), incl. practical examples of companies
- single score environmental assessment methods, with a focus on the ‘ecopoints’ method
- stakeholder management and sustainability oriented communication
- an intro into sustainability issues of supply chain management

Lecture notes

Documents will be available on Ilias

Literature

Will be made available.

Prerequisites / notice

This course is meant for any interested student.

(Student of ESD Ecological Systems Design should choose the combined "AESEA" course (102-0307-01), which is specifically offered and mandatory for their module and includes this course.

Basic knowledge of environmental assessment tools is a prerequisite for this class. Students who have not yet had classwork in this topic will profit more from this course after reading an appropriate textbook before or at the beginning of this course, e.g. Jolliet, O. et al. (2016). Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5.2).

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Social Competencies

Communication assessed
Cooperation and Teamwork fostered
Self-presentation and Social Influence fostered
Negotiation fostered

Personal Competencies

Critical Thinking assessed
Self-awareness and Self-reflection fostered

363-0537-00L Resource and Environmental Economics

Abstract

Relationship between economy and environment, market failures, external effects and public goods, contingent valuation, internalisation of externalities, economics of non-renewable resources, economics of renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.
A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power. When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

**Literature**

**Competencies**

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</table>

**Content**

The course explores current challenges of corporate sustainability and prepares students to become champions for sustainable business practices. The module combines asynchronous videos, live sessions, with a group work phase between weeks 5-10 of semester during which students deep-dive into one of 10 sustainability challenges.

**Objective**

Students
- assess the limits and the potential of corporate sustainability for sustainable development
- develop competencies that are useful in the context of corporate sustainability and beyond (analytical competency, critical thinking, problem solving)
- recognize and realize opportunities through team work for corporate sustainability in a business environment
- present strategic recommendations in teams

**Content**

Corporate Sustainability is the flagship course of the Group for Sustainability and Technology at D- MTEC. In this course, students learn about key concepts in corporate sustainability and develop skills to implement them in the real world. The course prepares students for making well-informed sustainability decisions in their future careers.

The course uses constructive alignment to bring the various innovative teaching and learning elements (e.g., case- based experiential learning, reflective thinking and blended learning with videos and quizzes) into a coherent transformational journey. Students can now flexibly, efficiently, and effectively acquire the conceptual foundations that are essential for a substantial understanding of corporate sustainability.

**Lecture notes**
http://www.sustec.ethz.ch/teaching/lectures/corporate-sustainability.html
Presentation slides will be made available on Moodle after lectures.

**Literature**
Literature recommendations will be distributed via Moodle, and are available from the start of the course.

**Prerequisites / notice**

TEACHING FORMAT/ ATTENDANCE: The course includes several mandatory sessions that participants must attend to successfully earn credit points. It is not possible to take the class purely online.

**Recommended Science in Perspective**

<table>
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<tr>
<th>Science in Perspective</th>
<th>Only courses offered under &quot;GESS Science in Perspective&quot; count in this category. See “Offered in” tab in course view. For more information, please refer to <a href="https://gess.ethz.ch/en/studies/science-in-perspective/SiP-FAQs.html">https://gess.ethz.ch/en/studies/science-in-perspective/SiP-FAQs.html</a></th>
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<tr>
<td>see Science in Perspective: Language Courses ETH/ UZH</td>
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<td>see Science in Perspective: Type A: Enhancement of Reflection Capability</td>
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Recommended Science in Perspective (Type B) for D-I>ET

**Master’s Thesis**

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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1101-00L</td>
<td>How to Write Scientific Texts</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>U. Koch</td>
</tr>
</tbody>
</table>

Strongly recommended prerequisite for Semester Projects and Master Theses at D-I>ET (MSc BME, MSc EET, MSc...
Abstract
This four-hour course covers the basics of writing and presenting scientific work. The focus lies on the structure and the main elements of a scientific text. Formatting guidelines, citation rules, good practice of scientific writing and hints to convince the audience are part of the course.

Objective
- You can write scientific texts using the correct structure
- You can convincingly present scientific work
- You can differentiate the scientific style from novels and news
- You can adhere to citation rules and scientific integrity

Content
The block course covers the following topics:
- Structure of Scientific Texts
- Structure of Scientific Presentations
- Formatting of Scientific Elements (figures, equations, tables)
- Citation Rules and Scientific Integrity

The lecture will be given in two parts on two afternoons. Some exercises will be built into the lecture.

Literature
Scientific Integrity, see https://ethz.ch/en/research/ethics-and-animal-welfare/research-integrity.html

Prerequisites / notice
You should be writing either a bachelor/semester/master thesis or a scientific publication in the immediate future.

Competencies
<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Media and Digital Technologies</td>
<td>fostered</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
</tr>
</tbody>
</table>

| 227-1601-00L | Master's Thesis | O | 30 credits | 40D | Supervisors |

Only students who fulfill the following criteria are allowed to enroll for and start with their master thesis:

a. successful completion of the bachelor program;
b. any additional requirements necessary to gain admission to the master program EST have been successfully completed;
c. both the semester project and the internship have been successfully completed.

Registration in mystudies required!

Abstract
The master program in Energy Science and Technology culminates in a six months research project which addresses a scientific research questions on one's chosen area of specialization. The masters thesis is supervised by a program-affiliated faculty member and the topic must be approved in advance by the tutor.

Objective
see above

Key for Type

| O | Compulsory | E- | Recommended, not eligible for credits |
| W+ | Eligible for credits and recommended | Z | Courses outside the curriculum |
| W | Eligible for credits | Dr | Suitable for doctorate |

Key for Hours

| V | lecture | P | practical/laboratory course |
| G | lecture with exercise | A | independent project |
| U | exercise | D | diploma thesis |
| S | seminar | R | revision course / private study |
| K | colloquium |

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Mathematics I

Abstract
This course covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems - notably through ordinary differential equations.

Objective
Mathematics is of ever increasing importance to the Natural Sciences and Engineering. The key is the so-called mathematical modelling cycle, i.e. the translation of problems from outside of mathematics into mathematics, the study of the mathematical problems (often with the help of high level mathematical software packages) and the interpretation of the results in the original environment.

The goal of Mathematics I and II is to provide the mathematical foundations relevant for this paradigm. Differential equations are by far the most important tool for modelling and are therefore a main focus of both of these courses.

Content
2. Linear Algebra and Complex Numbers:
   systems of linear equations, Gauss-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, complex roots, fundamental theorem of algebra.

3. Ordinary Differential Equations:
   separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

Literature
- Bretscher, O.: Linear Algebra with Applications (Pearson Prentice Hall).
This course is intended to provide an overview of experimental chemical methods.

Objectives:
- Understanding basic geological and geophysical processes
- Providing an introduction to elementary laboratory techniques
- The central aim is to provide an individual experience of the physical phenomena and the basic principles of the experiment. By conducting experiments, the students will learn how to properly use physical instruments and how to evaluate the results correctly.
- The handling of chemicals and proper laboratory techniques represent the main learning targets. Furthermore, the description and recording of laboratory processes is an essential part of this course.
- The synthesis of simple inorganic complexes or organic molecules is practised. Selected samples (e.g. soil and water) will be analysed with various methods, such as titrations, spectroscopy or ion chromatography. The chemistry of aqueous solutions (acid-base equilibria and solvatation or precipitation processes) is studied.
- The experiments cover a wide range of analytic and synthetic tasks: analytical and synthetic techniques (e.g. investigation of soil and water samples or the preparation of simple compounds). Furthermore, the handling of gaseous substances is practised.
- The students will conduct exercises in small groups (10-15 students) that will be led by student assistants. Specific topics in earth sciences will be discussed using examples and case studies. Hand samples of the major rock types will be described and interpreted. Short excursions in the region of Zurich will permit direct experience with earth science processes (e.g. earth surface processes) and recognition of earth science problems and solutions relevant for modern society (e.g. building materials, water resources). Working in small groups will allow for discussion and examination of actual earth science themes.

First Year Additional Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0030-00L</td>
<td>Laboratory Course: Elementary Chemical Techniques</td>
<td>O</td>
<td>3</td>
<td>4P</td>
<td>A. de Mello, F. Jenny, N. Kobert, M. H. Schrotth</td>
</tr>
</tbody>
</table>

Abstract:
- This practical course provides an introduction to elementary laboratory techniques. The experiments cover a wide range of techniques, including analytical and synthetic techniques (e.g. investigation of soil and water samples or the preparation of simple compounds). Furthermore, the handling of gaseous substances is practised.

Objective:
- This course is intended to provide an overview of experimental chemical methods.
- The handling of chemicals and proper laboratory techniques represent the main learning targets. Furthermore, the description and recording of laboratory processes is an essential part of this course.

Content:
- The classification and analysis of natural and artificial compounds is a key subject of this course. It provides an introduction to elementary laboratory techniques, and the experiments cover a wide range of analytic and synthetic tasks: selected samples (e.g. soil and water) will be analysed with various methods, such as titrations, spectroscopy or ion chromatography. The chemistry of aqueous solutions (acid-base equilibria and solvatation or precipitation processes) is studied.
- The synthesis of simple inorganic complexes or organic molecules is practised. Furthermore, the preparation and handling of environmentally relevant gaseous species such as carbon dioxide or nitrogen oxides is a central subject of the Praktikum.

Lecture notes:
- The instructions to the experiments will be published on Moodle.

Literature:
- A thorough study of all script materials is requested before the course starts.

Competencies:
- Subject-specific Competencies: concepts and theories; techniques and technologies; cooperation and teamwork
- Social Competencies: fostering of learning targets. Furthermore, the description and recording of laboratory processes is an essential part of this course.

Basic Courses II

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0000-03L</td>
<td>Laboratory Course in Physics for Students in Earth Sciences</td>
<td>O</td>
<td>2</td>
<td>4P</td>
<td>A. Biland, A. Eggenberger, A. Müller</td>
</tr>
</tbody>
</table>

Abstract:
- The central aim is to provide an individual experience of the physical phenomena and the basic principles of the experiment. By conducting simple physical experiments the student will learn how to properly use physical instruments and how to evaluate the results correctly.

Objective:
- Laboratory work forms an important part of the education in natural sciences. The overhead topic in this lab course is the confrontation of fundamental problems of any experiment. Using the example of simple tasks, the following aspects should be considered in particular:
  - the practical structure of the experiment and the knowledge of the measuring methods
  - the use and handling of measuring instruments
  - the correct evaluation and assessment of the observations
  - deepening the knowledge in some areas of elementary physics
  - physics as a personal experience.

Content:
- Lab safety; error calculation and report writing; 6 selected experiments on a variety of topics. Selection of experiments may vary between courses.

Lecture notes:
- Manuals for the experiments in the physics lab; additional material is provided on the course website.

Competencies:
- Subject-specific Competencies: concepts and theories; techniques and technologies; fostering of learning targets. Furthermore, the description and recording of laboratory processes is an essential part of this course.
- Social Competencies: fostering of learning targets. Furthermore, the description and recording of laboratory processes is an essential part of this course.

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1098 of 2653
This course is an introduction into geochemistry with a special focus on the basic concepts used in this rapidly evolving field. The course fosters knowledge about the Earth’s chemical and physical structure, the processes occurring within it, and the interactions between the Earth and its environment. The students will learn how to apply geochemical methods to study natural processes and to solve complex problems.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Communication

#### Method-specific Competencies
- Problem-solving
- Critical Thinking

#### Personal Competencies
- Self-direction and Self-management

#### Social Competencies
- Communication

### Prerequisites

- Basic chemical and nuclear properties of elements from the periodic table
- Basic inorganic chemistry and physics
- Basics of Python programming

### Literature


### Examination Block 1

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<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0063-00L</td>
<td>Physics II</td>
<td>O</td>
<td>5 credits</td>
<td>3V+1U</td>
<td>A. Vaterlaus</td>
</tr>
</tbody>
</table>

**Abstract**

Introduction to the way physicists think and work with the help of concept questions, demonstration experiments and problem solving. Wherever possible, applications from thermodynamics, electricity and magnetism are taught from the areas of the degree programmes.

**Objective**

Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve them.

**Content**

Thermodynamics with first and second law, phase transformations, transport phenomena. Introduction to electricity and magnetism, as well as waves and modern physics.

**Lecture notes**

A script will be distributed.

**Literature**


### Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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</thead>
<tbody>
<tr>
<td>701-0023-00L</td>
<td>Atmosphere</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Schönächter, D. Vance</td>
</tr>
<tr>
<td>651-3400-00L</td>
<td>Geochemistry I</td>
<td>O</td>
<td>3 credits</td>
<td>2V</td>
<td>E. Fischer, U. Lohmann</td>
</tr>
<tr>
<td>402-0063-00L</td>
<td>Mathematics III: Systems Analysis</td>
<td>O</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>C. Brunner, R. Knutti, H. Wernli</td>
</tr>
</tbody>
</table>
The objective of the systems analysis course is to deepen and illustrate the mathematical concepts on the basis of a series of very concrete examples. Topics covered include: linear box models with one or several variables, non-linear box models with one or several variables, time-discrete models, and continuous models in time and space.

Learning and applying concepts (models) and quantitative methods to address concrete problems of environmental relevance. Understanding and applying the systems-analytic approach, i.e., Recognizing the core of the problem - simplification - quantitative approach - prediction.

https://iac.ethz.ch/edu/courses/bachelor/vorbereitung/systemanalyse.html

Overhead slides will be made available through the course website.


<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td></td>
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<tr>
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<td>Analytical Competencies</td>
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<td></td>
<td>Problem-solving</td>
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<td>assessed</td>
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<td></td>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>fostered</td>
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<tr>
<td></td>
<td></td>
<td>Critical Thinking</td>
<td>fostered</td>
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</table>

651-3543-00L  Geophysics I

Abstract  General knowledge of seismology.

Objective  General knowledge of seismology.

651-3507-00L  Introduction to Oceanography and Hydrogeology

Abstract  This course is designed to provide an introduction to hydrogeology and oceanography for all Earth Science students at ETH. It provides an overview of the physical controls on water flow in streams, aquifers, and the oceans. It also deals with the basics of groundwater chemistry, biogeochemical cycling in the oceans, the role of the oceans as carbon reservoirs and their dynamic redox state.

Objective  To understand and describe the basic principles of the hydrologic cycle and water flow in streams and aquifers.

To conduct simple calculations of water transfer in streams and aquifers as well as of flood frequencies and magnitudes.

To discuss surface and groundwater as a water resource.

To interpret different ion distributions in aquifers in terms of basic water chemistry, fluid-mineral reactions, water contamination, and water origin.

To understand the major features of ocean basins and the tectonic controls on their structure.

To identify the major controls on the temperature, salinity and density structure of the oceans.

To describe how these controls interact to drive surface and interior ocean circulation.

To interpret different kinds of element distribution in the oceans in terms of basic chemistry, sinks, sources and internal biogeochemical cycling.

To discuss the cycles of carbon and oxygen in the ocean, with a view to the critical analysis of how the oceans respond to, cause and record the dynamics of these cycles in Earth history.

Content  This course provides an introduction to oceanography and hydrogeology, with a special focus on the basic physicochemical concepts that control the properties and behaviour of two major reservoirs of water on Earth.

The hydrogeology component will: 1) describe the hydrologic cycle, with a focus on the importance of groundwater to society; introduce the basic physical aspects of groundwater flow, including Darcy's law, hydraulic head, hydraulic conductivity, aquifers; 2) describe the basics of groundwater chemistry, including major ions and mean meteoric water line, basics of groundwater contamination; 3) introduce the interface with the oceans, including hydrothermal circulation at mid-ocean ridges, ocean-water intrusion into groundwater at coasts.

The oceanography component will: 1) provide an overview of the physical circulation of the oceans, including its importance for heat transfer around the surface of the Earth and for climate; 2) describe the basic processes that control the chemistry of the oceans, including its temporal and spatial variability; 3) introduce some simple concepts in biological oceanography, including the dependence of ocean ecology on nutrient distributions. There will be a specific focus on how the physics, chemistry and biology of the ocean might have changed through Earth history, and the impact of oceanic processes on Earth's climate.


Chemie I and II, Physik I and II, Mathematik I and II.

Erdwissenschaftliche Datenanalyse und Visualisierung mit Python

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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<td>assessed</td>
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<tr>
<td></td>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<tr>
<td></td>
<td>Media and Digital Technologies</td>
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<tr>
<td></td>
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<td></td>
<td>assessed</td>
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<tr>
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<tr>
<td></td>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>651-4143-00L</td>
<td>Geobiology</td>
<td>O</td>
<td>3</td>
<td>2V+1U</td>
<td>C. Magnabosco, T. I. Eglington</td>
</tr>
</tbody>
</table>

Students registering for the course confirm having read and accepted the terms and conditions for excursions and field courses of D-ERDW:
We will study traces in the lithosphere that have been left behind by organisms during the course of Earth history and mineral components, which were built through biological processes or used as sources of energy and nutrients by organisms. Traces of life from the past will be compared with the development of the diversity of today’s organisms.

The course will allow you to ask questions about the origin and the evolution of life on Earth, to understand contemporary hypotheses and create new methods of developing them further. Theory is supplemented with observations in the field, exercises and the application of simple mathematical models. The course will enable you to integrate geobiological knowledge into topics that will be taught in subsequent earth science courses and into the current understanding of Earth history. You will learn to better understand modern geological settings and, if necessary, to recommend biogeochemically well-founded and responsible interventions or protective measures.

The course focuses on (a) geobiological cycles that play major roles in Earth history in aquatic and terrestrial ecosystems, (b) biosynthetic and metabolic processes, which are essential for life, (c) organisms which regulate and maintain geochanical cycling, and (d) chemical signals of past life in the geological record.

Accordingly, we must understand

- how biological cells and its components are built from essential elements and molecules,
- how cells function and which life styles organisms developed,
- where organisms can exist and which factors select for their persistence,
- where biologically usable forms of energy come from, and under which conditions they can be exploited,
- how biological metabolism can change environmental conditions and composition,
- which biological products can lead to signals preserved in the rock record, and how biomolecules and elements are altered in sedimentary deposits.

- how organic and inorganic components are cycled through the biosphere, and how biogeochemical cycles function,
- how "biological innovations" evolved and changed in response to environmental changes.

Applied Case Studies, which supplement and illustrate the contents:

- Scientific applications of geobiological knowledge are found in fields like Microbial Ecology, Geochemistry, Palaeontology, Sedimentology, Petrology, Ocean Research, Environmental Sciences, Astrobiology and Archaeology.
- Practical applications of geobiological knowledge are needed in fields like stabilisation of existing and design of safe waste repositories, surveilling ground water resources, sewage treatment, exploitation of and prospecting for fossil carbon sources, soil remediation, mineral exploration and teaching, forensic science and medicine.

At the end of the lecture part, students should be able to explain the following,

- formation processes of the solar system, the earth, and the moon.
- structure of the earth
- some important experimental approaches to determine the structure of the earth
- some important phase transformations appeared in the Earth’s deep interior.
- some important crystal structures appeared in the Earth’s deep interior.
- mineralogy of the upper mantle, transition zone, lower mantle, and the core.
- chemical composition of the mantle and core.

At the end of the exercise course, the students will be able to determine and describe the macroscopically observable properties of about 70 minerals and know the sum formulae of about 50 of them.

In the exercise part, the students familiarize with about 70 minerals and their macroscopic properties.

At the end of the lecture part, students should be able to explain the following,

- formation processes of the solar system, the earth, and the moon.
- structure of the earth
- some important experimental approaches to determine the structure of the earth
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- some important crystal structures appeared in the Earth’s deep interior.
- mineralogy of the upper mantle, transition zone, lower mantle, and the core.
- chemical composition of the mantle and core.

At the end of the exercise course, the students will be able to determine and describe the macroscopically observable properties of about 70 minerals and know the sum formulae of about 50 of them.

651-3301-00L Crystals and Minerals O 4 credits 2V+3U M. Murakami, P. Saha, to be announced

Abstract

In the lecture part, the objective of this course is to understand the basic concepts needed to understand the evolution, structure, and dynamics of the Earth from the perspectives of the mineralogy and crystallography.

In the exercise part, the students familiarize with about 70 minerals and their macroscopic properties.

Objective

At the end of the lecture part, students should be able to explain the following,

- formation processes of the solar system, the earth, and the moon.
- structure of the earth
- some important experimental approaches to determine the structure of the earth
- some important phase transformations appeared in the Earth’s deep interior.
- some important crystal structures appeared in the Earth’s deep interior.
- mineralogy of the upper mantle, transition zone, lower mantle, and the core.
- chemical composition of the mantle and core.

At the end of the exercise course, the students will be able to determine and describe the macroscopically observable properties of about 70 minerals and know the sum formulae of about 50 of them.

Content

Lecture part:

• Introduction of the course
• formation of the solar system
• formation of the earth
• formation of the moon
• structure of the earth
• compared with methods for exploring the structure of the planets
- high pressure and high temperature experiments
- X-ray diffraction
- laser spectroscopy
• phase transformation in deep planetary interiors
• chemical composition of the earth
• mineralogy of the upper mantle
• mineralogy of the mantle transition zone
• mineralogy of the lower mantle
• mineralogy of the Core-Mantle-Boundary (CMB)
• mineralogy of the core

Exercise part:

About 70 of the most important rock-forming and ore minerals and their properties

Lecture notes

Tabellen zum Mineralbestimmen, W.F. Oberholzer und V. Dietrich
The surface Earth is often thought of as a set of interacting systems, often with positive and negative feedbacks between them. These interacting systems control the tectonics, geomorphology, climate, and biology of the surface Earth. To fully understand the nature of the Earth System, including the controls on its past evolution, its present state, and its future, an integrated perspective is required.

To encourage students in the critical analysis of data and models in Earth Science, Planet Earth has had a complex history since its formation ~4.6 billion years ago. The surface Earth is often thought of as a set of interacting systems, often with positive and negative feedbacks between them. These interacting systems control the tectonics, geomorphology, climate, and biology of the surface Earth. To fully understand the nature of the Earth System, including the controls on its past evolution, its present state, and its future, an integrated perspective is required. This is a subject that pulls in observations and models from many areas of the Earth Sciences, including geochemistry, geophysics, and biology. The main goal of the course is to convey this integrated view of the surface of our planet.

We will achieve this integrated view through a series of lectures, exercises, and tutorials. We take as our framework some of the key events in Earth history, encouraging understanding of the controlling processes through integrated observations, ideas and models from disciplines across science.

### Majors

#### Major: Geology and Geophysics
Methods

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>651-3527-00L</td>
<td>Earth Science Mapping Exercises II</td>
<td>W+</td>
<td>2</td>
<td>2P</td>
<td>S. Volante</td>
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<tr>
<td>Abstract</td>
<td>Reading and interpretation of geological maps.</td>
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<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>All participants are able to:</td>
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</tr>
<tr>
<td></td>
<td>- Read and understand complex geological maps;</td>
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<td></td>
<td>- Assess, select, and project information from real case studies;</td>
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<td></td>
<td>- Make tectonic overview sketches and construct meaningful cross-sections;</td>
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<tr>
<td>Content</td>
<td>Advanced analysis of geological maps and construction of geological sections. Special points: normal faults of the Rheintal graben, Val de Ruz, Helvetic nappes of the Säntis area. Reconstruction of the geological history of the map areas. References to the Geology of Switzerland.</td>
<td></td>
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<tr>
<td>Lecture notes</td>
<td>Exercises and instructions are handed out.</td>
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<tr>
<td>Literature</td>
<td>Not required but for reference (in library holdings):</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>- Lisle, R.J., 1985: Geological structures and maps. Butterworth Heinemann</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Requirement: Earth science mapping exercises I</td>
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<tbody>
<tr>
<td>651-4031-00L</td>
<td>Geographic Information Systems</td>
<td>W+</td>
<td>3</td>
<td>4G</td>
<td>A. Baltensweiler</td>
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<tr>
<td>Abstract</td>
<td>Introduction to the fundamental concepts and data processing capabilities of Geographic Information Systems (GIS). Practical application of geospatial data management and analysis functions based on a selected geoscience project.</td>
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<tr>
<td>Objective</td>
<td>Students can:</td>
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<tr>
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<td>- explain the basic principles of GIS</td>
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<td>- solve a complex, real-world GIS problem in the field of Earth Science</td>
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<td>- apply the principles of data modelling and geoprocessing with ArcGIS Pro: data design and modelling, data acquisition, data integration and spatial analysis of vector and raster data, special functions for digital terrain modelling and hydrology, map production and 3D visualization.</td>
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<tr>
<td>Content</td>
<td>Theoretical introduction to the concepts, spatial data types and spatial data handling functions of Geographic Information Systems (GIS). Application of data modeling principles and geoprocessing capabilities using ArcGIS Pro: data design and modeling, data acquisition, data integration and spatial analysis of vector and raster data, particular functions for digital terrain modeling and hydrology, map generation and 3D-visualization.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture Script: Introduction to Geographic Information Systems, Tutorial: Introduction to ArcGIS Pro. All lecture materials are provided digitally.</td>
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<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Self-direction and Self-management</td>
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Advanced

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<tr>
<td>651-3521-00L</td>
<td>Tectonics</td>
<td>W+</td>
<td>3</td>
<td>2V</td>
<td>W. Behr, S. Willett</td>
</tr>
<tr>
<td>Abstract</td>
<td>Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales. Evaluation of plate tectonic and other orogenic processes through the study of reference examples of taken in Alps-Himalaya orogenic system.</td>
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</table>
Objective
Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales.
Assessment of mechanisms responsible for plate movements (the Earth as a heat transfer machine, dynamics of earth mantle, plate driving forces) and subsequent large-scale structures (oceanic basins and cycle of the oceanic lithosphere, convergence and mountain systems and continental growth, etc) through theoretical and experimental information.
Evaluation of plate tectonic and other orogenic processes through the study of reference examples of taken in Alps-Himalaya orogenic system.

Content
Plate tectonic frame work: earth cooling and mantle-plate interaction, three kinds of plate boundaries and their roles and characteristics, cycle of oceanic lithosphere, longevity and growth of continents, supercontinents.
Rheology of layered lithospheric and upper mantle.
Oclusion systems
Collision systems
Extensational systems
Basin evolution
Passive and active continental margin evolution

Literature

651-3501-00L Geochemistry II W+ 3 credits 2G S. Bernasconi, M. Schönächler
Abstract
The course focuses on the most important systems of radioactive and stable isotopes used in geochemistry and geology. Applications of isotope geochemistry for solving fundamental geological problems are discussed on the basis of case studies.

Objective
Development of a basic knowledge and understanding of the applications of the most important systems of stable and radiogenic isotopes.

Content
The following methods will be discussed in detail: the radioactive-radiogenic systems Rb-Sr, Sm-Nd, U-Th-Pb and K-Ar, as well as the stable isotope systems of oxygen, carbon, nitrogen, sulfur and hydrogen.

We will discuss how these methods are used in the following research fields: geochemistry of the earth, age dating, paleotemperature reconstructions, evolution of the crust and mantle reservoirs, sediment diagenesis, fluid rock interactions, hydrothermal activity, paleoceanography, biogeochemical cycles.

Lecture notes
Slides are provided online.

651-3440-02L Geophysics I W+ 4 credits 3G A. Jackson, P. Tackley
Abstract
This course builds on Geophysik I and Geophysik II, broadening the students' education in seismology, geodynamics and geodynamics theory, by considering various specific topics of particular interest.

Objective
To teach students the basics of observational seismology, earthquake source seismology, seismotectonics and the principle of seismic tomography, mantle convection over Earth history, structure of the oceanic and continental lithosphere, plate tectonics, hotspots, global heat flux, dynamo operation and magnetic field generation in Earth, planets, the Sun and stars; electromagnetic to probe the mantle.

Content
Obsrervational seismology, earthquake source seismology, seismotectonics and the principle of seismic tomography. Mantle convection over Earth history, structure of the oceanic and continental lithosphere, plate tectonics, hotspots, global heat flux. Dynamo operation and magnetic field generation in Earth, planets, the Sun and stars; electromagnetic to probe the mantle.

Applied
Literature


Further literature will be indicated during the lecture.

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**651-3541-00L Exploration and Environmental Geophysics**

**W+** 4 credits  **3V**  4 credits  **H. Maurer, A. Shakas**

**Abstract**
Overview and understanding of the most important geophysical methods: Potential field methods (Gravimetrics and Magnetics), Electrical and electromagnetic methods, Refraction and reflection seismics, Georadar. Discussion of survey design, sources and receivers and data processing.

**Objective**
Overview and understanding of the most important geophysical methods. Proposed solutions to assess and observe problems relevant to exploration and environmental geophysics in soil, ice and lithosphere at different scales. Getting familiar with measuring- and interpretation procedures. Pointing out the possibilities and limitations of geophysical methods.

**Content**

**Competencies**

- Subject-specific Competencies: Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Problem-solving
- Critical Thinking

**Lecture notes**
Available through Moodle / eDoz.

**Literature**

Handouts will be distributed during the teaching semester.

**Additional material will be provided by the lecturers.**

**EOCTs**

- 3 credits

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**651-4903-00L Quaternary Geology and Geomorphology**

**W** 3 credits  **2G**  4 credits  **H. Stoll**

**Abstract**
In this course the student is familiarized with the manner in which glacial, periglacial, fluvial, gravitational, karst, coastal and aeolian processes produce characteristic landforms and sedimentary deposits. The student is introduced to subdivisions of the Quaternary, with a focus on climatic changes in the Alps. Competency in these themes is gained through practical exercises and discussion.

**Competencies**

- Subject-specific Competencies: Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Creative Thinking
- Critical Thinking

**Lecture notes**

Handouts will be distributed during the teaching semester.

**Literature**


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**ELECTIVES**

The electives listed are recommended.

Additional courses can be chosen from the complete offerings of the ETH Zurich and University of Zurich.
This course provides an overview of the main natural hazards and their importance in a national and international context. The probability, risk and implications of various natural hazards will be discussed, along with potential management options. The course consists of introductory lectures and exercises, seminars with guest lectures by experts and a field trip.

By the end of the course, students will be able to:

- describe the main natural hazards, their processes and their importance in different contexts.
- describe the likelihood, risk, and consequences of natural hazards and their management options.
- identify and discuss the development of natural hazards in the context of climate change.

In this seminar, students learn to search efficiently for scientific literature and to present scientific findings orally and in written form. The students learn the principles of presenting scientific material orally. They become acquainted with the structure of scientific publications, and learn how to find, read and evaluate scientific literature. Furthermore, the course will introduce basic aspects of scientific writing.

At the end of this course, students are able to:

1. describe the structure of the atmosphere and list atmospheric components and their main properties.
2. define and describe the chemical and physical processes in the stratosphere and troposphere, follow reaction mechanisms, and apply rate laws.
3. describe the physical and chemical principles of air pollution and summarize the most important legislative measures.
4. discuss the local, regional, and global aspects of interactions between air quality, ecosystem health, and climate.

This course covers the chemical and physical processes controlling the composition of the troposphere and stratosphere and introduces the relevant fundamentals for processes in the gas phase, in aerosols and clouds. These concepts are explored in the context of key environmental issues, such as urban air pollution, stratospheric ozone depletion, and air quality connections to climate change.

Atmospheric Chemistry

The world of atmospheric chemistry is vast and fascinating, with a myriad of processes and reactions taking place in the Earth's atmosphere. This course introduces students to the fundamental concepts and theories of atmospheric chemistry, including the chemistry of the gas phase, aerosols, and clouds.

1. The chemistry of the gas phase: This section covers the basic principles of chemical reactions and their rate laws in the gas phase. Students will learn about the role of temperature, pressure, and concentration on chemical reaction rates, and how to apply these concepts to real-world atmospheric systems.
2. Aerosols: This section introduces the properties of aerosols, their formation and transformation, and their impact on atmospheric processes. Students will learn about the various sources of aerosols, their chemical and physical properties, and how they interact with other atmospheric constituents.
3. Clouds and precipitation: This section covers the formation and evolution of clouds, their role in precipitation processes, and their impact on the Earth's climate. Students will learn about the various types of clouds, their properties, and how they form and evolve in the atmosphere.

Lecture notes

Lecture materials (slides) are provided continuously during the semester, at least 2 days before each lecture. Annotations and corrections are provided at the latest within the same week.

Prerequisites / notice

Attendance of the lecture "Atmosphäre" LV 701-0023-00L or equivalent knowledge is a pre-requisite, and basic courses in physics and chemistry are expected. On Mondays (or upon agreement) a tutorial is offered. This allows the students to discuss unresolved issues from the lecture or to discuss the problems of the exercise series and their solution. Participation is recommended.

Atmospheric Physics

This course covers the physical and chemical processes controlling the composition of the troposphere and stratosphere and introduces the relevant fundamentals for processes in the gas phase, in aerosols and clouds. These concepts are explored in the context of key environmental issues, such as urban air pollution, stratospheric ozone depletion, and air quality connections to climate change.

Atmospheric Physics

This course covers the physical and chemical processes controlling the composition of the troposphere and stratosphere and introduces the relevant fundamentals for processes in the gas phase, in aerosols and clouds. These concepts are explored in the context of key environmental issues, such as urban air pollution, stratospheric ozone depletion, and air quality connections to climate change.

1. The chemistry of the gas phase: This section covers the basic principles of chemical reactions and their rate laws in the gas phase. Students will learn about the role of temperature, pressure, and concentration on chemical reaction rates, and how to apply these concepts to real-world atmospheric systems.
2. Aerosols: This section introduces the properties of aerosols, their formation and transformation, and their impact on atmospheric processes. Students will learn about the various sources of aerosols, their chemical and physical properties, and how they interact with other atmospheric constituents.
3. Clouds and precipitation: This section covers the formation and evolution of clouds, their role in precipitation processes, and their impact on the Earth's climate. Students will learn about the various types of clouds, their properties, and how they form and evolve in the atmosphere.

Lecture notes

Lecture materials (slides) are provided continuously during the semester, at least 2 days before each lecture. Annotations and corrections are provided at the latest within the same week.

Prerequisites / notice

Attendance of the lecture "Atmosphäre" LV 701-0023-00L or equivalent knowledge is a pre-requisite, and basic courses in physics and chemistry are expected. On Mondays (or upon agreement) a tutorial is offered. This allows the students to discuss unresolved issues from the lecture or to discuss the problems of the exercise series and their solution. Participation is recommended.
Abstract
This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation, especially prediction of showers and severe convective storms, and optical phenomena.

Objective
Students are able
- to explain the mechanisms of convective storm formation using knowledge of thermodynamics and cloud microphysics.
- to interpret precipitation radar images.
- to evaluate the significance of clouds and aerosol particles for artificial weather modification.

Content
In the course "Atmospheric Physics", the competencies of process understanding, system understanding and data analysis & interpretation are taught, applied and examined. Measurement methods are taught as well.

Students are able to
- qualitatively explain relevant processes, feedbacks and relationships between the different components of the cryosphere,
- quantify and interpret physical processes, which determine the state of the cryospheric components, with simple calculations.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

With these basics, the different forms of precipitation (convective vs. stratiform) are discussed and how they can be identified in radar images. Students will also learn under which conditions severe convective storms (especially supercells with tornados) can form.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

Lecture notes
Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=20400

Literature

An electronic version of this book can be obtained via the ETH library.

data-files of the revised book will be provided on moodle on a chapter-by-chapter basis.

Prerequisites / notice
We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Social Competencies
Communication assessed

Personal Competencies
Critical Thinking assessed
Self-direction and Self-management assessed

651-3561-00L
Cryosphere

Abstract
The course introduces the different components of the cryosphere - snow, glaciers, ice sheets, sea ice and lake ice, and permafrost - and their respective roles in the climate system. For each subsystem, essential physical aspects are emphasized, and their dynamics are described quantitatively and using examples.

Objective
Students are able to
- to evaluate the significance of clouds and aerosol particles for artificial weather modification.
- to interpret precipitation radar images.
- to explain the mechanisms of convective storm formation using knowledge of thermodynamics and cloud microphysics.

Content
The course provides an introduction into the various components of the cryosphere: snow, glaciers, ice sheets, sea ice and lake ice, permafrost, and their roles in the climate system. Essential physical aspects are emphasized for each subsystem: e.g. the material properties of ice, mass balance and dynamics of glaciers, or the energy balance of sea ice.

Lecture notes
Handouts will be distributed during the teaching semester.

Literature

Further literature will be indicated during the lecture.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies assessed
Problem-solving assessed

Social Competencies
Communication fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-direction and Self-management fostered

701-0473-00L
Weather Systems

Abstract
Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; Potential Vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer; water isotopes.
### Electives

The electives listed are recommended. Additional courses can be chosen from the complete offerings of the ETH Zurich and University of Zurich.

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<tr>
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<tr>
<td>401-0649-00L</td>
<td>Applied Statistical Regression</td>
<td>W</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>M. Dettling</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning &quot;good practice&quot; that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.</td>
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<tr>
<td><strong>Content</strong></td>
<td>The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.</td>
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<td><strong>Lecture notes</strong></td>
<td>A script will be available.</td>
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</table>
| **Literature**| Faraway (2006): Linear Models with R
Draper & Smith (1998): Applied Regression Analysis
Fox (2008): Applied Regression Analysis and GLMs
Montgomery et al. (2006): Introduction to Linear Regression Analysis |
| **Prerequisites / notice**| The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held. |

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

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<td>Customer Orientation</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td><strong>Personal Competencies</strong></td>
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<tr>
<td>701-0535-00L</td>
<td>Environmental Soil Physics/Vadose Zone Hydrology</td>
<td>W</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>A. Carminati, P. U. Lehmann Grunder</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The course provides theoretical and practical foundations for understanding and characterizing physical soil properties and processes and their relevance for terrestrial ecosystems, plant growth, hydrological processes and atmospheric-land gas exchange, across all relevant scales.</td>
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Objective

Students are able to:
- Characterize the different soils based on their key textural and structural properties.
- Simulate and predict soil water retention and flow under varying environmental conditions and understand the key driving forces (capillarity, gravity, friction) and related water properties (surface tension and viscosity).
- Predict soil hydraulic properties for varying soil textural classes.
- Predict solute transport in soils for varying environmental conditions.
- Predict energy balance and temperature dynamics in soils.
- Predict conditions for plant water stress
- Estimate the impact of soil properties on the hydrological cycle and on plant growth.

Content

INTRODUCTION

Week 1 (September 18)
Presentation of the role of soil physics in environmental sciences and terrestrial ecosystems: soils in the water cycle; soils and vegetation; soils and solute transport. Survey on students' interests and expectations. Presentation of course structure and learning objectives.

BASIC SOIL PROPERTIES

Week 2 (September 25) and Week 3 (October 02)
soil texture, particle size distribution, soil structure, soil surface area, porosity and bulk density
Pore scale consideration (water in a single pore); pore sizes and shapes; surface tension; Young-Laplace equation; capillary rise; contact angle
Friction and laminar flow; Hagen-Poiseuille's law; Washburn equation; numerical lab (REPORT 1)

SOIL HYDRAULIC PROPERTIES

Week 4 (October 09) and Week 5 (October 16)
Soil water content and soil water potential - The energy state of soil water; total water potential and its components; volumetric and gravimetric water contents; field capacity and wilting point
Soil water characteristics and pore size distribution
Saturated water flow in soils - Laminar flow in tubes (Poiseuille's Law); Darcy's Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts; effective conductivity; unsaturated hydraulic conductivity; Buckingham law.
Unsaturated water flow in soils - Unsaturated hydraulic conductivity models and applications

TOOLBOX – MEASUREMENTS AND MODELING

Week 6 (October 23) and Week 7 (October 30)
Measuring soil hydraulic properties, fitting and interpretation; Lab tour - demonstration of soil physical methods; lecture on HYPROP method; report on Hyprop data (REPORT 2)
Modelling unsaturated water flow based on Richards equation - Using Hydrus1D for simulation of unsaturated flow; simulating HYPROP measurements (REPORT 3)

SOIL IN THE WATER CYCLE

Week 8 (November 06) – Week 9 (November 13)
Water infiltration - steady state solutions for infiltration; approximate solutions to infiltration (Green-Ampt, Philip); infiltration rate and ponding; outlook to preferential flow
Water evaporation - Energy balance and land atmosphere interactions - potential and actual evaporation, evaporation stages;

SOIL PLANT INTERACTIONS

Week 10 (November 20) Week 11 (November 27)
Root water uptake and transpiration – Theory and mechanisms controlling root water uptake; hydraulic properties of rhizosphere; plant and stomatal conductance.
Modelling root water uptake and transpiration; analytical approaches and modeling using Hydrus (REPORT 4)

SOLUTE TRANSPORT

Week 12 (December 04) Week 13 (December 11)
Transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application
Transport of reactive substances, preferential flow, simulations with Hydrus

CLOSURE

Week 14 (December 18)
Summary, course synthesis, connections between the different topics, questions, exam preparation

Literature

Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel

Competencies

Subject-specific Competencies

Concepts and Theories  assessed
Techniques and Technologies  assessed

Method-specific Competencies

Analytical Competencies  assessed
Decision-making  assessed
Problem-solving  assessed
Project Management  fostered

Social Competencies

Communication  fostered
Cooperation and Teamwork  fostered
Leadership and Responsibility  fostered

Personal Competencies

Adaptability and Flexibility  fostered
Creative Thinking  fostered
Critical Thinking  fostered
Integrity and Work Ethics  fostered
Self-awareness and Self-reflection  fostered
Self-direction and Self-management  fostered

701-0479-00L Environmental Fluid Dynamics  W  3 credits  2G  H. Wernli, L. Papritz

Abstract

This course covers the basic physical concepts and mathematical equations used to describe environmental fluid systems on the rotating Earth. Fundamental concepts (e.g. vorticity dynamics and waves) are formally introduced, applied quantitatively and illustrated using examples. Exercises help to deepen knowledge of the material.
The students will be able to use the software R for simple data analysis and graphics.

The course provides the first part of an introduction to the statistical software R for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very basic and methodological level. The course focuses on practical work at the computer with R. We will make use of the graphical user interface RStudio: www.rstudio.org

Part I of the course covers the following topics:
- What is R?
- R Basics: reading and writing data from/to files, creating vectors & matrices, selecting elements of dataframes, vectors and matrices, arithmetics;
- Types of data: numeric, character, logical and categorical data, missing values;
- Simple (statistical) functions: summary, mean, var, etc., simple statistical tests;
- Writing simple functions;
- Introduction to graphics: scatter-, boxplots and other high-level plotting functions, embellishing plots by title, axis labels, etc., adding elements (lines, points) to existing plots.

The course focuses on practical work at the computer with R. We will make use of the graphical user interface RStudio: www.rstudio.org

Note: Part I of UsingR is complemented and extended by Part II, which is offered during the second part of the semester and which can be taken independently from Part I.

The practical takes place in spring semester.

Bachelor's Seminar

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0459-00L</td>
<td>Seminar for Bachelor Students: Atmosphere and Climate</td>
<td>O</td>
<td>3</td>
<td>2S</td>
<td>M. Windisch, S. I. Seneviratne, O. Stebler</td>
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</table>
Abstract
The seminar brings together students in the field of atmosphere and climate. Based on classic and current scientific articles, presentation techniques (presentations, poster presentations) are practised and students get a first insight into research in the field of atmosphere and climate.

Objective
In this seminar, students learn how to read scientific publications and how to transfer the scientific knowledge to a broader audience by means of oral and poster presentations. Students also get insight into the different research areas at the Institute for Atmospheric and Climate Science.

Content
1st week: course organisation and presentation of the institute
2nd and 3rd week: introduction to oral presentation technique
11th week: introduction to poster presentation technique
12th and 13th week: poster design
14th week: concluding poster presentation

Lecture notes
Documents are offered via the course's web page.

Literature
Documents are offered via the course's web page.

Prerequisites / notice
This course can only be offered to a limited number of students, however, in any case for everybody having to attend it compulsory. We beg you to sign in to this course early.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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Science in Perspective

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-ERDW

Language Courses

see Science in Perspective: Language Courses ETH/UZH

Bachelor’s Thesis

The Bachelor Thesis and Bachelor-Seminar are offered once per year in the 6th semester, in the spring semester.

Earth and Climate Sciences Bachelor - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Eligible for credits and recommended</th>
<th>Eligible for credits</th>
<th>Recommended, not eligible for credits</th>
<th>Courses outside the curriculum</th>
<th>Suitable for doctorate</th>
<th>Compulsory</th>
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<td>E-</td>
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Key for Hours

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<tr>
<th>Type</th>
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<th>Exercise</th>
<th>Seminar</th>
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<td>G</td>
<td>practical/laboratory course</td>
<td>independent project</td>
<td>diploma thesis</td>
<td>revision course / private study</td>
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</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Repetition of methods using optic properties of crystals and the polarising microscope.

Objective
- Advanced knowledge in optical mineralogy
- Application of methods to determine minerals in thin sections
- Identification and characterisation of metamorphic minerals
- Description of rocks. Derive correct petrographic rock name, based on modal abundance and microstructure/texture
- Interpretation of rock fabric/microstructure, parageneses and mineral reactions

Content
- Repetition of principal optical properties and of microscopic methods to identify minerals. Emphasis on interpretation of interference figures.
- Study typical metamorphic rocks in thin sections
- Description and interpretation of parageneses and texture/microstructures. Study the age relationship of crystallisation and deformation.
- Estimation of metamorphic grade
- Quantification: To determine volume percentage of rock components
- Scientific documentation: Descriptions, drawings, photomicrography using different kinds of illumination and using plane- or circular-polarised light.

Lecture notes
handouts with additional information on theory and for exercises, in English.

Literature
- Nesse, W.D.: Introduction to optical mineralogy. 3. Ed. (2004). Figures from this book will be used in lectures. Besides the theory, this book describes all optical properties of important minerals. Petrographers working on varying types of silicate rocks should have a look at this book.

Prerequisites / notice
Participants should have basic knowledge in crystallography, mineralogy and petrology, and have taken practical courses in microscopy of thin sections, as well as lectures in metamorphic petrology and structural geology! Other microscopy courses at department D-ERDW are on:
- magmatic rocks, following this course in second half of semester (P. Ulmer, IGP; Inst. for Geochemistry and Petrology)
- sedimentary rocks (Geol. Institute)
- ore minerals (reflected light microscopy, Th. Driesner, IGP)
- microstructures, deformed rocks (Geol. Institute)

Microscopy of Magmatic Rocks
This course provides practical knowledge in magmatic microscopy. It includes the identification of common igneous minerals in thin sections and in crystal separates, but also aims at providing a deeper understanding of mineral equilibrium assemblages and disequilibrium textures. These are useful skills in studying magmatic processes and reconstructing igneous conditions.

Objective
The main objectives are to acquire expertise in:

(1) Optical determination of minerals in igneous rocks;
(2) Identification of igneous rocks and their emplacement history based on mineralogy, structure and texture;
(3) Identifying the igneous processes that are revealed by the rock record, and understanding how to use the minerals to reconstruct magma chamber physical-chemical conditions;
(4) Application of phase diagrams to natural rocks.

Content
In this class, we’ll look together at how to identify plutonic and volcanic rocks and at what their minerals and textures can tell us about the igneous conditions and styles of eruption. We’ll follow different magmatic lines of descent to understand the evolution of magmas formed in different conditions and tectonic settings, focusing on the tholeiitic, calc-alkaline and alkaline series. We’ll look at how magmatic conditions affect the order of crystallization and the chemistry of minerals, and how we can use this knowledge to reconstruct magmatic processes. We’ll learn about equilibrium assemblages, which allow us to see which minerals grew together and record the same magmatic conditions (this is key for petrology and mineral geochemistry), but we’ll also learn to interpret disequilibrium textures, which relate to processes commonly responsible for volcanic eruptions.

Lecture notes
For the optical determination of igneous minerals using the polarizing microscope, the tables of Tröger (‘Optische Bestimmung der gesteinsbildenden Minerale’, Optical determination of rock-forming minerals, 1982) are particularly useful. These are available in sufficient number in the class room.

Literature
This class requires basic knowledge of optical mineralogy and the use of the polarizing microscope, which is taught in the previous class: ‘Microscopy of metamorphic rocks’ (A. Galli). For external students, an equivalent course is required to follow this practical course. Delivering 3 acceptably solved homework assignments results in an increase of the final grade by 0.25 (in other words, we give goodies).

Other microscope courses taught at ETH Zürich at the D-ERDW are:
- Basics of optical mineralogy and petrography (M.W. Schmidt, BSc-course in German)
- Microscopy of metamorphic rocks (A. Galli)
- Sedimentary petrography and microscopy (V. Picotti & M.G. Fellin)
- Reflected Light Microscopy and Ore Deposits Practical (T. Driesner)
**651-4051-00L Reflected Light Microscopy and Ore Deposits**

*Practical*

**W+ 2 credits 2P** T. Driesner

**Abstract**
Introduction to reflected light microscopy. Use of the microscope. Identification of opaque minerals through the use of determination tables. Description of textures and paragenetic sequences. Taking the course in parallel with Ore Deposits I (651-4037-00L) is recommended but not mandatory.

**Objective**
Recognition of the most important ore minerals in polished section, interpretation of ore mineral textures from important ore deposit types (of hydrothermal, magmatic, sedimentary and metamorphic origin) in geological context.

**Content**
Introduction to reflected light microscopy as a petrographic technique. Leaning main diagnostic criteria. Study of a small selection of important and characteristic ore minerals. Interpreting polished (thin) sections from the most important ore deposit types.

**Lecture notes**
Lecture ppt's and determination tables are handed out in class.

**Literature**

(Hands on table book with optical and other properties of most important ore minerals in reflected light. Reprints can be still obtained from the SEG online bookstore. Copies of this book will be used in the course throughout.)


Good graduate level introductory textbook, covers principles of reflected-light microscopy, interpretation of ore textures and most common ore mineral assemblages. Still available.

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**651-4113-00L Sedimentary Petrography and Microscopy**

**W+ 2 credits 2G** V. Picotti, M. G. Fellin

**Abstract**
Microscopy of carbonate (1st half of semester) and siliciclastic rocks (2nd half) rocks as well as siliceous, phosphatic and evaporitic sediments.

**Objective**
Description of grains and cement/matrix, texture, classification of the main sedimentary rocks. Discussion and interpretation of the environment of sedimentation. Diagenetic Processes.

**Content**
Microscopy of carbonate and siliciclastic rocks, siliceous and phosphatic rocks, their origin and classification. Diagenesis.

**Lecture notes**

**Prequisites / notice**
Credits and mark based on an independent description of one selected polished section at the end of the course.

**Literature**

(Hands on table book with optical and other properties of most important ore minerals in reflected light. Reprints can be still obtained from the SEG online bookstore. Copies of this book will be used in the course throughout.)


(Good comparable book.)


(The technical part is a good german equivalent of Craig & Vaughan while the sections on textures and their interpretation is much less systematic.)


(Largest monograph about ore minerals and their textures, excellent reference book for assemblages and textures, but not useful for determination of common and typical minerals, interpretation of textures often outdated. Only available in the library.)


(Comprehensive collection of photomicrographs of ore minerals in reflected light. Not very helpful for determination purposes but instructive for comparison with own samples.)


(Extensive and well organized tables for practical determination of common and less abundant ore minerals. Only available in the library.)


(Handbook of ore mineral assemblages. Still available.

Good graduate level introductory textbook, covers principles of reflected-light microscopy, interpretation of ore textures and most common ore mineral assemblages. Still available.

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### Part B: Methods

**Number**

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<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>651-4055-00L Analytical Methods in Petrology and Geology</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>J. Allaz, S. Bernasconi, N. Seibel</td>
</tr>
</tbody>
</table>

**Abstract**
Practical work in analytical chemistry for Earth science students.

**Objective**
Knowledge of some analytical methods used in Earth sciences, introduction to data interpretation, writing of a scientific report.
Introduction to analytical geochemistry and atom physics, notably:
- X-ray diffraction (XRD),
- X-ray fluorescence analysis (XRF),
- Electron Probe Microanalyzer (EPMA),
- Laser Ablation Inductively Coupled Plasma Mass Spectroscopy (LA-ICP-MS),
- Mass spectroscopy for light isotopes.

**Subject-specific Competencies**
- Analytical Competencies
- Problem-solving

**Method-specific Competencies**
- Project Management

**Social Competencies**
- Cooperation and Teamwork

**Personal Competencies**
- Creative Thinking
- Integrity and Work Ethics
- Self-direction and Self-management

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**651-4117-00L Sediment Analysis**

**Prerequisite:** Successful completion of the MSc-course "Sedimentology I" (651-4041-00L).

**Abstract**
Theoretical background and application of some basic methods for sediment analysis.

**Objective**
The main goal is to learn how to describe sediments in the field and to collect samples for grain-size and compositional analysis. Application of the same analytical techniques on samples of unknown origin: the sampling sites will be revealed at the end of the course. Discussion of the theoretical background and of the results in class. At the end of the course, the student will have to hand in a report with the presentation and discussion of all the data produced during the course.

**Lecture notes**
For the various analytical methods English texts will be provided in class.

**Literature**
Introduction to clastic sedimentology, R.J. Cheel, Brock University

**Prerequisites / notice**
No prerequisite required beside basic knowledge of petrology and mineralogy. Attending the "Analytical Methods in Geology and Petrology" prior to this course is an advantage.

**Competencies**

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<tr>
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**651-0046-00L Electron Microscopy Course (SEM and EPMA)**

**Prerequisite:** Successful completion of the MSc-course "Sedimentology I" (651-4041-00L).

**Abstract**
Theory and lab demo of scanning electron microscope (SEM) and electron microprobe analysis (EPMA) applied to geological materials: introduction to the instruments, interaction of electron with matter, electron imaging (SE, BSE, CL), electron backscatter diffraction (EBSD), X-ray analysis for the chemical characterisation of solid material at the micron-scale.

**Objective**
Understand how the instrument works, why it is used, and how the different signals are being generated and analysed. Ability to treat and to present analytical results, such as calculating a mineral formula from a mineral analysis.

**Content**
Physical principles of electron microscopy: electron optics, interaction of electrons with matter, production of X-rays, interaction of X-rays with matter, X-rays detection and analysis. The second part of the course includes several demonstrations on various SEMs (at ERDW and ScopeM) and one EPMA at DERDW.

**Lecture notes**
Script will be provided, along with copies of the course presentations.

**Literature**

- [Additional references]


- Reed, S.J.B. (1993, second ed.): Electron Microprobe Analysis


**Prerequisites / notice**
No prerequisite required beside basic knowledge of petrology and mineralogy. Attending the "Analytical Methods in Geology and Petrology" prior to this course is an advantage.

**Competencies**

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**651-4063-00L X-Ray Powder Diffraction**

**Prerequisite:** Successful completion of the MSc-course "Sedimentology I" (651-4041-00L).

**Abstract**
In the course the students learn to measure X-ray diffraction patterns of minerals and to evaluate these using different software for qualitative and quantitative mineral composition as well as crystallographic parameters.

**Objective**
Upon successful completion of this course students are able to:
- describe the principle of X-ray diffraction analysis
- carry out a qualitative and quantitative mineralogical analysis independently,
- critically assess the data,
- communicate the results in a scientific report.

The competencies of system understanding, concept development, and measurement methods are taught and examined.
Content
Fundamental principles of X-ray diffraction
Setup and operation of X-ray diffractometers
Interpretation of powder diffraction data
Qualitative and quantitative phase analysis of crystalline powders (e.g. with Rietveld analysis)

Lecture notes
Selected handouts will be made available in the lecture

Literature

Prerequisites / notice
The course includes a high portion of practical exercises in sample preparation as well as measurement and evaluation of X-ray powder diffraction data.

Software will be provided for future use on own Laptop.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making fostered
- Media and Digital Technologies assessed
- Problem-solving fostered
- Project Management fostered

Social Competencies
- Communication assessed
- Cooperation and Teamwork assessed
- Customer Orientation fostered
- Leadership and Responsibility fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

Restricted Choice Modules Geology
A minimum of two restricted choice modules must be completed for the major Geology.

Biogeochernistry

Biogeochernistry: Compulsory Courses
The compulsory courses of the module take place in spring semester.

Biogeochernistry: Courses of Choice

Number Title Type ECTS Hours Lecturers
651-4043-00L Sedimentology II: Biological and Chemical Processes in Lacustrine and Marine Systems W 3 credits 2G V. Picotti, A. Gill, I. Hernández Almeida, H. Stoll

Abstract
The course will focus on biological and chemical aspects of sedimentation in marine environments. Marine sedimentation will be traced from coast to deep-sea. The use of stable isotopes, palaeoceanography will be discussed. Neritic, hemipelagic and pelagic sediments will be used as proxies for environmental change during times of major perturbations of climate and oceanography.

Objective
- You will understand chemistry and biology of the marine carbonate system
- You will be able to relate carbonate mineralogy with facies and environmental conditions
- You will see carbonate and organic-carbon rich sediments as part of the global carbon cycle
- You will be able to recognize links between climate and marine carbonate systems (e.g. acidification of oceans and reef growth)
- You will be able to use geological archives as source of information on global change
- You will have an overview of marine sedimentation through time

Content
- carbonates: chemistry, mineralogy, biology
- carbonate sedimentation from the shelf to the deep sea
- carbonate facies
- cool-water and warm-water carbonates
- organic-carbon and black shales
- C-cycle, carbonates, Corg : CO2 sources and sink
- Carbonates: their geochemical proxies for environmental change: stable isotopes, Mg/Ca, Sr
- marine sediments through geological time
- carbonates and evaporites
- lacustrine carbonates
- economic aspects of limestone

Lecture notes
no script. scientific articles will be distributed during the course

Literature
We will read and critically discuss scientific articles relevant for "biological and chemical processes in marine and lacustrine systems"

Prerequisites / notice
The grading of students is based on in-class exercises and end-semester examination.

651-4057-00L Climate History and Palaeoclimatology W 4 credits 2G H. Stoll, I. Hernández Almeida

Abstract
Climate history and paleoclimatology explores how the major features of the earth's climate system have varied in the past, and the driving forces and feedbacks for these changes. The major topics include the earth's CO2 concentration and mean temperature, the size and stability of ice sheets and sea level, the amount and distribution of precipitation, and the ocean heat transport.
Objective

The student will be able to describe the natural factors lead to variations in the earth's mean temperature, the growth and retreat of ice sheets, and variations in ocean and atmospheric circulation patterns, including feedback processes. Students will be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geological records. Students will be able to use data from climate proxies to test if a given hypothesized mechanism for the climate change is supported or refuted. Students will be able to compare the magnitudes and rates of past changes in the carbon cycle, ice sheets, hydrological cycle, and ocean circulation, with predictions for climate changes over the next century to millennia.

Content

The course spans 5 thematic modules:

1. Cyclic variation in the earth’s orbit and the rise and demise of ice sheets. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth’s ice sheets and the consequent effect on sea level? How do cyclic variations in the earth’s orbit affect the size of ice sheets under modern climate and under past warmer climates? What conditions the mean size and stability or fragility of the large polar ice caps and is their evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? How stable or fragile is the ocean heat conveyor, past and present?
2. Feedbacks on climate cycles from CO2 and methane. What drives CO2 and methane variations over glacial cycles? What are the feedbacks with ocean circulation and the terrestrial biosphere?
3. Atmospheric circulation and variations in the earth’s hydrological cycle - How variable are the earth’s precipitation regimes? How large are the orbital scale variations in global monsoon systems?
4. Century-scale droughts and civil catastrophes. Will mean climate change El Nino frequency and intensity? What factors drive change in mid and high-latitude precipitation systems? Is there evidence that changes in water availability have played a role in the rise, demise, or dispersion of past civilizations?
5. How sensitive is Earth’s long term climate to CO2 and cloud feedbacks? What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years?

The weekly two hour lecture periods will feature lecture on these themes interspersed with short interactive tasks to apply new knowledge. Over the semester, student teams will each present in class one debate based on two scientific articles of contrasting interpretations. With flexible scheduling, students will participate in a laboratory activity to generate a new palaeoclimatic record from stalagmites. Student teams will be supported by an individual tutorial meeting to assist in debate preparation and another to assist in the interpretation of the lab activity data.

Competencies

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Palaeoclimatology

Palaeoclimatology: Compulsory Courses

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<td>Climate History and Palaeoclimatology</td>
<td>W+</td>
<td>4 credits</td>
<td>2G</td>
<td>H. Stoll, I. Hernández Almeida</td>
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Abstract

Climate history and palaeoclimatology explores how the major features of the earth’s climate system have varied in the past, and the driving forces and feedbacks for these changes. The major topics include the earth's CO2 concentration and mean temperature, the size and stability of ice sheets and sea level, the amount and distribution of precipitation, and the ocean heat transport.

Objective

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Content

The course spans 5 thematic modules:

1. Cyclic variation in the earth’s orbit and the rise and demise of ice sheets. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth's ice sheets and the consequent effect on sea level? How do cyclic variations in the earth’s orbit affect the size of ice sheets under modern climate and under past warmer climates? What conditions the mean size and stability or fragility of the large polar ice caps and is their evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? How stable or fragile is the ocean heat conveyor, past and present?
2. Feedbacks on climate cycles from CO2 and methane. What drives CO2 and methane variations over glacial cycles? What are the feedbacks with ocean circulation and the terrestrial biosphere?
3. Atmospheric circulation and variations in the earth’s hydrological cycle - How variable are the earth’s precipitation regimes? How large are the orbital scale variations in global monsoon systems?
4. Century-scale droughts and civil catastrophes. Will mean climate change El Nino frequency and intensity? What factors drive change in mid and high-latitude precipitation systems? Is there evidence that changes in water availability have played a role in the rise, demise, or dispersion of past civilizations?
5. How sensitive is Earth's long term climate to CO2 and cloud feedbacks? What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years?

The weekly two hour lecture periods will feature lecture on these themes interspersed with short interactive tasks to apply new knowledge. Over the semester, student teams will each present in class one debate based on two scientific articles of contrasting interpretations. With flexible scheduling, students will participate in a laboratory activity to generate a new palaeoclimatic record from stalagmites. Student teams will be supported by an individual tutorial meeting to assist in debate preparation and another to assist in the interpretation of the lab activity data.
## Palaeoclimatology: Courses of Choice

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4043-00L</td>
<td>Sedimentology II: Biological and Chemical Processes in Lacustrine and Marine Systems</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>V. Picotti, A. Gilli, I. Hernández Almeida, H. Stoll</td>
</tr>
</tbody>
</table>

**Abstract**
The course will focus on biological and chemical aspects of sedimentation in marine environments. Marine sedimentation will be traced from coast to deep-sea. The use of stable isotopes palaeoceanography will be discussed. Neritic, hemipelagic and pelagic sediments will be used as proxies for environmental change during times of major perturbations of climate and oceanography.

**Objective**
- You will understand chemistry and biology of the marine carbonate system
- You will be able to relate carbonate mineralogy with facies and environmental conditions
- You will be familiar with cool-water and warm-water carbonates
- You will see carbonate and organic-carbon rich sediments as part of the global carbon cycle
- You will be able to recognize links between climate and marine carbonate systems (e.g. acidification of oceans and reef growth)
- You will be able to use geological archives as source of information on global change
  - You will have an overview of marine sedimentation through time

**Content**
- carbonates: chemistry, mineralogy, biology
- carbonate sedimentation from the shelf to the deep sea
- carbonate facies
- cool-water and warm-water carbonates
- organic-carbon and black shales
- C-cycle, carbonates, Corg : CO2 sources and sink
- Carbonates: their geochemical proxies for environmental change: stable isotopes, Mg/Ca, Sr
- marine sediments through geological time
- carbonates and evaporites
- lacustrine carbonates
- economic aspects of limestone

**Lecture notes**
no script. scientific articles will be distributed during the course

**Literature**
We will read and critically discuss scientific articles relevant for "biological and chemical processes in marine and lacustrine systems"

## Sedimentology

### Sedimentology: Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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</tr>
</thead>
<tbody>
<tr>
<td>651-4041-00L</td>
<td>Sedimentology I: Physical Processes and Sedimentary Systems</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>V. Picotti</td>
</tr>
</tbody>
</table>

**Abstract**
Sediments preserved a record of past landscapes. This course focuses on understanding the processes that modify sedimentary landscapes with time and how we can read this changes in the sedimentary record.

**Objective**
- The students learn basic concepts of modern sedimentology and stratigraphy in the context of sequence stratigraphy and sea level change.
- They discuss the advantages and pitfalls of the method and look beyond. In particular we pay attention to introducing the importance of considering entire sediment routing systems and understanding their functioning.

**Content**
- carbonates: chemistry, mineralogy, biology
- carbonate sedimentation from the shelf to the deep sea
- carbonate facies
- cool-water and warm-water carbonates
- organic-carbon and black shales
- C-cycle, carbonates, Corg : CO2 sources and sink
- Carbonates: their geochemical proxies for environmental change: stable isotopes, Mg/Ca, Sr
- marine sediments through geological time
- carbonates and evaporites
- lacustrine carbonates
- economic aspects of limestone

**Lecture notes**
no script. scientific articles will be distributed during the course

**Literature**
We will read and critically discuss scientific articles relevant for "biological and chemical processes in marine and lacustrine systems"

**Prerequisites / notice**
The grading of students is based on in-class exercises and end-semester examination.

### Sedimentology: Courses of Choice

<table>
<thead>
<tr>
<th>Number</th>
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</table>

**Abstract**
The course will focus on biological and chemical aspects of sedimentation in marine environments. Marine sedimentation will be traced from coast to deep-sea. The use of stable isotopes palaeoceanography will be discussed. Neritic, hemipelagic and pelagic sediments will be used as proxies for environmental change during times of major perturbations of climate and oceanography.

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- You will be able to use geological archives as source of information on global change
  - You will have an overview of marine sedimentation through time

**Content**
- carbonates: chemistry, mineralogy, biology
- carbonate sedimentation from the shelf to the deep sea
- carbonate facies
- cool-water and warm-water carbonates
- organic-carbon and black shales
- C-cycle, carbonates, Corg : CO2 sources and sink
- Carbonates: their geochemical proxies for environmental change: stable isotopes, Mg/Ca, Sr
- marine sediments through geological time
- carbonates and evaporites
- lacustrine carbonates
- economic aspects of limestone

**Lecture notes**
no script. scientific articles will be distributed during the course

**Literature**
We will read and critically discuss scientific articles relevant for "biological and chemical processes in marine and lacustrine systems"

**Prerequisites / notice**
The grading of students is based on in-class exercises and end-semester examination.
**Quaternary Dating Methods**

**Objective**

Students will be made familiar with the details of the six dating methods through lectures on basic principles, analysis of case studies, solving of problem sets for age calculation and visits to dating laboratories.

At the end of the course, students will:

1. understand the fundamental principles of the most frequently used dating methods for Quaternary studies.
2. choose which dating method (or combination of methods) suits a certain field problem.
3. critically read and evaluate the application of dating methods in scientific publications.

**Content**

1. Introduction: Isotopes and decay
2. Radiocarbon dating: principles and applications
3. AMS technique and its application in Quaternary geochronology
4. U-series disequilibrium dating
5. Luminescence dating
6. Introduction to incremental: varve counting, dendrochronology, and ice cores chronologies
7. Dating anthropogenic records

**Prerequisites / notice**

Visit to radiocarbon lab, cosmogenic nuclide lab, and accelerator (AMS) facility.

Required: attending the lecture, visiting laboratories, handing back solutions for problem sets, short presentations or written report

Optional (individual): 1-5 days of hands-on radiocarbon dating at the 14C lab, ETH Hoenggerberg

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Problem-solving
- Social Competencies
  - Communication
  - Cooperation and Teamwork

- Personal Competencies
  - Critical Thinking

**X-Ray Powder Diffraction**

**Objective**

Upon successful completion of this course students are able to:

- describe the principle of X-ray diffraction analysis
- carry out a qualitative and quantitative mineralogical analysis independently,
- critically assess the data,
- communicate the results in a scientific report.

The competencies of system understanding, concept development, and measurement methods are taught and examined.

**Content**

- Fundamental principles of X-ray diffraction
- Setup and operation of X-ray diffractometers
- Interpretation of powder diffraction data
- Qualitative and quantitative phase analysis of crystalline powders (e.g. with Rietveld analysis)

**Prerequisites / notice**

The course includes a high portion of practical exercises in sample preparation as well as measurement and evaluation of X-ray powder diffraction data.

Optional: own sample will be analysed qualitatively and quantitatively. Knowledge in mineralogy of this system is essential.

**Software**

Software will be provided for future use on own Laptop.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Problem-solving
- Social Competencies
  - Communication
  - Cooperation and Teamwork
- Personal Competencies
  - Critical Thinking

**Source to Sink Sedimentary Systems**

**Abstract**

Transfer and redistribution of material on Earth's surface is controlled by myriad processes. To investigate these, this course will address the production, transport, and deposition of sediments and will probe their interactions with biogeochemical cycles. We will integrate catchment-scale sediment dynamics with associated (organic) carbon cycling at all stages of the "source to sink" continuum.

**Prerequisites**

- Attending the lecture, visiting laboratories, solving of problem sets for age calculation and visits to dating laboratories.
- Required: attending the lecture, visiting laboratories, handing back solutions for problem sets, short presentations or written report.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Problem-solving
- Social Competencies
  - Communication
  - Cooperation and Teamwork
- Personal Competencies
  - Critical Thinking
  - Self-awareness and Self-reflection
  - Self-direction and Self-management
This course will integrate several Earth-science disciplines (geology, geomorphology, and biogeochemistry) to provide a holistic understanding of the physical and biogeochemical processes that control sediment and (organic) carbon production and mobilization along geomorphic cascades. The primary objective is to track the evolution of a particle as it is produced by rock weathering, transformed during soil development, eroded and transported by fluvial processes, and eventually buried in depositional systems. In doing so, students will learn how to “see a world through a grain of sand.”

Objective

This course will comprise three main components:

(i) Lectures will introduce the main “source to sink” concepts and will focus on both physical and biogeochemical processes from uplands, sediment-producing regions to lowland, sediment-depositing regions (i.e., erosion and mass movements; hillslopes, soil development, and the “critical zone”); transport and storage in rivers and floodplains; and deposition in sedimentary archives.

(ii) A three-day field excursion from the Rhône Glacier to the Rhône Delta in Lake Geneva (Sept. 27-29, 2024) will provide hands-on examples of these concepts within the upper Rhône Basin. During the excursion, students will present a summary of an assigned relevant scientific paper and will sample solid- and dissolved-phase materials (soils, sediments, river water) from different geomorphic settings and upstream to downstream fluvial environments; these samples will form the basis of two laboratory-based practical exercises.

(iii) Practicals will comprise two group exercises: (1) an assessment of Rhône river chemical weathering, including its erosional and lithological controls, using dissolved river-water samples; and (2) an investigation of Alpine soil formation and erosion, including its lithological and environmental controls, using solid-phase soil and sediment samples. For both practicals, students will learn relevant analytical instrumentation; generate data using samples collected in the field; and write a scientific report on their findings, environmental context, and interpretation within the “source to sink” concept.

Grading will be distributed as: 30% field excursion participation and literature review, 35% Practical 1, 35% Practical 2.

Content

The four day course consists of lectures that are accompanied by a variety of exercises.

Day 1:
Introduction seismic facies analysis with exercise
Seismic resolution
Seismic facies of contourite drift systems and their value as physical indicators of global current changes.

Day 2:
Seismic attributes and seismic geomorphology
Siliciclastic deltas, shelves and turbidite systems, 2D-3D
Exercise: Seismic section Tarragon Basin and reconstructing the basin evolution with respect to the climate conditions at the end of the Miocene.
Seismic facies carbonate systems
Carbonates as recorders of sea level and paleoclimate
Deepwater environments, including cold-water coral habitats

Day 3:
Carbonates versus volcanic seismic facies
Introduction seismic attributes
Faults and structures on seismic sections
Seismic facies of mixed systems with
Exercises from Canada and the Paradox Basin

Day 4:
Sea level and sedimentation
Telling ages on seismic section
Seismic stratigraphy and sequence stratigraphy
Exercise: Sequence analysis Straits of Andros
Final discussion

Lecture notes

An original script (110 pages) designed for the class will be distributed at the beginning of the course.
### Structural Geology

#### Structural Geology: Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>651-4132-00L</td>
<td>Field Course IV: Alpine Field Course</td>
<td>W+</td>
<td>4 credits</td>
<td>6P</td>
<td>W. Behr, V. Picotti</td>
</tr>
</tbody>
</table>

**Prerequisites / notice**

- Basic knowledge in sedimentology and stratigraphy
- Students confirming having read and accepted the terms and conditions for excursions and field courses of D-ERDW

**Competencies**

- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies
- Social Competencies: Communication
- Personal Competencies: Creative Thinking

**Objective**

- The objective of this course is to introduce rock physics and rock deformation, and discuss the aid of laboratory tests to interpretation at large scale.
- Rock Physics provides the understanding to connect geomechanical and geophysical data to the intrinsic properties of rocks, such as mineral composition and texture. Rock Physics is a key component in geo-resources exploration and exploitation, and in geo-hazard assessment.
- For rock deformation we will illustrate how to determined flow-laws of rocks from experiments and how to extrapolate to natural conditions. Since the time scale of laboratory experiments is several orders of magnitude faster than nature, we will compare the microstructure of natural rocks with that produced during the experiments to prove that the same mechanisms are operating.
- For this purpose, the fundamental techniques of experimental rock deformation will be illustrated and test on natural rock samples in the lab, to acquire the data, to correct for calibration and to process the data and finally to interpret the data.

**Literature**

Books Seismic Interpretation of Depositional Systems:


**Prerequisites / notice**

- Students registering for the course confirm having read and accepted the terms and conditions for excursions and field courses of D-ERDW.

**Deadline for motivation letter:** 31 October 2018  
**Final decision**: 20 November 2018

**Literature**


#### Structural Geology: Courses of Choice

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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</tr>
</thead>
<tbody>
<tr>
<td>651-4111-00L</td>
<td>Experimental Rock Physics and Deformation</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td></td>
</tr>
</tbody>
</table>

**Abstract**

- We illustrate some physical properties, deformation mechanisms, and define flow laws. We show the fundamental techniques for the measurement in laboratory of density, permeability, elastic properties and deformation. We presented actual case studies and discuss upscaling from laboratory to field.

**Objective**

- The objective of this course is to introduce rock physics and rock deformation, and discuss the aid of laboratory tests to interpretation at large scale.
- Rock Physics provides the understanding to connect geomechanical and geophysical data to the intrinsic properties of rocks, such as mineral composition and texture. Rock Physics is a key component in geo-resources exploration and exploitation, and in geo-hazard assessment.
- For rock deformation we will illustrate how to determined flow-laws of rocks from experiments and how to extrapolate to natural conditions. Since the time scale of laboratory experiments is several orders of magnitude faster than nature, we will compare the microstructure of natural rocks with that produced during the experiments to prove that the same mechanisms are operating.
- For this purpose, the fundamental techniques of experimental rock deformation will be illustrated and test on natural rock samples in the plastic deformation regime (high temperature) as well in the brittle regime (room temperature) will be presented. We will perform tests in the lab, to acquire the data, to correct for calibration and to process the data and finally to interpret the data.

**Prerequisites / notice**

- The course is at Master student level, but will be useful for PhDs students who want to begin to work in experimental deformation or who want to know the meaning and the limitation of laboratory flow-laws for geodynamic modelling.
The course will focus on research-based term project, lectures will alternate with laboratory demonstrations. We will illustrate how intrinsic properties of rocks (mineral composition, porosity, pore fluids, crystallographic orientation, microstructures) are connected to the following physical properties:
- permeability;
- elastic properties for seismic interpretations;
- anisotropy of the above physical properties.
We will measure some of those parameters in laboratory and discuss real case studies and applications.

Principles of deformation mechanisms, flow laws, and deformation mechanism maps will be presented in lectures. In laboratory we will show:
- Experimental deformation rigs (gas, fluid and solid confining media);
- Main part of the apparatus (mechanical, hydraulic, heating system, data logging);
- Calibration of an apparatus (distortion of the rig; transducers calibration);
- Various types of tests (axial deformation; diagonal cut and torsion; deformation; constant strain rate tests; creep tests; stepping tests);

Prerequisites / notice
The course of Structural Geology (651-3422-00L) is highly recommended before attending this course. Moreover the students should have basic knowledge in geophysics and mineralogy/crystallography.

In doubt, please contact the course responsible beforehand.

651-3521-00L  Tectonics  W  3 credits  2V  W. Behr, S. Willett

Abstract
Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales. Evaluation of plate tectonic and other orogenic processes through the study of reference examples of taken in Alps-Himalaya orogenic system.

Objective
Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales.

Assessment of mechanisms responsible for plate movements (the Earth as a heat transfer machine, dynamics of earth mantle, plate driving forces) and subsequent large-scale structures (oceanic basins and cycle of the oceanic lithosphere, convergence and mountain systems and continental growth, etc) through theoretical and experimental information.

Evaluation of plate tectonic and other orogenic processes through the study of reference examples of taken in Alps-Himalaya orogenic system.

Content

Literature

Open Choice Modules Geology
Basin Analysis
Basin Analysis: Compulsory Courses

Number  Title  Type  ECTS  Hours  Lecturers
651-4341-00L  Source to Sink Sedimentary Systems  W+  3 credits  2G  T. I. Eglington, J. Hemingway, L. Bröder

Abstract
Transfer and redistribution of material on Earth's surface is controlled by myriad processes. To investigate these, this course will address:
(i) Lectures will introduce the main "source to sink" concepts and will focus on both physical and biogeochemical processes from uplands, sediment-producing regions to lowland, sediment-depositing regions (i.e., erosion and mass movements; hillslopes, soil development, and the "critical zone"; transport and storage in rivers and floodplains; and deposition in sedimentary archives),
(ii) A three-day field excursion from the Rhône Glacier to the Rhône Delta in Lake Geneva (Sept. 27-29, 2024) will provide hands-on examples of these concepts within the upper Rhône Basin. During the excursion, students will present a summary of an assigned relevant scientific paper and will sample solid- and dissolved-phase materials (soils, sediments, river water) from different geomorphic settings and upstream to downstream fluvial environments; these samples will form the basis of two laboratory-based practical exercises.
(iii) Practical will comprise two group exercises: (1) an assessment of Rhône river chemical weathering, including its erosional and lithological controls, using dissolved river-water samples; and (2) an investigation of Alpine soil formation and erosion, including its lithological and environmental controls, using solid-phase soil and sediment samples. For both practicals, students will learn relevant analytical instrumentation; generate data using samples collected in the field; and write a scientific report on their findings, environmental context, and interpretation within the “source to sink” concept.

Grading will be distributed as: 30% field excursion participation and literature review, 35% Practical 1, 35% Practical 2.

Lecture notes
Lecture notes will be provided online during the course. These will provide necessary theoretical background, summarize relevant "source to sink" topics, and serve as the basis for knowledge to be incorporated into both Practical assignments.

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1121 of 2653
Prior knowledge on the fundamentals of geomorphology, (bio)geochemistry, and/or soil science is highly encouraged. While not strictly required, additional suggested literature includes:

- "Sediment routing systems: the fate of sediments from Source to Sink" by Philip A. Allen (Cambridge University Press)
- "Principles of soilscape and landscape evolution" by Garry Willgoose (Cambridge University Press)
- "Geomorphology, the mechanics and chemistry of landscapes" by Robert S. Anderson & Suzanne P. Anderson (Cambridge University Press)

### Competencies

#### Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

#### Method-specific Competencies
- Analytical Competencies
- Project Management

#### Social Competencies
- Communication
- Cooperation and Teamwork

#### Personal Competencies
- Critical Thinking

### Literature

- Books Seismic Interpretation of Depositional Systems:

### Basin Analysis: Courses of Choice

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
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</tr>
</thead>
<tbody>
<tr>
<td>651-4243-00L</td>
<td>Seismic Stratigraphy and Facies</td>
<td>W+</td>
<td>2</td>
<td>3G</td>
<td></td>
</tr>
</tbody>
</table>

**Abstract**
The course teaches the techniques of seismic interpretation for solving geological and environmental problems. A special focus is given to the seismic facies analysis and seismic sequence stratigraphy of different depositional systems. In addition, examples are presented how seismic data can be integrated into research projects in basin analysis, paleoceanography and paleoclimatology.

**Objective**
1. Acquire techniques for a comprehensive interpretation of seismic sections for solving geologic, stratigraphic and environmental problems
2. Correlation of seismic facies and seismic attributes to lithologic facies in different sedimentary systems
3. Learn the principles and techniques of seismic sequence stratigraphy and the differences between lithostratigraphy and sequence stratigraphy
4. Learn to integrate seismic data into paleoceanographic and paleoclimatic research.

**Content**
The four day course consists of lectures that are accompanied by a variety of exercises.

**Day 1:**
Introduction seismic facies analysis with exercise
Seismic resolution
Seismic facies of contourite drift systems and their value as physical indicators of global current changes.

**Day 2:**
Seismic attributes and seismic geomorphology
Siliciclastic deltas, shelves and turbidite systems, 2D-3D
Exercise: Seismic section Tarragon Basin and reconstructing the basin evolution with respect to the climate conditions at the end of the Miocene.
Seismic facies carbonate systems
Carbonates as recorders of sea level and paleoclimate
Deepwater environments, including cold-water coral habitats

**Day 3:**
Carbonates versus volcanic seismic facies
Introduction seismic attributes
Faults and structures on seismic sections
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Exercises from Canada and the Paradox Basin

**Day 4:**
Sea level and sedimentation
Telling ages on seismic section
Seismic stratigraphy and sequence stratigraphy
Exercise: Sequence analysis Straits of Andros
Final discussion

**Lecture notes**
An original script (110 pages) designed for the class will be distributed at the beginning of the course.

**Prerequisites / notice**
Basic knowledge in sedimentology and stratigraphy
Earthquake Seismology

Earthquake Seismology: Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4021-00L</td>
<td>Engineering Seismology</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>P. Bergamo, M. Koroni</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course is a general introduction to the methods of seismic hazard analysis. It provides an overview of the input data and the tools in deterministic and probabilistic seismic hazard assessment, and discusses the related uncertainties.</td>
<td></td>
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</tr>
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<td>Objective</td>
<td>This course is a general introduction to the methods of seismic hazard analysis.</td>
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</tr>
<tr>
<td>Content</td>
<td>In the course it is explained how the disciplines of seismology, geology, strong-motion geophysics, and earthquake engineering contribute to the evaluation of seismic hazard. It provides an overview of the input data and the tools in deterministic and probabilistic seismic hazard assessment, and discusses the related uncertainties. The course includes the discussion related to Intensity and macroseismic scales, historical seismicity and earthquake catalogues, ground motion parameters used in earthquake engineering, definitions of the seismic source, ground motion attenuation, site effects and microzonation, and the use of numerical tools to estimate ground motion parameters, both in a deterministic and probabilistic sense. During the course recent earthquakes and their impacts are discussed and related to existing hazard assessments for the areas of interest.</td>
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Earthquakes I: Seismotectonics

<table>
<thead>
<tr>
<th>Number</th>
<th>Earthquakes I: Seismotectonics</th>
<th>W+</th>
<th>3</th>
<th>2G</th>
<th>A. P. Rinaldi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>If you're interested in knowing more about the relationship between seismicity and plate tectonics, this is the course for you. (If you're not that interested, but your program of study requires that you complete this course, this is also the course for you.)</td>
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<tr>
<td>Objective</td>
<td>The aim of the course is to obtain a basic understanding of the physical process behind earthquakes and their basic mathematical description. By the conclusion of this course, we hope that you will be able to:</td>
<td></td>
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<tr>
<td>Content</td>
<td>- describe the relationship between earthquakes and plate tectonics in a more sophisticated and complete way</td>
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<td>- explain earthquake source representations of varying complexity;</td>
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<td>- address earthquakes in the context of different tectonic settings;</td>
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<tr>
<td></td>
<td>- explain the statistical behaviour of global earthquakes</td>
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<tr>
<td></td>
<td>- describe and connect the ingredients for a seismotectonic study</td>
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</tbody>
</table>

Topics covered in the course include:
- review of stress and deformation in the Earth, stress and strain tensors, rheology and failure criteria, fault stresses, friction and effects of fluids
- earthquake focal mechanisms; relationship between stress fields and focal mechanisms;
- seismic moment and moment tensors;
- crustal deformation from seismic, geologic, and geodetic observations;
- earthquake stress drop, scaling, and source parameters;
- global earthquake distribution; current global earthquake activity;
- different seismotectonic regions; examples of earthquake activity in different tectonic settings.

Lecture notes

Course notes will be made available on a designated course web site. Most of the topics discussed in the course are available in the book mentioned below.

Literature


Prerequisites / notice

Basic knowledge of continuum mechanics and rock mechanics, as well as notion of tensor analysis is strongly suggested. We recommend to have taken the course Continuum Mechanics (generally taught during the Fall semester).

This course will be taught in fall 2017 and it will be followed by Earthquakes 2: Source Physics in Spring 2018.

The course will be evaluated in a final written test covering the topics discussed during the lectures.

The course will be worth 3 credit points, and a satisfactory total grade (4 or better) is needed to obtain 3 ECTS.

The course will be given in English.

Earthquake Seismology: Compulsory Courses

One additional elective course of at least 3KP has to be completed for this Module according to prior agreement with the Subject Advisor (Autumn or Spring Semester).

Geographic Information Systems

The courses of this module are offered by UZH and must be registered at UZH.

Geographic Information Systems: Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4267-00L</td>
<td>Advanced Geographic Information Science V</td>
<td>W+</td>
<td>5</td>
<td>2V+2U</td>
<td>University lecturers</td>
</tr>
<tr>
<td>Number</td>
<td>(University of Zürich)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<tr>
<td></td>
<td>UZH Module Code: GEO372</td>
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<tr>
<td></td>
<td>Mind the enrolment deadlines at UZH:</td>
<td></td>
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</tr>
</tbody>
</table>
This elective module provides an in-depth study of basic concepts and techniques of GIS at an advanced level. This is intended to provide a foundation for independent and well-informed development of GIS application projects. The course communicates the basics of the Python programming language and provides a general introduction to the ArcGIS Pro Python scripting framework. It also introduces several Python libraries (pandas, numpy, scipy, statsmodels, geopandas, rasterio) that greatly extend the capabilities of spatial data analysis and modelling. Students will learn the basics of geographic data processing using the Python programming language and ArcGIS Pro (arcpy). They will be able to implement their own geoprocessing scripts for spatial data analysis and modelling. Students will be able to integrate open source libraries into their Python scripts and know how to apply the libraries to geospatial datasets. The course covers basic Python language concepts such as data types, control structures and functions. These concepts are then used to gain a deeper understanding of ArcGIS Pro’s geoprocessing framework (arcpy). This includes vector data processing functions as well as geoprocessing functions for raster data analysis. It also introduces the use of key Python libraries in conjunction with geospatial datasets.

- Knowledge of important terms and aspects of spatial data quality and data uncertainty, and can discuss them for given data.
- Ability to explain in detail how selected spatial algorithms work. Ability to discuss and compare alternative algorithms and implementations for given spatial problems.
- Ability to propose relevant GIS analyses and their implementation for complex spatial problems and to justify your choice.
- Understanding the important relationship between GIS and spatial databases as well as the increasing importance of internet applications of spatial data.

### Geographic Information Systems: Courses of Choice

The Courses of Choice are offered by UZH and must be approved by the subject advisor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1776-00L</td>
<td>Geographic Data Processing with Python and ArcGIS</td>
<td>W</td>
<td>1 credit</td>
<td>2U</td>
<td>A. Baltensweiler</td>
</tr>
</tbody>
</table>

#### Objective

- Students will learn the basics of geographic data processing using the Python programming language and ArcGIS Pro (arcpy). They will be able to implement their own geoprocessing scripts for spatial data analysis and modelling. Students will be able to integrate open source libraries into their Python scripts and know how to apply the libraries to geospatial datasets.
- The course provides an introduction into the various components of the cryosphere: snow, glaciers, ice sheets, sea ice and lake ice, permafrost and their roles in the climate system. Essential physical aspects are emphasized for each subsystem, their dynamics are described quantitatively and using examples. In the course “Cryosphere”, the competencies of process understanding, modeling, data analysis & interpretation and measurement methods are taught, applied and examined. System understanding is taught and examined.

#### Literature

- Handouts will be distributed during the teaching semester
- Further literature will be indicated during the lecture.

### Glaciology

#### Glaciology: Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-3561-00L</td>
<td>Cryosphere</td>
<td>W+</td>
<td>3 credits</td>
<td>2U</td>
<td>M. Huss, D. Farinotti, H. J. Horgan</td>
</tr>
</tbody>
</table>

#### Objectives

- Students are able to:
  - qualitatively explain relevant processes, feedbacks and relationships between the different components of the cryosphere,
  - quantify and interpret physical processes, which determine the state of the cryospheric components, with simple calculations.
- In the course “Cryosphere”, the competencies of process understanding, modeling, data analysis & interpretation and measurement methods are taught, applied and examined. System understanding is taught and examined.
- The course provides an introduction into the various components of the cryosphere: snow, glaciers, ice sheets, sea ice and lake ice, permafrost and their roles in the climate system. Essential physical aspects are emphasized for each subsystem: e.g. the material properties of ice, mass balance and dynamics of glaciers, or the energy balance of sea ice.

#### Literature


Further literature will be indicated during the lecture.

### Glaciology: Courses of Choice

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
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<td>701-1776-00L</td>
<td>Geographic Data Processing with Python and ArcGIS</td>
<td>W</td>
<td>1 credit</td>
<td>2U</td>
<td>A. Baltensweiler</td>
</tr>
</tbody>
</table>

#### Literature

- Handouts will be distributed during the teaching semester
- Further literature will be indicated during the lecture.

### Data: 15.06.2024 12:39

Autumn Semester 2024

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Seminar in Glaciology

W 3 credits 2S  A. Bauder, M. Jacquemart

Abstract
Introduction to classic and modern literature of research in Glaciology. Active participation is expected and participants are mentored by PhD students of Glaciology.

Objective
In-depth knowledge of selected topics of research in Glaciology. Introduction to different types of scientific presentation. Improve ability of the discussion of scientific topics.

Content
Selected topics of scientific research in Glaciology

Lecture notes
Copies/pdf of scientific papers will be distributed during the course (moodle interface)

Prerequisites / notice
Active participation is expected with presence at the sessions. Only a limited number of participants can be accepted. One of the following courses should be taken as preparation:
- 651-3561-00L Kryosphäre
- 101-0289-00L Applied Glaciology
- 651-4101-00L Physics of Glaciers

Competencies

Concepts and Theories  fostered
Techniques and Technologies  fostered
Analytical Competencies  fostered
Decision-making  fostered
Media and Digital Technologies  fostered
Communication  fostered
Cooperation and Teamwork  fostered
Self-presentation and Social Influence  fostered
Sensitivity to Diversity  fostered
Negotiation  fostered
Adaptability and Flexibility  fostered
Creative Thinking  fostered
Critical Thinking  fostered
Self-awareness and Self-reflection  fostered

Quantification and Modeling of the Cryosphere: Dynamic Processes (University of Zurich)

W 3 credits 1V  University lecturers

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: GEO815

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

Abstract
This course introduces quantitative approaches and models to processes of the cryosphere in high mountain areas. The main focus are dynamic and thermal processes related to glaciers and permafrost. During the course, simple simple mathematical and numerical models will be used to investigate ground temperature profiles as well as glacier evolution and dynamics in relation to climate.

Objective
This course combines lectures providing the background on the physical processes and methods with computer practicals in which quantitative methods are applied to glaciers and permafrost processes. These lectures and practicals run as 2-hour blocks per week and are combined with group and individual exercises. Topics indicative for the content of this course are:

- Heat flow processes in the ground and in glaciers, and their solution with numerical models.
- Glacier dynamics and evolution in relation to climate change.
- Simple and reduced mathematical models for glaciers flow.
- Numerical models for glacier dynamics.

Content
The course starts with lectures introducing the basic concepts of the different topics. The main focus lies on extensive computer practicals in which the related quantitative methods and models are applied and explored. Extensive group work on a topic of choice, using the quantitative models, will give a deep understanding how computer models are used in applied science.

Physics of Glaciers

W 3 credits 3G  M. Lüthi, F. T. Walter, M. Werder

Abstract
Understanding glaciers and ice sheets with simple physical concepts. Topics include the reaction of glaciers to the climate, flow of glacier ice, temperature in glaciers and ice sheets, glacier hydrology, glacier seismology, basal motion and calving glaciers. A special focus is the current development of the ice sheets of Greenland and Antarctica.

Objective
After the course the students are able understand and interpret measurements of ice flow, subglacial water pressure and ice temperature. They will have an understanding of glaciology-related physical concepts sufficient to understand most of the contemporary literature on the topic. The students will be well equipped to work on glacier-related problems by numerical modeling, remote sensing, and field work.

Content
The dynamics of glaciers and polar ice sheets is the key requisite to understand their history and their future evolution. We will take a closer look at ice deformation, basal motion, heat flow and glacier hydraulics. The specific dynamics of tide water and calving glaciers is investigated, as is the reaction of glaciers to changes in mass balance (and therefore climate).

Lecture notes
Will be provided on Moodle

Literature
A list of relevant literature is available on Moodle

Prerequisites / notice
High-school mathematics and physics knowledge required.
### Applied Glaciology

**W** 4 credits 2G  D. Farinotti, A. Bauder, M. Werder

**Abstract**
The course transmits fundamental knowledge for treating applied glaciological problems. Topics include climate-glacier interactions, glacier ice flow, glacier hydrology, ice avalanches, and lake ice.

**Objective**
The objectives of the courses are to:
- learn about fundamental glaciological processes, including glacier mass balance, ice dynamics, and glacier-related hazards;
- apply the above knowledge to some case studies inspired by contract-works performed at ETH's Glaciology section;
- generate the own computer code to solve the above case studies, and interpret the results;
- understand, both in class and in the field, the practical relevance of glaciology, with a focus on the Swiss applications.

**Content**
The course will develop along the following outline:
- How glaciology became a scientific discipline
- Glaciology and hydropower
- Glacier mechanics and ice flow
- Gravitational glacier instabilities
- Glacier hydrology and glacier lake outbursts
- Lake ice and ice bearing capacity
- Field excursion to Jungfraujoch
- Discussion of the exercises performed during the semester

**Lecture notes**
Digital lecture handouts will be distributed prior to each class.

**Literature**
Links to relevant literature will be provided during the classes.

**Prerequisites / notice**
Completed BSc studies. Basic knowledge in computer scripting in any language (e.g. Python, R, Julia, Matlab, IDL, ...) will be advantageous for solving the exercises. The exercises will be performed in groups. A minimal level of fitness is required for the field excursion.

### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

**Method-specific Competencies**
- Analytical Competencies: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered

**Personal Competencies**
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Sensitivity to Diversity: fostered
- Adaptable and Flexibility: fostered
- Sensitivity to Diversity: fostered
- Critical Thinking: assessed

### Lithosphere Structure and Tectonics

**Number** 651-3521-00L

**Title** Tectonics

**Type** W+

**ECTS** 3 credits

**Hours** 2V

**Lecturers** W. Behr, S. Willett

**Abstract**
Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales. Evaluation of plate tectonic and other orogenic processes through the study of reference examples of taken in Alps-Himalaya orogenic system.

**Objective**
Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales. Assessment of mechanisms responsible for plate movements (the Earth as a heat transfer machine, dynamics of earth mantle, plate driving forces) and subsequent large-scale structures (oceanic basins and cycle of the oceanic lithosphere, convergence and mountain systems and continental growth, etc) through theoretical and experimental information. Evaluation of plate tectonic and other orogenic processes through the study of reference examples of taken in Alps-Himalaya orogenic system.

**Content**
Plate tectonic frame work: earth cooling and mantle-plate interaction, three kinds of plate boundaries and their roles and characteristics, cycle of oceanic lithosphere, longifity and growth of continents, supercontinents. Rheology of layered lithosphere and upper mantle. Obduction systems Collisions systems Extensional systems Basin evolution Passive and active continental margin evolution
Earthquakes I: Seismotectonics

Abstract
If you're interested in knowing more about the relationship between seismicity and plate tectonics, this is the course for you. (If you're not that interested, but your program of study requires that you complete this course, this is also the course for you.)

Objective
The aim of the course is to obtain a basic understanding of the physical process behind earthquakes and their basic mathematical description. By the conclusion of this course, we hope that you will be able to:
- describe the relationship between earthquakes and plate tectonics in a more sophisticated and complete way
- explain earthquake source representations of varying complexity
- address earthquakes in the context of different tectonic settings
- explain the statistical behaviour of global earthquakes
- describe and connect the ingredients for a seismotectonic study

Content
The course features a series of 14 meetings, in which we review some fundamentals of continuum mechanics and tensor analysis required for a complete understanding of the relation between earthquakes and plate tectonics. Our goal is to help you understand deformation the small scale (fault) to the scale of plate tectonics. We will tell you about several ways to represent an earthquake source; we'll present these in order of increasing sophistication. You will enjoy (at least) a computer/class exercise and a guest lecture.

Topics covered in the course include:
- review of stress and deformation in the Earth, stress and strain tensors, rheology and failure criteria, fault stresses, friction and effects of fluids
- earthquake focal mechanisms; relationship between stress fields and focal mechanisms; seismic moment and moment tensors;
- crustal deformation from seismic, geologic, and geodetic observations;
- earthquake stress drop, scaling, and source parameters;
- global earthquake distribution; current global earthquake activity;
- different seismotectonic regions; examples of earthquake activity in different tectonic settings.

Lecture notes
Course notes will be made available on a designated course web site. Most of the topics discussed in the course are available in the book mentioned below.

Literature

Prerequisites / notice
Basic knowledge of continuum mechanics and rock mechanics, as well as notion of tensor analysis is strongly suggested. We recommend to have taken the course Continuum Mechanics (generally taught during the Fall semester).

This course will be taught in fall 2017 and it will be followed by Earthquakes 2: Source Physics in Spring 2018.

The course will be evaluated in a final written test covering the topics discussed during the lectures.

The course will be worth 3 credit points, and a satisfactory total grade (4 or better) is needed to obtain 3 ECTS.

The course will be given in English.

Seismic Waves II

Abstract
This course provides an overview on the most widely used seismological methods to image the Earth's interior with a focus on crustal and upper-mantle structures. Topics include controlled source methods such as refraction and wide-angle reflection, as well as passive body-wave and surface-wave based methods. The course will discuss the strengths and weaknesses of each method.

Objective
Understand the strengths and weaknesses of various active and passive tomographic methods to image the structure of the Earth.

Literature

Competencies
- Subject-specific Competencies
  - Concepts and Theories
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Problem-solving
- Social Competencies
  - Cooperation and Teamwork
- Personal Competencies
  - Creative Thinking
  - Critical Thinking

Palaeontology
Palaeontology: Compulsory Courses
The compulsory courses take place in spring semester.

Palaeontology: Courses of Choice
The courses of choice are offered by the Climate Geology group or UZH.
This course introduces quantitative approaches and models to processes of the cryosphere in high mountain areas. The main focus are fostered

### Critical Thinking

### Paleontological Excursions on Weekends (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.  
**UZH Module Code: BIO279**

> Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html

#### Abstract

Usually one to three day excursions (possibly including museum visits) to deepen regional geological and evolutionary knowledge and to gain practical paleontological experience.

#### Prerequisites / notice

The course will only take place, if specific excursions are planned for the semester: https://www.pim.uzh.ch/studium/exkursionen/ Only in case a planned excursion is advertised, signing up for BIO 279 will be possible via the secretary office of the Paleontological Institute, UZH main building. Limited number of participants. Consideration after receipt of the registration. Please note the respective registration deadline. Further details can be found in the respective advertisements on the above-mentioned website.

#### Quaternary Geology and Geomorphology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4901-00L</td>
<td>Quaternary Dating Methods</td>
<td>W+</td>
<td>2 credits</td>
<td>1G</td>
<td>I. Hajdas</td>
</tr>
</tbody>
</table>

#### Abstract

Reconstruction of time scales is critical for all Quaternary studies in Geology and Archeology. Various methods are applied depending on the time range of interest and the archive studied. In this lecture, we focus on the last 50 ka and the methods that are most frequently used for dating Quaternary sediments and landforms in this time range.

#### Objective

At the end of the course, students will:
1. understand the fundamental principles of the most frequently used dating methods for Quaternary studies.
2. choose which dating method (or combination of methods) suits a certain field problem.
3. critically read and evaluate the application of dating methods in scientific publications.

#### Content

1. Introduction: Isotopes and decay  
2. Radiocarbon dating: principles and applications  
3. AMS technique and its application in Quaternary geochronology  
4. U-series disequilibrium dating  
5. Luminescence dating  
6. Introduction to incremental: varve counting, dendrochronology, and ice cores chronologies  
7. Dating anthropogenic records

#### Prerequisites / notice

Visit to radiocarbon lab, cosmogenic nuclide lab, and accelerator (AMS) facility.

Required: attending the lecture, visiting laboratories, handing back solutions for problem sets, short presentations or written report

#### Competencies

- Optional (individual): 1-5 days of hands-on radiocarbon dating at the 14C lab, ETH Hoenggerberg

#### Quantiﬁcation and Modeling of the Cryosphere: Dynamic Processes (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.  
**UZH Module Code: GEO815**

> Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html

#### Abstract

This course introduces quantitative approaches and models to processes of the cryosphere in high mountain areas. The main focus are dynamic and thermal processes related to glaciers and permafrost. During the course, simple simple mathematical and numerical models will be used to investigate ground temperature profiles as well as glacier evolution and dynamics in relation to climate.

#### Objective

This course combines lectures providing the background on the physical processes and methods with computer practicals in which quantitative methods are applied to glaciers and permafrost processes. These lectures and practicals run as 2-hour blocks per week and are combined with group and individual excercises. Topics indicative for the content of this course are:

- Heat ﬂow processes in the ground and in glaciers, and their solution with numerical models.
- Glacier dynamics and evolution in relation to climate change.
- Simple and reduced mathematical models for glaciers flow.
- Numerical models for glacier dynamics.

#### Content

For the modeling and project parts of the course, programs written in the Python programming language are used. Prior Python or programming knowledge is not necessary, and introductory tutorials are given.

The course starts with lectures introducing the basic concepts of the different topics. The main focus lies on extensive computer practicals in which the related quantitative methods and models are applied and explored. Extensive group work on a topic of choice, using the quantitative models, will give a deep understanding how computer models are used in applied science.

#### Remote Sensing
The courses of this module are offered by UZH and must be registered at UZH.

Remote Sensing: Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4263-00L</td>
<td>Remote Sensing and Geographic Information Science V (University of Zurich)</td>
<td>W+</td>
<td>5 credits</td>
<td>2V+2U</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: GEO371

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

Abstract

The course "Methoden der Fernerkundung" (Remote Sensing Methods) introduces advanced remote sensing methods and techniques for interpreting and analysing optical, RADAR and LiDAR data. The large variety of topics covered in this module range from radiative transfer over environmental monitoring to geometric and radiometric data processing techniques.

Objective

At the end of the module, students should: • Have a thorough understanding of advanced image understanding techniques and can apply these to optical, RADAR and LiDAR imagery. • Be able to choose the appropriate methods and use them to solve a given real-world task. • Be able to write basic programming scripts and use common remote sensing software to analyze geospatial data. • Be able to work scientifically on a given project (e.g. defining hypothesis and research questions). • Be able to comprehensively interpret data, critically discuss the results and draw the main conclusions.

Remote Sensing: Courses of Choice

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4269-00L</td>
<td>Specialisation in Remote Sensing: Spectroscopy of the Earth System (University of Zurich)</td>
<td>W</td>
<td>6 credits</td>
<td>2V+2U</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

Prerequisite: Remote Sensing Methods (UZH Module Code: GEO371)

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

Abstract

The Spectroscopy of the Earth System course series outlines key contributions of imaging spectroscopy to advance understanding of the Earth System. Various Earth spheres (i.e. Atmosphere, Biosphere, Cryosphere, Hydrosphere, and Pedosphere) are addressed and spectroscopic approaches to quantify biogeophysical ecosystem properties and Earth surface processes are discussed.

Objective

The aim of the module is to give students a thorough understanding of the concepts, principles and processing of imaging spectroscopy data applied to various spheres of the Earth system. Students will be able to carry out typical workflows in data acquisition, processing and product generation. They will be able to assess the quality of the product and understand the nature of the errors affecting the product. Students will acquire both theoretical and practical knowledge and understanding of ground-based, aerial and satellite spectroscopy data. They will be able to derive solutions to given problems and will have an understanding of diverse Earth sphere applications and associated limitations of learned techniques.

Content

The individual lectures inherently focus on fundamentals of radiation interaction with the atmosphere and the surface, as well as on aspects of data acquisition, quality assessment and pre-processing. A comprehensive set of methods to extract information from imaging spectroscopy data is described (e.g. spectral feature analysis, spectral unmixing, radiative transfer modeling, reflectance and fluorescence retrieval, calculation of spectral albedo). The module is composed of the lecture GEO 442.1, outlining the underlying principles, and the exercise GEO442.2, conveying important methods and skills of data processing and analysis.

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>651-4257-00L</td>
<td>Specialisation in Remote Sensing: SAR and LiDAR (University of Zurich)</td>
<td>W</td>
<td>6 credits</td>
<td>2V+2U</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

Prerequisite: Remote Sensing Methods (UZH Module Code: GEO371)

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

Abstract

This module introduces advanced remote sensing methods and techniques to interpret and analyse RADAR and LiDAR data. The variety of topics covered in this module begin with image focussing, move through geometric and radiometric data processing, as well as interferometric and polarimetric evaluations.

Objective

The aim of the module is to give students a thorough understanding of the concepts, principles and processing of SAR and LiDAR data. Students will be able to carry out typical workflows in data processing and product generation. They will also be able to assess the quality of data products and understand the nature of errors that can affect the datasets. Students will acquire both theoretical and practical knowledge and understanding of aerial and satellite SAR imagery and LiDAR point cloud data. They will be able to derive solutions to problems presented and will have an understanding of applications including associated limitations.

Content

The module provides students with the skills to use state of the art software tools (e.g. SNAP, Matlab) to process data sets and develop new tools within existing frameworks. Examples of SAR applications treated include glacier and volcano monitoring, as well as height estimation using interferometry. Laser scanning exercises are focused on understanding LiDAR intensity, terrain model creation and their respective uncertainties and terrestrial laser scanning methods and applications. The module is composed of the lecture GEO 443.1, which teaches the underlying principles, and the exercise GEO443.2, which conveys important methods and skills of data processing and analysis.

Shallow Earth Geophysics

Courses are only offered in spring semester.

Modules from the Engineering Geology Major

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1129 of 2653
All modules of the MSc in Earth Sciences are available as module of choice.

Modules from Engineering Geology

Modules from the Geophysics Major

All modules of the MSc in Earth Sciences are available as module of choice.

Restricted Choice Modules from Geophysics

Modules from the Mineralogy and Geochemistry Major

All modules of the MSc in Earth Sciences are available as module of choice.

Restricted Choice Modules from Geophysics

Open Choice Modules from Geophysics

Modules from the Major Geology Restricted Choice Modules

All modules of the MSc in Earth Sciences are available as module of choice.

Restricted Choice Modules from Geology

Open Choice Modules from Geology

Major in Engineering Geology

Compulsory Modules Engineering Geology

Engineering Geology: Fundamentals

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4025-00L</td>
<td>Rock Mechanics and Rock Engineering</td>
<td>W+</td>
<td>4</td>
<td>4V</td>
<td>P. A. Selvadurai</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course focusses on the principles (fundamentals) and basic concepts of rock mechanics and rock engineering (e.g. tunnelling, rock slope stability).</td>
<td></td>
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<tr>
<td>Objective</td>
<td>The course aims to introduce the fundamentals and basic concepts of rock mechanics and generic rock engineering. The student shall understand how rocks behave at different scales, under various artificial loads and in the shallow subsurface (a few km below ground). The link between rock mechanics, geology, hydrogeology and tectonics (i.e. the conditions under which the rock formed) will be clearly established. The student shall understand basic principles of rock mechanics and rock engineering. In addition, the student shall learn how to apply the results from lab and field investigations to simple engineering problems. This knowledge is required for subsequent integration courses (Landslide Analysis and Hazard Mitigation; Engineering Geology of Underground Excavations).</td>
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<tr>
<td>Content</td>
<td>This course focusses on the principles (fundamentals) and basic concepts of rock mechanics and generic rock engineering. The course is compulsory for the MSc Eng Geol. The applications of rock mechanical principles and rock engineering methods are extensively covered in subsequent courses.</td>
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<tr>
<td>Lecture notes</td>
<td>Written course documentation available on our homepage: <a href="https://www.ethz.ch/content/specialinterest/erdw/geological-institute/engineering-geology/en/teaching/msc/fall/rock_mechanics.html">https://www.ethz.ch/content/specialinterest/erdw/geological-institute/engineering-geology/en/teaching/msc/fall/rock_mechanics.html</a></td>
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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4033-00L</td>
<td>Soil Mechanics and Foundation Engineering</td>
<td>W+</td>
<td>4</td>
<td>3V</td>
<td>J. Aaron, L. de Palézieux dit Falconnet, S. Montani</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course presents the principles of soil mechanics and soil behaviour characteristics and its applications in geotechnical structures and systems. It is based on more descriptive courses on Engineering Geology within the BSc Geol. Program and is a compulsory prerequisite for other courses within the MSc Eng. Geol. program.</td>
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<tr>
<td>Objective</td>
<td>Understanding the principles of soil behaviour and the fundamentals of geotechnical practices in soils. Ability to communicate with geotechnical engineers.</td>
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<tr>
<td>Content</td>
<td>Soil Mechanics: Fundamental concepts of strength and deformation of different soils. Introduction to geotechnical calculations Significance of (ground)water Geotechnical Engineering in Soils: Evaluation of geotechnical scenarios, handling of forecast uncertainties, relation of soil properties and soil composition, interactions between soil and building, standard construction methods in soils (foundations, slopes, dams and levees), requirements for the geotechnical prognosis</td>
<td></td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>This lecture is supported by the textbook: &quot;Geotechnical Engineering&quot; by Donald P. Coduto, 2nd edition, 2011; ISBN-13: 978-0-13-135425-8</td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>Courses must be completed: Introduction to Engineering Geology (BSc level) Introduction to Groundwater Sedimentology and Quaternary deposits Principles of Physics Courses recommended: Eng Geol Site Investigations Eng Geol Field Course 1 (soils) Clay Mineralogy</td>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4023-00L</td>
<td>Groundwater</td>
<td>W+</td>
<td>4</td>
<td>4G</td>
<td>X.-Z. Kong</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course provides an introduction into quantitative analysis of groundwater flow and solute transport. It is focussed on understanding, formulating, and solving groundwater flow and solute transport problems.</td>
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<tr>
<td>Objective</td>
<td>a) Students understand the basic concepts of groundwater flow and solute transport processes, and boundary conditions. b) Students are able to formulate simple, practical groundwater flow and solute transport problems. c) Students are able to understand and apply simple analytical and/or numerical solutions to fluid flow and solute transport problems.</td>
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</tbody>
</table>
This course aims at introducing the general procedures taken during an engineering geological site investigation. Students who complete

The methods that are routinely employed in site investigations will be described focusing on their applicability in different geologic environments. The limitations of the data in constraining the parameters of interest will be addressed together with problems of interpretation and cost-versus-information value. Specific topics addressed include drilling, coring, sampling, borehole testing, geophysical methods used in engineering geology, satellite, air- and ground-based surface and displacement monitoring (photogrammetry, LIDAR and Radar), and in-situ deformation measurement methods.

Lecture notes
Lecture notes will be available for download 1-2 days before each class.
Literature


Online (ETH): http://www.icevirtuallibrary.com/content/book/100017


Supplemental literature will be suggested and made available during the course.

Prerequisites / notice

Students registering for the course confirm having read and accepted the terms and conditions for excursions and field courses of D-ERDW https://www.ethz.ch/content/dam/ethz/special-interest/erdw/department/dokumente/studium/exkursionen/AGB_ERDW_Exkursionen_en.pdf

Competencies

Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed

Social Competencies

- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies

- Adaptability and Flexibility: assessed
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: fostered

Engineering Geology: Integration

Courses for this Module take place in spring semester.

Engineering Geology: Industrial Internship

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
651-4071-00L | Industrial Internship | O | 12 credits | external organisers

The Industrial Internship of the Eng Geol Major takes place in the second MSc year after consultation with Dr. Heike Willenberg. Detailed regulations of this practical are published on the Engineering Geology Website.

Abstract

The industry practical is supervised both from the industry partner and ETH and consists of technically and/or scientifically challenging work in the engineering geology domain. The regular duration of the practical is 10 weeks. The practical is is pre-defined in a work plan and concluded with a report written by the student.

Objective

The goals of the industry practical are to become familiar with technical, economic, legal and communication issues of real-life work in private industry or technical administration.

Major in Geophysics

Compulsory Modules Geophysics

Geophysics: Methods I

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
651-4005-00L | Geophysical Data Processing | W+ | 3 credits | 2G | C. V. Cauzzi, L. Ermert

Abstract

This course presents fundamental digital signal processing and filter theory with a focus on geophysical applications.

Objective

The goal of the course is to provide an understanding of the fundamental principles of digital signal processing and filter theory for application in geophysics and seismology. Form: two hours lecture and two hours of computer aided exercises per week.

Content

Seismic station; noise; digitisation; the seismometer; Laplace transform; Z-Transform; digital filters design and application; inverse filters design and application; appendixes (e.g., response spectra).

Lecture notes

Lecture notes will be made available for download from the website of the course.

Literature

The class follows no single book. A list of relevant texts will be given in class.

Prerequisites / notice

- Assumed existing knowledge:
  - (a) time series, discrete systems, Fourier transform, Fourier and power spectra, convolution, correlation, stochastic time series (a course dealing with these topics is “Analysis of Time Series in Environmental Physics and Geophysics”);
  - (b) Python, Jupyter.

Students must bring their own laptop in class for computer exercises based on Python / Jupyter.
The goal of this course is for students to learn how to program numerical applications from scratch. By the end of the course, students should be able to write state-of-the-art MATLAB codes that solve systems of partial-differential equations relevant to Earth and Planetary Science applications using finite-difference method and marker-in-cell technique. Applications include Poisson equation, buoyancy driven variable viscosity flow, heat diffusion and advection, and state-of-the-art thermomechanical code programming. The emphasis will be on commonality, i.e., using a similar approach to solve different applications, and modularity, i.e., re-use of code in different programs. The course will emphasise a hands-on learning approach rather than extensive theory, and will begin with an introduction to programming in MATLAB.

A provisional week-by-week schedule (subject to change) is as follows:

**Week 1**: Introduction to the finite difference approximation to differential equations. Introduction to programming in Matlab. Solving of 1D Poisson equation.

**Week 2**: Direct and iterative methods for obtaining numerical solutions. Solving of 2D Poisson equation with direct method. Solving of 2D Poisson equation with Gauss-Seidel and Jacobi iterative methods.

**Week 3**: Solving momentum and continuity equations in case of constant viscosity with stream function/vorticity formulation.

**Week 4**: Staggered grid for formulating momentum and continuity equations. Indexing of unknowns. Solving momentum and continuity equations in case of constant viscosity using pressure-velocity formulation with staggered grid.

**Week 5**: Conservative finite differences for the momentum equation. "Free slip" and "no slip" boundary conditions. Solving momentum and continuity equations in case of variable viscosity using pressure-velocity formulation with staggered grid.

**Week 6**: Advection in 1-D. Eulerian methods. Marker-in-cell method. Comparison of different advection methods and their accuracy.

**Week 7**: Advection in 2-D with Marker-in-cell method. Combining flow calculation and advection for buoyancy driven flow.


**Week 9**: Solving 2D heat conservation equation in case of constant thermal conductivity with explicit and implicit approaches.

**Week 10**: Solving 2D heat conservation equation in case of variable thermal conductivity with implicit approach. Temperature advection with markers. Creating thermomechanical code by combining mechanical solution for 2D buoyancy driven flow with heat diffusion and advection based on marker-in-cell approach.

**Week 11**: Implementation of radioactive, adiabatic and shear heating to the thermomechanical code.

**Week 12**: Programming of solution of coupled solid-fluid momentum and continuity equations for the case of melt percolation in a rising mantle plume.

**Week 13**: Subgrid diffusion of temperature and its implementation. Implementation of temperature-, pressure- and strain rate-dependent viscosity, temperature- and pressure-dependent density and temperature-dependent thermal conductivity to the thermomechanical code.

**Week 14**: Final project description for slab breakoff modeling.

GRADING will be based on weekly programming homeworks (50%) and a term project (50%) to develop an application of their choice to a more advanced level.

**Numerical Modelling I and II: Theory and Applications**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4241-00L</td>
<td>Introduction to Fluid Dynamics</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>J. A. Noir</td>
</tr>
</tbody>
</table>

This course aims to provide the students with a general introduction of the fundamental concepts of fluid dynamics such as viscous flows, potential flows, instabilities. The course is a combination of lectures, exercises and demo experiments.
In this course, students learn crucial partial differential equations (conservation laws) that are applicable to any continuum including the Earth's mantle, core, atmosphere and ocean. The course will provide step-by-step introduction into the mathematical structure, physical meaning and analytical solutions of the equations. The course has a particular focus on solid Earth applications.

The goal of this course is to learn and understand few principal partial differential equations (conservation laws) that are applicable for analysing and modelling of any continuum including the Earth's mantle, core, atmosphere and ocean. By the end of the course, students should be able to write, explain and analyse the equations and apply them for simple analytical cases. Numerical solving of these equations will be discussed in the Numerical Modelling I and II course running in parallel.

A provisional week-by-week schedule (subject to change) is as follows:

Weeks 1, 2: The continuity equation
- Exercise: Computing the divergence of velocity field.

Weeks 3, 4: Density and gravity
- Exercises: Computing density, thermal expansion and compressibility from an equation of state. Derivation of gravitational acceleration and its divergence from gravitational potential.

Weeks 5, 6: Stress and strain

Weeks 7, 8: The momentum equation
  - Deriving momentum equation. Computing velocity for magma flow in a channel.

Week 9: Viscous rheology of rocks
- Theory: Solid-state creep of minerals and rocks as the major mechanism of deformation of the Earth's interior. Dislocation and diffusion creep mechanisms. Rheological equations for minerals and rocks. Effective viscosity and its dependence on temperature, pressure and strain rate. Formulation of the effective viscosity from empirical flow laws.
- Exercise: Deriving viscous rheological equations for computing effective viscosities from empirical flow laws.

Weeks 10: The heat conservation equation

Week 11, 12: Elasticity and plasticity
- Exercise: compute viscoelastic stress evolution.

The course features a series of 14 meetings, in which we review some fundamentals of continuum mechanics and tensor analysis required for a complete understanding of the relation between earthquakes and plate tectonics. Our goal is to help you understand deformation from small scale (fault) to the scale of plate tectonics. We will tell you about several ways to represent an earthquake source; we'll present these in order of increasing sophistication. You will enjoy (at least) a computer/class exercise and a guest lecture.

Topics covered in the course include:

- review of stress and deformation in the Earth, stress and strain tensors, rheology and failure criteria, fault stresses, friction and effects of fluids
- earthquake focal mechanisms; relationship between stress fields and focal mechanisms; seismic moment and moment tensors;
- crustal deformation from seismic, geologic, and geodetic observations; earthquake stress drop, scaling, and source parameters;
- global earthquake distribution; current global earthquake activity; different seismotectonic regions; examples of earthquake activity in different tectonic settings.

Lecture notes
Course notes will be made available on a designated course web site. Most of the topics discussed in the course are available in the book mentioned below.

Literature
This course aims to give a physical understanding of the formation, structure, dynamics and evolution of planetary bodies in our solar system. It is recommended but not mandatory to buy one of these books:


### Physics of the Earth's Interior

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4010-00L</td>
<td>Planetary Sciences: a Physical Perspective</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>C. Gillmann</td>
</tr>
</tbody>
</table>

- **Abstract**: This course aims to give a physical understanding of the formation, structure, dynamics and evolution of planetary bodies in our solar system and also apply it to ongoing discoveries regarding planets around other stars.
- **Objective**: The goal of this course is to enable students to understand current knowledge and uncertainties regarding the formation, structure, dynamics and evolution of planets and moons in our solar system, as well as ongoing discoveries regarding planets around other stars. Students will practice making quantitative calculations relevant to various aspects of these topics through weekly homeworks.
- **Content**: The main topics covered are: Orbital dynamics and Tides, Solar heating and Energy transport, Planetary atmospheres, Planetary surfaces, Planetary interiors, Asteroids and Meteorites, Comets, Planetary rings, Magnetic fields and Magnetospheres, The Sun and Stars, Planetary formation, Exoplanets and Exobiology
- **Lecture notes**: Slides and scripts will be posted on Moodle.
- **Literature**: It is recommended but not mandatory to buy one of these books:

### Physics of Planetary Interiors

<table>
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<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>651-5107-00L</td>
<td>Physics of Planetary Interiors</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>A. Khan</td>
</tr>
</tbody>
</table>

- **Abstract**: Planetary science encompasses the study of the physical and chemical nature of planetary bodies both in the Solar System and in extrasolar systems. The formation of planets, the forces that shaped their orbits and the processes that molded their interiors are part of planetary science. Understanding these complex phenomena requires knowledge from various geo- and astrophysically-related fields.
- **Objective**: The goal of this course is to provide students with quantitative understanding of planetary science. The emphasis in this course will be on theoretical development of the fundamentals needed for understanding planetary materials, planetary formation and evolution, and planetary interiors.
- **Content**: The course will loosely be divided into ~14 lectures on various topics to be held by the main lecturer. In addition to the lectures, the students will solve a number ’take-home’ problems and will hand in reports.

- **Topics that will be covered in the course include:**
  1. Elasticity
  2. Equations of state
  3. Thermodynamics applied to mantle materials
  4. Harmonicity and anharmonicity
  5. Tidal potential, gravity and figure of a planet
  6. Orbital rotation, precession and nutation
  7. Orbital evolution and tidal dissipation
  8. Heat
  9. Free oscillations of a planet

- **Prerequisites / notice**: Completion of “651-4130-00 Mathematical Methods” is required.

- **Prerequisites / notice**: Completion of “651-4013-00L Potential Field Theory” is required.
  Completion of “651-4096-00L Inverse Theory for Geophysics I: Basics” would be helpful.

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Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management assessed

Personal Competencies
- Creative Thinking assessed
- Critical Thinking assessed
- Self-direction and Self-management assessed

-- Applied Geophysics

-- Applied Geophysics: Compulsory Courses
The compulsory courses take place in spring semester.

-- Applied Geophysics: Courses of Choice
The compulsory courses take place in spring semester.

► Major in Mineralogy and Geochemistry

► Compulsory Module in Analytical Methods in Earth Sciences
Students have to complete 6 credits in part A (microscopy courses), and 6 credits in part B (methods).

►► Microscopy Courses

Compulsory Module in Analytical Methods in Earth Sciences: Microscopy Courses

►► Analytical Methods Courses

Compulsory Module in Analytical Methods in Earth Sciences: Analytical Methods Courses

► Restricted Choice Modules Mineralogy and Geochemistry

A minimum of two restricted choice modules must be completed in the major Mineralogy and Geochemistry.

►► Mineralogy and Petrology

►►► Mineralogy and Petrology: Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4028-00L</td>
<td>Physical Properties of Minerals</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>P. Saha, to be announced</td>
</tr>
<tr>
<td>Abstract</td>
<td>Physical properties of minerals, e.g. electrical properties, elasticitcal properties are discussed. The effect of the crystal symmetry on the symmetry of physical properties as well as the mathematical formulation of the physical properties are major topics.</td>
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<tr>
<td>651-4039-00L</td>
<td>Thermodynamics Applied to Earth Materials</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>P. A. Sossi</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course develops the thermodynamic concepts necessary to predict phase equilibria and to compute chemical and physical properties from thermodynamic data in an Earth and planetary science context.</td>
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<tr>
<td>Objective</td>
<td>To provide students with the conceptual and practical skills necessary to implement thermodynamic models and data as provided in the Earth and planetary science literature.</td>
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<tr>
<td>Content</td>
<td>Elementary concepts (1st and 2nd Laws; composition, state and extent); stability criteria; Legendre transforms; Maxwell relations and other manipulations of thermodynamic functions; calculation of Gibbs energy for pure solid, liquids and gases; simple solution models; order-disorder solution models; reciprocal solution models; equations of state for molecular fluids and real gases; free energy minimisation.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The grade for the course is based on exercises assigned as homework. Some familiarity with elementary thermodynamics (phase rule, reactions) and mathematics (differentiation, integration) is assumed.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Method-specific Competencies</td>
<td>Problem-solving</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>fostered</td>
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<tr>
<td></td>
<td></td>
<td>Critical Thinking</td>
<td>fostered</td>
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►►► Mineralogy and Petrology: Courses of Choice

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4063-00L</td>
<td>X-Ray Powder Diffraction</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Plötze</td>
</tr>
<tr>
<td>Abstract</td>
<td>In the course the students learn to measure X-ray diffraction patterns of minerals and to evaluate these using different software for qualitative and quantitative mineral composition as well as crystallographic parameters.</td>
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<tr>
<td>Objective</td>
<td>Upon successful completion of this course students are able to: - describe the principle of X-ray diffraction analysis - carry out a qualitative and quantitative mineralogical analysis independently, - critically assess the data, - communicate the results in a scientific report.</td>
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<tr>
<td>Content</td>
<td>Fundamental principles of X-ray diffraction Setup and operation of X-ray diffractometers Interpretation of powder diffraction data Qualitative and quantitative phase analysis of crystalline powders (e.g. with Rietveld analysis)</td>
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<tr>
<td>Lecture notes</td>
<td>Selected handouts will be made available in the lecture</td>
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</tbody>
</table>
Literature


Prerequisites / notice

The course includes a high portion of practical exercises in sample preparation as well as measurement and evaluation of X-ray powder diffraction data.

Software will be provided for future use on own Laptop.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technique and Technologies</td>
<td></td>
<td>assessed</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Decision-making</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Problem-solving</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Project Management</td>
<td>fostered</td>
</tr>
</tbody>
</table>

Social Competencies

| Cooperation and Teamwork | assessed |
| Customer Orientation     | fostered |
| Leadership and Responsibility | fostered |

Personal Competencies

| Adaptable and Flexibility   | fostered |
| Creative Thinking           | assessed |
| Critical Thinking           | assessed |
| Integrity and Work Ethics   | fostered |
| Self-awareness and Self-reflection | fostered |
| Self-direction and Self-management | fostered |

651-4233-00L Composition and Evolution of the Earth and Planets W 3 credits 2V P. A. Sossi, S. Flemetakis, E. Schettino, M. A. Thompson

Abstract

In this Masters-level course, we address the formation and evolution of the rocky planets with a particular focus on the chemical and isotopic make-up of the Earth and its mantle. This is achieved through analysis of its partial melting products in different tectonic settings and through time.

Objective

Students will gain an insight into cutting-edge research in planetary science and the geochemical evolution of Earth's mantle. The objective is to be able to synthesise scientific studies whose conclusions differ, and, eventually, to form a coherent opinion by debating and scrutinising the available data. This will be achieved by weekly lectures and exercises throughout the semester, culminating in a debate on a topical subject in Earth and planetary science.

Petrology and Volcanology

Petrology and Volcanology: Compulsory Courses

The compulsory courses take place in spring semester.

Petrology and Volcanology: Courses of Choice

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>651-4063-00L</td>
<td>X-Ray Powder Diffraction</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Plötze</td>
</tr>
</tbody>
</table>

Abstract

In the course the students learn to measure X-ray diffraction patterns of minerals and to evaluate these using different software for qualitative and quantitative mineral composition as well as crystallographic parameters.

Objective

Upon successful completion of this course students are able to:

- describe the principle of X-ray diffraction analysis
- carry out a qualitative and quantitative mineralogical analysis independently,
- critically assess the data,
- communicate the results in a scientific report.

The competencies of system understanding, concept development, and measurement methods are taught and examined.

Content

Fundamental principles of X-ray diffraction
Setup and operation of X-ray diffractometers
Interpretation of powder diffraction data
Qualitative and quantitative phase analysis of crystalline powders (e.g. with Rietveld analysis)

Lecture notes

Selected handouts will be made available in the lecture

Literature


Prerequisites / notice

The course includes a high portion of practical exercises in sample preparation as well as measurement and evaluation of X-ray powder diffraction data.

Software will be provided for future use on own Laptop.
In this Masters-level course, we address the formation and evolution of the rocky planets with a particular focus on the chemical and isotopic makeup of the Earth and its mantle. This is achieved through analysis of its partial melting products in different tectonic settings and through time.

Objective

Students will gain an insight into cutting-edge research in planetary science and the geochemical evolution of Earth's mantle. The objective is to be able to synthesise scientific studies whose conclusions differ, and, eventually, to form a coherent opinion by debating and scrutinising the available data. This will be achieved by weekly lectures and exercises throughout the semester, culminating in a debate on a topical subject in Earth and planetary science.

### Mineral Resources

#### Mineral Resources: Compulsory Courses

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<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>651-4037-00L</td>
<td>Mineral Resources I</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>C. Chelle-Michou</td>
</tr>
</tbody>
</table>

#### Competencies

- Subject-specific Competencies
- Method-specific Competencies
- Social Competencies
- Personal Competencies

#### Content

(a) Principles of hydrothermal ore formation: base metal deposits in sedimentary basins. Practical classification of sample suites by genetic ore deposit types.

(b) Introduction to orthomagmatic ore formation. Chromite, Ni-Cu sulphides and PGE in layered mafic intrusions. Distribution coefficients between silicate and sulphide melts. Carbonatites and pegmatite deposits.

(c) Introduction to supergene residual deposits with emphasis on Ni laterites and bauxites.

#### Literature

Extensive literature list distributed in course

### Mineral Resources: Courses of Choice

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>651-4069-00L</td>
<td>Fluid and Melt Inclusions: Theory and Practice</td>
<td>W</td>
<td>3</td>
<td>3P</td>
<td>T. Driesner</td>
</tr>
<tr>
<td>651-4221-00L</td>
<td>Numerical Modelling of Ore Forming Hydrothermal</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>T. Driesner</td>
</tr>
</tbody>
</table>
Introduction to computer tools for the simulation of hydrothermal fluid flow and hydrothermal reactions. The computer programs are
fostered
assessed
Resource Economics and Mineral Exploration
assessed
Resource Economics and Mineral Exploration
assessed
practical understanding of the procedure of exploring a mineral prospect, based on geological analysis, exploration by drilling, resource
private
Global mineral economics and the strategies of mineral exploration -- including geological, geochemical and geophysical methods, but also
non-geological factors such as organisational, political and environmental aspects. Changing external lecturers.
Prerequisites / notice
This course is intended for earth science students; people interested but with a different background should contact the lecturer before signing up.
Competencies
Subject-specific Competencies
Concepts and Theories
analyzed
Techniques and Technologies
analyzed
Method-specific Competencies
Analytical Competencies
fostered
Media and Digital Technologies
fostered
Problem-solving
assessed
Project Management
fostered
Social Competencies
Cooperation and Teamwork
fostered
Personal Competencies
Creative Thinking
fostered
Critical Thinking
fostered

651-4034-00L  Resource Economics and Mineral Exploration
Does not take place this semester.
Restricted participation with priority for MSc Earth Science students taking the Module 'Mineral Resources and Applied Mineralogy'. Interested ETH students please register through myStudies by second semester week.
Abstract
Global mineral economics and the strategies of mineral exploration -- including geological, geochemical and geophysical methods, but also
non-geological factors such as organisational, political and environmental aspects. Changing external lecturers.
Objective
Practical understanding of the procedure of exploring a mineral prospect, based on geological analysis, exploration by drilling, resource
calculation of tonnage and grade as a basis for economic evaluation for reporting to investors.
Content
This block course in will comprise 4 half-day lectures and a series of practical exercises from selection of a mineral property to discovery of
mineral resources and their valuation. Teams are formed as Limited Partnership companies that have to select and bid for a mineral
property offered during an auction. Each company has the same nominal budget. The highest bidder purchases the selected property,
others need to purchase the remaining properties during an auction. Justification for selecting the property is justified in a report. The
companies must interpret the geology of their mineral property to prepare a diamond drill program to discover and, eventually, delineate the
mineral resources. This drill program is presented in a report prior to drilling. Drilling in the tri-dimensional matrix of the property is
simulated using the software FOREUR, until budget lapse. The companies must select drill intervals for chemical analysis to document the
extent and composition of the discovered mineralization. Portions of the mineral rights can be traded for capital between the companies. An
estimate of the tonnage and grade of the discovered resource is prepared using geometric methods and GIS software (ex. ArcGIS). The
ground value of the resource is estimated by a computation of the Net Smelter Return at current metal prices. The results of the exploration
program are presented in a comprehensive report.
Lecture notes
Handouts for background information and a computer simulation program for the case-study exercise will be provided. Participants must
bring a Windows-based laptop computer.
Prerequisites / notice
Prerequisites: Knowledge of mineral deposit-type characteristics is useful (orogenic gold, Cu-Zn VMS, Ni-Cu-PGE); at least "Integrierte
Erdsysteme", "Ore Deposit 1", or adequate knowledge of mineral deposits acquired by preparatory reading. Basic knowledge of ArcGIS
software is important to produce maps and sections required in reports. Training exercises and tutorials will be provided in advance to
prepare for the course. Taught biennially in collaboration with University of Geneva.
Competencies
Subject-specific Competencies
Concepts and Theories
analyzed
Techniques and Technologies
analyzed
Method-specific Competencies
Analytical Competencies
fostered
Decision-making
assessed
Problem-solving
assessed
Project Management
assessed
Social Competencies
Communication
assessed
Cooperation and Teamwork
fostered
Leadership and Responsibility
fostered
Negotiation
assessed
Personal Competencies
Adaptability and Flexibility
fostered
Creative Thinking
assessed
Critical Thinking
assessed
Integrity and Work Ethics
fostered
Self-direction and Self-management
fostered

651-4049-00L  Conceptual and Quantitative Methods in Geochemistry

Geochemistry: Compulsory Courses

Number  Title  Type  ECTS  Hours  Lecturers
651-4049-00L Conceptual and Quantitative Methods in Geochemistry  W+  3 credits  2G  G. De Souza, B. J. Peters
Prerequisite: Successful completion of the BSc-course "Geochemistry" (651-3400-00L).

Abstract
This course will introduce some of the main quantitative methods available for the quantitative treatment of geochemical data, as well as the main modelling tools. Emphasis will both be on conceptual understanding of these methods as well as on their practical application, using key software packages to analyse real geochemical datasets.

Objective
The following approaches will be discussed in detail: major and trace element modelling of magmas, with application to igneous systems; methods and statistics for calculation of isochrons and model ages; reservoir dynamics and modelling of ocean (biogeo)chemistry.

Content
We will discuss how these methods are applied in a range of Earth Science fields, from cosmochemistry, through mantle and crustal geochemistry, volcanology and igneous petrology, to chemical oceanography.

A special emphasis will be put on dealing with geochemical problems through modeling. Where relevant, software packages will be introduced and applied to real geochemical data.

Lecture note
Slides of lectures will be available.

Pre-requisite
Pre-requisite: Geochemie I and II

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Media and Digital Technologies
Problem-solving

Social Competencies
Communication

Personal Competencies
Creative Thinking

ECTS
2V

Programme Code
651-4227-00L

Planetary Sciences: a Chemical Perspective
W+ 3 credits 2G M. Schönächler, H. Busemann

Abstract
Formation and evolution of the solar system and its planets from a geochemical perspective

Objective
To understand the formation and the evolution of the solar system and its planets from a geochemical perspective

Content
The Sun and solid objects in the solar system (planets, comets, asteroids, meteorites, interplanetary dust) are discussed from a geochemical perspective. What does their present-day composition tell us about the origin, formation and evolution of the solar system? The lectures introduce the basics of the terrestrial and giant planets, comets and asteroids, gained from modern space missions and the study of extraterrestrial materials. The chemical and isotopic composition of meteorites, being the most primitive material available for study, is a further major topic.

Lecture note
Slides and additional materials are available electronically

Competencies
Subject-specific Competencies
Concepts and Theories

Method-specific Competencies
Analytical Competencies
Problem-solving

Personal Competencies
Creative Thinking

ECTS
2V

Programme Code
651-4233-00L

Composition and Evolution of the Earth and Planets
W 3 credits 2V P. A. Sossi, E. Schettino, M. A. Thompson

Abstract
In this Masters-level course, we address the formation and evolution of the rocky planets with a particular focus on the chemical and isotopic make-up of the Earth and its mantle. This is achieved through analysis of its partial melting products in different tectonic settings and through time.

Objective
Students will gain an insight into cutting-edge research in planetary science and the geochemical evolution of Earth's mantle. The objective is to be able to synthesise scientific studies whose conclusions differ, and, eventually, to form a coherent opinion by debating and scrutinising the available data. This will be achieved by weekly lectures and exercises throughout the semester, culminating in a debate on a topical subject in Earth and planetary science.

ECTS
3 credits

Programme Code
651-4057-00L

Climate History and Palaeoclimatology
W 4 credits 2G H. Stoll, I. Hernández Almeida

Abstract
Climate history and paleoclimatology explores how the major features of the earth's climate system have varied in the past, and the driving forces and feedbacks for these changes. The major topics include the earth's CO2 concentration and mean temperature, the size and stability of ice sheets and sea level, the amount and distribution of precipitation, and the ocean heat transport.

Objective
The student will be able to describe the natural factors lead to variations in the earth's mean temperature, the growth and retreat of ice sheets, and variations in ocean and atmospheric circulation patterns, including feedback processes. Students will be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geological records. Students will be able to use data from climate proxies to test if a given hypothesized mechanism for the climate change is supported or refuted. Students will be able to compare the magnitudes and rates of past changes in the carbon cycle, ice sheets, hydrological cycle, and ocean circulation, with predictions for climate changes over the next century to millennia.

ECTS
4 credits

Programme Code
651-4227-00L

Geochemistry: Courses of Choice

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<td>Composition and Evolution of the Earth and Planets</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>P. A. Sossi, E. Schettino, M. A. Thompson</td>
</tr>
<tr>
<td>651-4057-00L</td>
<td>Climate History and Palaeoclimatology</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>H. Stoll, I. Hernández Almeida</td>
</tr>
</tbody>
</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1141 of 2653
Content

The course spans 5 thematic modules:

1. Cyclic variation in the earth's orbit and the rise and demise of ice sheets. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth's ice sheets and the consequent effect on sea level? How do cyclic variations in the earth's orbit affect the size of ice sheets under modern climate and under past warmer climates? What conditions the mean size and stability or fragility of the large polar ice caps and is their evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? How stable or fragile is the ocean heat conveyor, past and present?
2. Feedbacks on climate cycles from CO2 and methane. What drives CO2 and methane variations over glacial cycles? What are the feedbacks with ocean circulation and the terrestrial biosphere?
3. Atmospheric circulation and variations in the earth's hydrological cycle - How variable are the earth's precipitation regimes? How large are the orbital scale variations in global monsoon systems?
4. Century-scale droughts and civil catastrophes. Will mean climate change El Nino frequency and intensity? What factors drive change in mid and high-latitude precipitation systems? Is there evidence that changes in water availability have played a role in the rise, demise, or dispersion of past civilizations?
5. How sensitive is Earth's long term climate to CO2 and cloud feedbacks? What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years?

The weekly two hour lecture periods will feature lecture on these themes interspersed with short interactive tasks to apply new knowledge. Over the semester, student teams will each present in class one debate based on two scientific articles of contrasting interpretations. With flexible scheduling, students will participate in a laboratory activity to generate a new paleoclimate record from stalagmites. Student teams will be supported by an individual tutorial meeting to assist in debate preparation and another to assist in the interpretation of the lab activity data.

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<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td></td>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Creative Thinking</td>
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<td>Techniques and Technologies</td>
<td>Problem-solving</td>
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<td>Critical Thinking</td>
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<th>651-4225-00L</th>
<th>Topics in Geochemistry</th>
<th>W 3 credits</th>
<th>2G</th>
<th>S. Bernasconi</th>
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<tbody>
<tr>
<td>Abstract</td>
<td>In this course we present and discuss advanced topics in geochemistry based on the critical reading of research papers. Themes include hydrothermal geochemistry, isotopes in meteorites, low temperature geochemistry and biogeochemistry.</td>
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<tr>
<td>Objective</td>
<td>The goal of the course is discuss topics in advanced geochemistry which were not covered in other general and specialized geochemistry courses. In addition, we aim at training the student's ability to critically evaluate research papers and to summarize the findings concisely in an oral presentation.</td>
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</tr>
<tr>
<td>Literature</td>
<td>Will be identified based on the chosen topic.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
<td>Social Competencies</td>
<td>Personal Competencies</td>
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<tr>
<td></td>
<td>Concepts and Theories</td>
<td>Communication</td>
<td>Creative Thinking</td>
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<td></td>
<td>Techniques and Technologies</td>
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<td>Critical Thinking</td>
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<tr>
<th>651-4010-00L</th>
<th>Planetary Sciences: a Physical Perspective</th>
<th>W 3 credits</th>
<th>2G</th>
<th>C. Gillmann</th>
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<tbody>
<tr>
<td>Abstract</td>
<td>This course aims to give a physical understanding of the formation, structure, dynamics and evolution of planetary bodies in our solar system and also apply it to ongoing discoveries regarding planets around other stars.</td>
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<tr>
<td>Objective</td>
<td>The goal of this course is to enable students to understand current knowledge and uncertainties regarding the formation, structure, dynamics and evolution of planets and moons in our solar system, as well as ongoing discoveries regarding planets around other stars. Students will practice making quantitative calculations relevant to various aspects of these topics through weekly homeworks.</td>
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<tr>
<td>Competencies</td>
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<td>Method-specific Competencies</td>
<td>Personal Competencies</td>
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<td></td>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Creative Thinking</td>
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<td></td>
<td>Techniques and Technologies</td>
<td>Adaptability and Flexibility</td>
<td>Critical Thinking</td>
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<table>
<thead>
<tr>
<th>651-4229-00L</th>
<th>Advanced Geochronology</th>
<th>W 3 credits</th>
<th>2G</th>
<th>H. Busemann, M. G. Fellin</th>
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</thead>
<tbody>
<tr>
<td>Abstract</td>
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<tr>
<td>Objective</td>
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<td></td>
</tr>
<tr>
<td>Literature</td>
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</table>
This lecture gives an overview of methods and applications of geochronology across a wide range of Earth Science disciplines. Several in their field specialized lecturers cover the principles and methods and will give insight into recent applications and research projects.

Objective

The purpose of this lecture is to provide a comprehensive overview of:

a) the different radiometric methods in Geology, the different dating tasks and the constraints put by the complexity of natural systems, including dating by cosmogenic nuclides,

b) the various analytical tools available today for radiometric dating, their advantages and disadvantages,

c) the use of noble gases in Geochemistry and
d) detailed description of case studies, as examples of approach of a number of geological problems and interpretation of the data.

At the end students know the different isotope systems, methods and their application. Understand literature and critical reading and interpretation of published data is possible. For simple geochronological questions they can describe a scientific approach and possible solution. They can plot and interpret data using IsoplotR for different applications.

Content

1. Introduction and overview, Data visualization and statistics in IsoplotR, Principles of U-Pb geochronology
2. In situ U-Pb geochronology 1 (LA-ICPMS/SIMS principles, zircon)
3. In situ U-Pb geochronology 2 (calcite, garnet, other minerals)
4. High-precision ID-TIMS U-Pb geochronology (principles and applications)
5. High-precision U-series geochronology (carbonates, silicates)
6. In situ U-series geochronology (zircon, garnet etc.)
7. K-Ar and 40Ar/39Ar geochronology , Principles and Applications
8. Fission Track dating
9. U-Th/He dating
10. Thermochronology applications/lab visit
11. Noble gases - basics, reservoirs, geo/cosmochem. applications: mainly chronology
12. Cosmogenic nuclides (stable and radionuclides) - basics, geo/cosmochem. applications, C14

Lecture notes

Script (for part of the lecture), partly power point presentations (in the web)

Literature

http://elementsmagazine.org/get_pdf.php?fn=e9_1.pdf&dr=e9_1

Geochronology and Thermochronology

Author(s): Peter W. Reiners Richard W. Carlson Paul R. Renne Kari M. Cooper Darryl E. Granger Nancy W. McLean Blair Schoene

First published: 8 January 2018


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Open Choice Modules

Module: Mineralogy and Geochemistry

All modules of the MSc in Earth Sciences are available as module of choice.

Modules from the Geology Major

All modules of the MSc in Earth Sciences are available as module of choice.

Restricted Choice Modules from Geology

Modules of Choice from Geology

Modules from the Geophysics Major

All modules of the MSc in Earth Sciences are available as module of choice.

Compulsory Modules from Geophysics

Restricted Choice Modules Geophysics

Restricted Choice Module from Mineralogy and Geochemistry

All modules of the MSc in Earth Sciences are available as module of choice.

Restricted Choice Modules from Mineralogy and Geochemistry

Modules of Choice from Mineralogy and Geochemistry

Electives

Courses can be chosen from the complete offerings of the ETH Zurich and University of Zurich (according to prior agreement with the subject advisor).

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>651-0048-00L</td>
<td>Electron Microprobe Course 2 - Practice</td>
<td>W Dr</td>
<td>1 credit</td>
<td>2G</td>
<td>J. Allaz</td>
</tr>
</tbody>
</table>

Abstract


Objective

Ability to perform a high precision EPMA analysis with minimal assistance, optimise the analysis setup in order to obtain excellent results, identify possible source of error (troubleshooting) and fix them, data treatment (and interpretation).

Content

Physical principles of electron optics, interaction of electrons with matter, production of X-rays, interaction of X-rays with matter. Detection of X-rays. Laboratory work in the field of Earth sciences.

Lecture notes

Script and User Manual will be provided.

Literature


Prerequisites / notice

- 4 full days.
- Prerequisite: Analytical methods in Petrology and Geology (651-4055-00L) and 651-0046-00 Electron Microprobe Course 1 - Theory

- Restricted attendance, max. 8 students (incl. Doctoral students and external participants). Contact J. Allaz.
Competencies

Subject-specific Competencies: Techniques and Technologies
Method-specific Competencies: Analytical Competencies
Social Competencies: Cooperation and Teamwork
Personal Competencies: Creative Thinking

Electron Microscopy in Material Science

W 4 credits 2V+2U

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication

Personal Competencies
- Creativity

Exploration and Environmental Geophysics

W 4 credits 3V

Subject-specific Competencies
- Concepts and Theories

Method-specific Competencies
- Analytical Competencies

Social Competencies
- Communication

Personal Competencies
- Creativity

Experimental Methods in Petrology

W 3 credits 2P

Subject-specific Competencies
- Concepts and Theories

Method-specific Competencies
- Analytical Competencies

Social Competencies
- Self-presentation and Social Influence

Personal Competencies
- Critical Thinking

Abstract
A comprehensive understanding of the interaction of electrons and ions with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

Objective
Overview and understanding of the most important geophysical methods: Potential field methods (Gravimetrics and Magnetics), Electrical and electromagnetic methods, Refraction and reflection seismics, Georadar. Discussion of survey design, sources and receivers and data processing.

Content
Overview and understanding of the most important geophysical methods. Proposed solutions to assess and observe problems relevant to exploration and environmental geophysics in soil, ice and lithosphere at different scales. Getting familiar with measuring- and interpretation procedures. Pointing out the possibilities and limitations of geophysical methods.

Literature
- Erni: Aberration-corrected imaging in transmission electron microscopy, Imperial College Press (2010, and 2nd ed. 2015)

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1144 of 2653
Among other aspects 'Experimental methods in petrology' covers the following subjects:

1. Introduction and historical development of experimental petrology.
2. Experimental methods at ambient pressure (1 bar) with practical exercise to determine basic thermodynamic data.
3. Starting and capsule materials; techniques to buffer chemical activities.
4. Experimental methods at moderate pressures: externally and internally heated gas-pressure devices.
5. High-pressure solid-media experimental techniques (piston cylinders).
7. Evaluation of petrologic experiments (preparation of run products, analytical and spectroscopic methods of examination and quantification).

The experiments performed during lab-work will be evaluated in the context of a small research project, which is introduced during the course.

Prerequisites / notice

This course is aimed at MSc and PhD students, who are interested in experimental methods. No foreknowledge on this is required but basic understanding of petrology and chemical thermodynamics is expected.

651-4114-00L Illustrations in Natural History (University of Zürich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: BIO271

Abstract

The general introduction to scientific graphics is followed by explanations and practical exercises with the use of important techniques of drawing: line drawing, hatching, stippling, shading with ink and pencil. Fossils and recent organisms serve as models. In addition basic knowledge in digital image processing will be taught (Photoshop).

Objective

By the end of the module, students are able to
- apply the most important conventional drawing techniques
- use PhotoShop or GIMP
- communicate scientific information in clearly designed illustrations using these techniques

Lecture notes

Own laptop with image processing program (PhotoShop or GIMP) is required.

651-4273-00L Numerical Modelling in Fortran

Abstract

This course gives an introduction to programming in Fortran, and is suitable for students who have only minimal programming experience. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts.

Objective

Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in this language, and is suitable for students who have only minimal programming experience, for example with MATLAB scripts. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts, using example scientific problems relevant to Earth science.

Lecture notes

See http://jupiter.ethz.ch/~pj/FORTRAN/FortranClass.html

Competencies

Subject-specific Competencies
- Techniques and Technologies
- Media and Digital Technologies
- Problem-solving

651-4273-01L Numerical Modelling in Fortran (Project)

Prerequisite: 651-4273-00L Numerical Modelling in Fortran.

Abstract

This course gives an introduction to programming in Fortran, and is suitable for students who have only minimal programming experience. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts.

Objective

Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in this language, and is suitable for students who have only minimal programming experience, for example with MATLAB scripts. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts, using example scientific problems relevant to Earth science.

Content

The project consists of writing a Fortran program to solve a problem agreed upon between the instructor and student; the topic is often related to (and helps to advance) the student's Masters or PhD research. The project is typically started towards the end of the end of the main Fortran class when the student has acquired sufficient programming skills, and is due by the end of Semesterprüfung week.

Lecture notes

See http://jupiter.ethz.ch/~pj/FORTRAN/FortranProject.html

651-1392-00L Palaeontological Colloquium (University of Zürich)

Abstract

Talks and discussion on current topics in Palaeontology (Palaeobotany, Palaeozoology and Micropalaeontology).

651-4101-00L Physics of Glaciers

Abstract

Understanding glaciers and ice sheets with simple physical concepts. Topics include the reaction of glaciers to the climate, flow of glacier ice, temperature in glaciers and ice sheets, glacier hydrology, glacier seismology, basal motion and calving glaciers. A special focus is the current development of the ice sheets of Greenland and Antarctica.
Objective
After the course the students are able understand and interpret measurements of ice flow, subglacial water pressure and ice temperature. They will have an understanding of glaciology-related physical concepts sufficient to understand most of the contemporary literature on the topic. The students will be well equipped to work on glacier-related problems by numerical modeling, remote sensing, and field work.

Content
The dynamics of glaciers and polar ice sheets is the key requisite to understand their history and their future evolution. We will take a closer look at ice deformation, basal motion, heat flow and glacier hydraulics. The specific dynamics of tide water and calving glaciers is investigated, as is the reaction of glaciers to changes in mass balance (and therefore climate).

Lecture notes
Will be provided on Moodle

Literature
A list of relevant literature is available on Moodle

Prerequisites / notice
High-school mathematics and physics knowledge required.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered

651-0254-00L Seminar Geochemistry and Petrology
E- 0 credits 2S O. Bachmann, M. Schönbächler, C. Chelle-Michou, M. W. Schmidt, D. Vance

Abstract
Seminar series with external and occasional internal speakers addressing current research topics. Changing programs announced via D-ERDW homepage (Veranstaltungskalender)

Objective
Presentations on isotope geochemistry, cosmochemistry, fluid processes, economic geology, petrology, mineralogy and experimental studies. Mostly international speakers provide students, department members and interested guests with insight into current research topics in these fields.

Content
Wöchentliches Seminar mit Fachvorträgen eingeladener oder interner Wissenschafter, vornehmlich zu Themen der Geochemie, Isotopengeochemie, Hydrothermalgeochemie, Lagerstättenbildung, Petrologie, Mineralogie und experimentelle Studien.

651-1692-00L Seminar in Applied and Environmental Geophysics
E- 0 credits 1S H. Maurer, J. Robertsson

101-0317-00L Tunnelling I
W 3 credits 2G G. Anagnostou, A. Nordas, E. Pimentel

Abstract
Basic aspects of design and analysis of underground structures. Conventional tunnel construction methods. Auxiliary measures (ground improvement and drainage, forepoling, face reinforcement). Numerical analysis methods.

Objective
Basic aspects of design and analysis of underground structures. Conventional tunnel construction methods. Auxiliary measures (ground improvement and drainage, forepoling, face reinforcement), Numerical analysis methods.

Content
Numerical analysis methods in tunnelling. Conventional excavation methods (full face, top heading and bench, side drift method, ...)

Auxiliary measures:
- Injections
- Jet grouting
- Ground freezing
- Drainage
- Forepoling
- Face reinforcement

Literature
Autographieblätter

Prerequisites / notice
This course will continue to be offered in German up to and including HS24.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed

651-1091-00L Colloquium Department Earth and Planetary Sciences
E- Dr 0 credits 1K Speakers

Abstract
Invited speakers from the entire range of Earth Sciences.

Objective
Selected themes in sedimentology, tectonics, paläontology, geophysics, geochemistry, mineralogy, paleoclimate and engineering geology on a regional and global scale.

Content
According to variable program.

Lecture notes
No

Literature
No

651-2613-00L Human Geography III (Geographies of Difference) (Universität Zürich)
W 5 credits 1G+2S University lecturers

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: GEO232

Recommended prerequisite: Human Geography II (UZH Module Code: GEO122)

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html
This course enables students to think through and about difference geographically: multi-scalar, critically, spatially. Students learn to understand selected theoretical perspectives in human geography.

Focusing on a chosen thematic area of human geography, they train using these perspectives to interpret empirical phenomena and raise questions about them.

### Objective

- To understand selected theoretical perspectives in human geography that problematize questions of difference; — To use these theoretical perspectives to interpret empirical phenomena of social difference and inequality and raise questions about them.
- To deepen knowledge on empirical phenomena of social difference in one specific topic of human geography.
- To write a seminar paper, using theoretical and empirical material.

### Content

Following an introductory lecture, students will split into four smaller seminar groups, focused on different thematic areas from urban, political and economic geography. Seminars will be based on a close reading of selected material and designed for interactive participation and discussion.

Each seminar consists of theory-oriented sessions, where students will gather first insights into selected theoretical perspectives of human geography; Using these perspectives, students develop their knowledge of each seminar group’s thematic area of focus and practice applying theory to empirical fields of research.

After the introductory lecture in week 1, students must enroll in one of four seminar groups via OLAT. Attendance of the introductory lecture is a prerequisite for participation in the first group session.

#### Prerequisites / notice

None.

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**651-2601-00L**  
**Human Geography I: One Earth - Many Worlds**  
*(University of Zurich)*

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**Abstract**

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: GEO112

Mind the enrolment deadlines at UZH:


**Objective**

You will learn the basics of physical geography and apply some of these exercises to the lectures.

- You know the basics of scientific work in human geography and can apply them in a small project.
- You acquire the physical-geographical background of current problems (climate change, erosion,...).
- You know the basics of physical geography and can use its definitions and technical terms correctly.
- In practical exercises they apply the principles of scientific work (analysis, interpretation, written summary).

**Literature**


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**651-4088-03L**  
**Physical Geography III (Geomorphology and Glaciology) (University of Zürich)**

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**Abstract**

Das Modul bietet eine kurze Einführung in einige Komponenten und Prozesse des hydrologischen Kreislaufes. Dabei werden einzelne Wasserspeicher (Schnee-, Boden und Grundwasser) und Flüsse zwischen den Speichern (Verdunstung, Niederschlag und Abfluss) betrachtet. Übungen ergänzen die Vorlesung.

**Literature**


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**651-4088-01L**  
**Physical Geography I (Basics and Spheres) (University of Zürich)**

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**Abstract**

Basics of scientific concepts and global relationships regarding the atmosphere, lithosphere, cryosphere, hydrosphere, pedosphere and biosphere.

**Objective**

- You will learn the basics of physical geography and apply some of these exercises to the lectures.
- You know the basics of physical geography and can use its definitions and technical terms correctly.
- You acquire the physical-geographical background of current problems (climate change, erosion,...).
- In practical exercises they apply the principles of scientific work (analysis, interpretation, written summary).

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**651-1617-00L**  
**Geophysical Fluid Dynamics and Numerical Modelling**

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**Seminar**

**651-4931-00L**  
**Seminar I: Heat and Mass Transfers in Magmatology**

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**Abstract**

Heat and mass transfers from the mantle to the crust control many aspects of the differentiation of our planet, including (1) primitive melt chemistry, (2) layering of the crust, (3) type of volcanic eruption, (4) formation of mineral deposits. This year, we will focus on processes in crystal mushes (formation, crystallization, remobilization, degassing).

**Objective**

This class will allow the students to learn about the modern methods and ideas on heat and mass transfers in magmatology through classic and recently published papers. Communication of scientific results to the scientific community and the public is critical. In the class, the students will read and analyse scientific papers and discuss them orally to the class. The students will also create a Wikipedia page and reformulate scientific results for the public.

**Content**

The class will focus mostly on 1) reading literature on topics of interests, 2) oral and written presentations of the papers, 3) exercises illustrating the topic, to allow students to work by themselves on some well-defined problems.

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**651-1091-02L**  
**Geological Colloquium**

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**Abstract**

Invited speakers from the entire range of Earth Sciences.
This blended learning course will provide an overview of cosmogenic and anthropogenic radionuclides, powerful tools for understanding environmental processes and global scale.

Abstract

With the registration for an excursion or a field course students acknowledge having read and understood the General Terms and Conditions for Field Trips and Excursions https://www.ethz.ch/content/dam/ethz/special-interest/erdw/department/dokumente/studium/exkursionen/AGB_ERDW_Exkursionen_en.pdf

Objective

Students deepen their knowledge in a specific topic. They familiarize with research procedures and scientific methods that are used in current research. They gain experience in writing scientific reports/papers.

Content

The content of the project consists of research activity aimed at producing new scientific results and/or data. It does not reduce to literature review.

Prerequisites / notice

Only for excursions outside of the Bachelor excursions 2.-6. semester program. The program varies from year to year, details published on https://www.conference.ethz.ch/erdw/

Competencies

Method-specific Competencies

Personal Competencies

Analytical Competencies

Creative Thinking

Critical Thinking

fostered

fostered

fostered

Advanced Earth Science Excursions for students with a special interest in Earth Science field studies.

Objective

Geological principles and observations in the field

Prerequisites / notice

Only for MSc and doctorate students of D-ERDW. Only for excursions that are not part of the BSc excursion program 2.-6. semester.

Abstract

This blended learning course will provide an overview of cosmogenic and anthropogenic radionuclides, powerful tools for understanding environmental processes and global scale.

Objective

Students will be able to explain the properties and characteristics of different types of radionuclides. They will describe how these radionuclides are utilized as environmental tracers through real-life case studies, covering topics such as understanding past climate changes, ocean currents, and other environmental processes.

Content

This blended learning course will provide students with a multi-dimensional learning experience by combining elements of self-study, in-class discussions and activities, lectures, and an excursion to visit the AMS facilities of ETH Zurich's Laboratory of Ion Beam Physics. Throughout the course, students will gain knowledge and understanding of natural and artificial radionuclides and their detection with AMS technology. Using case studies, they will explore the applications of long-lived radionuclides in various environmental compartments, including oceans, atmosphere, and terrestrial environments.

Prerequisites / notice

This course...

... is a blended learning course.

... contains active learning elements.

... will benefit from students coming from different fields.

... is well suited for doctoral students.


Competencies

Subject-specific Competencies

Concepts and Theories

fostered

Techniques and Technologies

fostered

Media and Digital Technologies

fostered

Problem-solving

fostered

Project Management

fostered

Cooperation and Teamwork

fostered

Radiocarbon Dating

Please contact the lecturer for details immediately after subscription.

Abstract

Radiocarbon (14C) dating is the most eminent dating tool for carbon containing samples younger than ~50 kyr and a useful tracer of the carbon cycle. Within this lab course, the sample preparation and 14C analysis of wood samples (or upon agreement other samples) will be performed.
Fracture Mechanics

Griffith’s criterion: stress concentrators, singularities, crack in uniform tension.

S. P. Quanz

Sampling of tree ring layers.
Preparation of reference materials and samples for AMS measurement, including chemical pre-treatment and graphitisation.
Assisting the AMS measurement.
Data evaluation and interpretation of results.

This is a block course for D-ERDW or D-USYS master or PhD students.

Recommended (but not a prerequisite 651-4191-00L Radionuclides as Environmental Tracers (in Autumn Semester)
OR 651-4901-00L Quaternary Dating Methods (in Autumn Semester)

651-4145-00L Seminar on Precambrian Geobiology and Biogeochmical Cycles

Abstract
The Precambrian Earth experienced several environmental states—all drastically different from today—that are recorded in sedimentological, fossil, and genetic records. We will review “classic” and more recent scientific literature on the evolution of chemical and biological processes to critically evaluate what we do and don’t know about how our planet’s biogeochemistry has changed through time.

Objective
For decades, researchers have attempted to reconstruct Precambrian environmental states and their relative timing using tracers recorded in the sedimentological, fossil, and genetic records. Here, by reading and discussing “classic” and more recently published scientific papers, students will learn about influential discoveries related to Earth history within the fields of geobiology and geochemistry.

In completing the course, students will specifically learn:
* Why Earth’s surface chemical composition evolved from anoxic to oxic environments
* How life evolved from simple prokaryotic metabolisms to multicellular eukaryotes
* The importance of geological, chemical, and biological feedback mechanisms
* How to discern between biologic innovation and environmental importance
* How to summarize, interpret, and discuss current evidence for what is and isn’t known about Earth’s biogeochemical evolution
* How to assess opposing scientific viewpoints and outstanding questions in the literature

Content
Each lecture period will consist of a presentation and discussion—to be led by 1-2 students (depending on class size)—covering a given paper or set of papers. All students are expected to read the relevant papers before class and come prepared for discussion. Lecture periods will be divided between “review” presentations aimed at introducing the background and fundamentals of each topic and “debate” or “comparison”-style presentations, in which two (sometimes opposing) views of a given topic will be discussed and assessed.

Lecture notes
Where available, presentations and notes will be provided online during the course.

Literature
All required and recommended scientific publications will be provided online during the course.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Social Competencies
- Communication
- Critical Thinking

Personal Competencies
- Creative Thinking
- Critical Thinking

651-4147-00L Fracture Mechanics

Abstract
The course provides an introduction to the concepts of fracture mechanics and its application to the Earth’s crust. Theoretical concepts, practical applications, and computational methods are covered. The course has a particular focus on solid Earth applications.

Objective
To acquire the theoretical background of fracture mechanics and to be able to apply them to the solution of relevant problems in geosciences.

Content
2. Elastodynamics: Hooke’s law, Navier–Cauchy equations.
5. Additional: dynamic (inertial) effects, fracture and breakdown energy, coupling between elastodynamics and shear heating, computational methods in fracture mechanics

Prerequisites / notice
Lecture notes and relevant reading materials will be provided. Students are encouraged to take their own notes.

651-2002-00L Semester Research Project (large)

Abstract
Small individual research project supervised by a lecturer of D-ERDW that builds on the skills acquired during the BSc or MSc studies. The project consists of research activity in a selected scientific topic aimed at producing new scientific results and/or data.

Objective
Students deepen their knowledge in a specific topic. They familiarize with research procedures and scientific methods that are used in current research. They gain experience in writing scientific reports/papers.

Content
The content of the project consists of research activity aimed at producing new scientific results and/or data. It does not reduce to literature work.

Prerequisites / notice
The project must be approved in advance by the study advisor.

The semester research project is determined by student and supervisor. The topic of each project is unique and not related to the BSc or MSc Thesis.

Only one project (small or large) is allowed per study degree.

402-0368-07L Lecture Series: Space Research and Exploration

Abstract
Lecture Series about selected topics of space research and exploration consisting of individual talks given by different leading experts from academia and industry.

Objective
Attending students will
- experience the interdisciplinarity of space research and exploration spanning physics, engineering, geosciences, biology and more
- get familiar with the Swiss space research and industry landscape
- enhance their communication skills by broadening their research horizon
- have the opportunity for direct learning by posing questions to experts
Geomicrobiology and Biogeochemistry Field Course (651-4044-02L). The attendance of "Micropalaeontology and Molecular Palaeontology" (651-4044-04L) or "The Global Carbon Cycle - Reduced" (651-4004-00L) is recommended but not mandatory.

Abstract
1. Analysis of organic molecules in extracts from soils of different ages in glacial flood fields, in altitudinal gradients from different bedrocks, from sediments, from Cryoconites in glacial ice and from living biofilms in high altitude aquatic ecosystems, and from mineral springs.
2. Analysis of matrix components of the ecosystems: dissolved compounds, minerals, clays, trace metals.

Objective
- design strategies for collecting samples in the field suitable for subsequent analyses in the laboratory
- critically evaluate his/her own analytical data and put it into a scientific context.

Content
1. Preparing field work based on research hypotheses.
2. Designing field sampling strategies, proper sampling collection and preservation.
3. Documenting environmental conditions and observations at the sampling sites.
4. Extracting organic molecules from environmental samples with different matrices.
5. Working under clean conditions and handling samples without contaminating them.
6. Discussing the results and documenting the outcomes in a scientific report.

Procedures for sampling, sample preparation and processing (extraction, analyses) will be defined on the first day of the field course.

Lecture notes
Procedures for sampling, extraction and analyses will be designed on a special preparation day during the field trips and later in the course of the lab sessions.

Literature
Field guides and details about the course logistics will become available to enrolled students on OLAT via Details under Prerequisites / notice.

The attendance of "Micropalaeontology and Molecular Palaeontology" (651-4044-04L) or "The Global Carbon Cycle - Reduced" (651-4004-00L) is recommended but not mandatory.

Abstract
The laboratory module (651-4044-01L) takes place as a small research project during the fall semester. Samples collected in the field will be analysed under guidance in the labs of the Biogeosciences Group. The timing of the lab work will be individually adjusted based on the availability of assistants and analytical resources.

Prerequisites / notice
Students who sign up for both, the field and the lab component, are given priority. There are 10 places available for the project section. The section requires participation on the field trips. It is possible, however, to participate in the field section only without signing up for the project section.

At the end of the project section, participants write a report in the style of a scientific paper that contains descriptions of the sampling location, the sample collection and preservation strategies and protocols, description of the analytical methods, the data obtained from analyses of the measured samples and a discussion of the results.

Prerequisites: "Geomicrobiology and Biogeochemistry Field Course" (651-4044-02L). The lecture course "651-4004-00L The Carbon Cycle - reduced" is recommended for the project.

Planetary Crusts: Composition, Origin and Evolution (651-4292-00L)

Objective
Primary objectives are to provide students with:
1. general understanding of comparative planetology using the diverse nature of planetary crusts as an example;
2. detailed understanding of the extreme diversity of planetary crustal evolution within our solar system and the causes of that diversity;
3. the ability to critically assess how the nature of planetary crusts within our solar system may inform any evaluation of the nature and significance of extrasolar planets.

Prior clarification with the study advisor of the chosen specialization/major is mandatory for taking this internship.

The vorgängige Abklärung mit dem/f der Fachberater/in der gewählten Vertiefungsrichtung/Major ist zwingend für eine Belegung dieses Berufspraktikums.

Planetary Crusts: Composition, Origin and Evolution (651-4292-00L)

Objective
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1. general understanding of comparative planetology using the diverse nature of planetary crusts as an example;
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Prior clarification with the study advisor of the chosen specialization/major is mandatory for taking this internship.

The vorgängige Abklärung mit dem/f der Fachberater/in der gewählten Vertiefungsrichtung/Major ist zwingend für eine Belegung dieses Berufspraktikums.
The course consists of 9 sections, each constituting one 2-hour class:

1. Introduction and overview
2. Formation and differentiation of terrestrial planets
3. Primary Crusts: Required but rarely observed
4. Secondary Crusts: The ubiquitous but diverse planetary crust
5. Tertiary Crusts: Is Earth's continental crust the only example?
6. Icy Crusts: Just special cases?
7. Crustal evolution: As diverse as the crusts themselves
8. Looking for unifying themes: Are there more variables than planetary bodies?
9. Exoplanets: Lessons from (or for?) our solar system

The course will be organised in the form of 9x2 hour lectures. The course will be either pass or fail based on performance in take-home exercises, written assignments and in-class participation.

Prerequisites / notice

The course contains at least one presentation from practice.

Competencies

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies

- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management

- Social Competencies
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
  - Negotiation

- Personal Competencies
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management
  

The introductory lecture on conduct as a scientist is an integral part of the course.

Abstract

The main purpose of the Master Project Proposal is to help students organize ideas, material and objectives for their Master Thesis, and to begin development of communication skills.

Objective

The main objectives of the Master Project Proposal are to demonstrate the following abilities:
- to formulate a scientific question
- to present scientific approach to solve the problem
- to interpret, discuss and communicate scientific results in written form
- to gain experience in writing a scientific proposal
### Master's Thesis

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<tr>
<td>651-4062-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
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</table>

**Abstract**

Only students who fulfill the following criteria are allowed to begin with their master thesis:

- successful completion of the bachelor programme;
- fulfilling of any additional requirements necessary to gain admission to the master programme;
- have successfully completed the MSc Project Proposal

**Objective**

Students are to prove their skills in working autonomously on a scientific project.

### Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
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<tr>
<td>651-3400-AAL</td>
<td>Fundamentals of Geochemistry</td>
<td>E-</td>
<td>6 credits</td>
<td>13R</td>
<td>C. Liebske, P. A. Sossi</td>
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<tr>
<td>406-0243-AAL</td>
<td>Analysis I and II</td>
<td>E-</td>
<td>14 credits</td>
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<td>M. Akveld</td>
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<tr>
<td>406-0062-AAL</td>
<td>Physics I</td>
<td>E-</td>
<td>5 credits</td>
<td>11R</td>
<td>A. Vaterlaus</td>
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<td>651-3521-AAL</td>
<td>Tectonics</td>
<td>E-</td>
<td>3 credits</td>
<td>6R</td>
<td>T. Gerya, W. Behr</td>
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</table>

**Abstract**

Self-study course. This course is only available for those who got it as an additional requirement in their MSc admission.

**Objective**

Mathematics as a tool to solve engineering problems. Mathematical formulation of technical and scientific problems.

**Content**

- Textbooks in English:

- Textbooks in German:
  - M. Akveld, R. Sperb: Analysis I, vdf
  - M. Akveld, R. Sperb: Analysis II, vdf
  - L. Papula: Mathematik für Ingenieure und Naturwissenschaftler, Vieweg Verlag
  - L. Papula: Mathematik für Ingenieure 2, Vieweg Verlag

**Competencies**

- Subject-specific Competencies: Concepts and Theories assessed, Techniques and Technologies fostered
- Method-specific Competencies: Analytical Competencies fostered, Problem-solving assessed
- Personal Competencies: Self-direction and Self-management fostered
### Enrolment Only

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

### Abstract

- **Comprehensive understanding of role and evolution of oceanic and continental lithosphere in global plate tectonics and evolution of earth.**
- **Understanding principles of theoretical and experimental geothermics and fundamentals of mantle and lithosphere rheologies.**

### Objective

- **Comprehensive understanding of role and evolution of oceanic and continental lithosphere in global plate tectonics and evolution of earth.**
- **Understanding principles of theoretical and experimental geothermics and fundamentals of mantle and lithosphere rheologies.**

### Content


### Lecture Notes

Detailed scriptum in digital form and additional learning modules (www.lead.ethz.ch) available on intranet.

### Literature

see list in scriptum.

### Prerequisites / Notice

PPT-files of each lecture may be played back for rehearsal on www.lead.ethz.ch.

<table>
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<th>Course Code</th>
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<td>529-2001-AAL</td>
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<td>E- 9 credits</td>
<td>19R</td>
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<tr>
<td>406-0603-AAL</td>
<td>Stochastics (Probability and Statistics)</td>
<td>E- 4 credits</td>
<td>9R</td>
<td>M. Kalisch</td>
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</table>

### Competencies

- **Subject-specific Competencies**: Concepts and Theories, Techniques and Technologies
- **Method-specific Competencies**: Analytical Competencies, Decision-making
- **Personal Competencies**: Adaptability and Flexibility, Critical Thinking

### Autumn Semester 2024
The course is an admission requirement given to students lacking fundamentals in geophysics related to the structure and evolution of the Earth.

For English speakers study chapters 1-3 of Part I of the book “Geological Engineering” (Gonzalez de Vallejo & Ferrer 2011, CRC Press), without groundwater flow, consolidation time, geophysical methods, details of triaxial tests in soils and rocks, details of clay mineralogy.

Understanding the basic geotechnical and geomechanical properties and processes of rocks and soils. Understanding the interaction of rock and soil masses with technical systems. Understanding the fundamentals of geological hazards.

Literature
- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
From within the ETH, this book is freely available online under: http://onlinelibrary.wiley.com/book/10.1002/0471477435

From within the ETH, this book is freely available online under: http://www.springerlink.com/content/m17578/

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
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<tr>
<td>Techniques and Technologies</td>
<td>Media and Digital Technologies</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
</tr>
</tbody>
</table>

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
This introductory course starts from a descriptions of the behavior and phenomena of soils and rocks under near surface loading conditions and their key geotechnical properties. Lab and field methods for the characterization of soils, rocks and rock masses are introduced. Finally practical aspects of ground engineering, including tunneling and landslide hazards are presented.

Objective
Understanding the basic geotechnical and geomechanical properties and processes of rocks and soils. Understanding the interaction of rock and soil masses with technical systems. Understanding the fundamentals of geological hazards.

Content

Lecture notes
Lecture Material as defined in German PPT Slides of the German Course “651-3525-00L Ingenieurgeologie”.
Moodle Course Materials available.

Literature
For English speakers study chapters 1-3 of Part I of the book “Geological Engineering” (Gonzalez de Vallejo & Ferrer 2011, CRC Press), without groundwater flow, consolidation time, geophysical methods, details of triaxial tests in soils and rocks, details of clay mineralogy.

Prerequisites / notice
Participate on all exercises of “651-3525-00L Ingenieurgeologie”, Tuesday 13-14 pm.
Participate in Written Exam together with students of the German Course.

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
The course is self taught and covers the following topics of fundamentals in geophysics:
- Seismology
- Tomography
- Gravimetry
- Geodesy
- Paleomagnetism

Objective
The course is an admission requirement given to students lacking fundamentals in geophysics related to the structure and evolution of the planet Earth. It will allow the student to acquire the necessary knowledge to pursue a Master in Geophysics, the student will learn the basics of seismology, tomography, gravimetry, geodesy and paleomagnetism and how these can be used to constrain the structure and evolution of the Earth.

Content
The course is based on the book “Fundamentals in Geophysics” 3rd edition by W. Lowrie available online from the ETH library. The list of chapters to read will be determined in an initial individual meeting with the student.

Prerequisites / notice
Enrollment ONLY for MSc students with an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.
Abstract
The course is self taught and covers the following topics of fundamentals in geophysics:
- Mantle dynamics
- Plate tectonics
- Core dynamics
- Earth's magnetic field
- Earth's rotation

Objective
The course is an admission requirement given to students lacking fundamentals in geophysics related to the structure and evolution of the planet Earth. It will allow the student to acquire the necessary knowledge to pursue a Master in Geophysics, the student will learn the basics of seismology, tomography, gravimetry, geodesy and paleomagnetism and how these can be used to constrain the structure and evolution of the Earth.

Content
The course is based on the book “Fundamentals in Geophysics” 3rd edition by W. Lowrie available online from the ETH library and from the Treatise of geophysics available online. The list of chapters to read will be determined in an initial individual meeting with the student.

Prerequisites / notice
Enrollment ONLY for MSc students with an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enroll for this course unit.
Fundamentals of Geology II: Surface of the Earth

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

The surface of the Planet Earth, main processes and formation of Sedimentary rocks in various environments. Time in Geology, stratigraphy and fossils, relative and absolute ages. Surface processes, water in the surface and subsurface, ice and glaciers, Climate systems, Carbon cycle. Impact of human activities, anthropogenic climate change. Geobiology and early history of Planet Earth.
Objective

Understanding the processes and environments of Planet Earth. The peculiar way of reading the fossil record in Geology: understanding stratigraphy and time in the frame of the actual sedimentary environments. Mineral/life interactions and the impact of anthropic activities.

CH 6 SEDIMENTATION: ROCKS FORMED BY SURFACE PROCESSES
Surface Processes of the Rock Cycle
Sedimentary Basins: The Sinks for Sediments
Sedimentary Environments
Sedimentary Structures
Burial and Diagenesis: From Sediment to Rock
Classification of Siliciclastic Sediments and Sedimentary Rocks
Classification of Chemical and Biological Sediments and Sedimentary Rocks

CH 12 THE CLIMATE SYSTEM
What Is Climate?
Components of the Climate System
The Greenhouse Effect
Climate Variation
The Carbon Cycle

CH 13 CIVILIZATION AS A GLOBAL GEOSYSTEM
Growth and Impact of Civilization
Fossil-Fuel Resources
Alternative Energy Resources
Our Energy Future

CH 14 ANTHROPOGENIC GLOBAL CHANGE
Rise of Carbon Dioxide in the Atmosphere: The Keeling Curve
Types of Anthropogenetic Global Change: Chemical, Physical, and Biological
Climate Change
Ocean Acidification
Loss of Biodiversity
Managing the Carbon Crisis

CH 15 GLACIERS: THE WORK OF ICE
Types of Glaciers
How Glaciers Form
How Glaciers Move
Isostasy and Sea Level Change
Glacial Landscapes
Glacial Cycles and Climate Change

CH 16 EARTH SURFACE PROCESSES AND LANDSCAPE DEVELOPMENT
Controls on Weathering
Chemical Weathering
Physical Weathering
Soils: The Residue of Weathering
Erosion and Formation of Stream Valleys
Mass Wasting
Classification of Mass Movements
Geomorphology and Landscape Development

CH 17 THE HYDROLOGIC CYCLE AND GROUNDWATER
The Geologic Cycling of Water
Hydrology and Climate
The Hydrology of Groundwater
Erosion by Groundwater
Water Quality
Water Deep in the Crust

CH 18 STREAM TRANSPORT: FROM MOUNTAINS TO OCEANS
The Form of Streams
Where Do Channels Begin? How Running Water Erodes Soil and Rock
How Currents Flow and Transport Sediment
Deltas: The Mouths of Rivers
Streams as Geosystems

CH 19 COASTLINES AND DESERTS
Coastal Processes
The Shaping of Shorelines
Hurricanes and Coastal Storm Surges
Desert Processes
Windblown Sand and Dust
The Desert Environment
Tectonic, Climatic, and Human Controls on Deserts

CH 20 EARLY HISTORY OF THE TERRESTRIAL PLANETS
Origin of the Solar System
Early Earth: Formation of a Layered Planet
Diversity of the Planets
What’s in a Face? The Age and Complexion of Planetary Surfaces
Mars Rocks!
Exploring the Solar System and Beyond

CH 22 GEOBIOLOGY: LIFE INTERACTS WITH EARTH
The Biosphere as a System
Microorganisms: Nature’s Tiny Chemists
Geobiological Events in Earth’s History
Evolutionary Radiations and Mass Extinctions
Astrobiology: The Search for Extraterrestrial Life
Fundamentals of Geochemistry I: Chemistry of the Earth and the Solar System

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Fundamentals of Geochemistry I is designed as self-study course for new MSc students who have gaps in geochemical education. The topics of this course are related to the chemistry of the Earth and the Solar System.

Objective

Understanding of the fundamental concepts related to the chemistry of the Earth and the Solar System. Study material and specific content is provided as a Moodle course.

Content

1) Chemistry of the Earth
   - structure of the Earth and chemical characteristics of its main units: crust, mantle, core
   - the silicate Earth: oceanic and continental crust, and major rock-forming minerals of crust and mantle
   - seismic discontinuities and mineral phase transitions

2) Chemistry of the Solar System
   - classification of the elements: atmophile, lithophile, chalcophile, siderophile; volatile, refractory
   - relation between composition of the solar photosphere and CI chondrites
   - relation between CI and other chondrites and Earth

Prerequisites / notice

Enrolment ONLY for MSc students with an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enroll for this course unit.

Fundamentals of Geochemistry II: Geochemical Systematics of the Earth’s Interior

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Fundamentals of Geochemistry II is designed as self-study course for new MSc students who have gaps in geochemical education. Topics are related to generation of magmas and their chemical and isotopic signatures.

Objective

Understanding of the fundamental concepts related to the generation of magmas and their chemical and isotopic signatures. Study material and specific content is provided as a Moodle course.

Content

Generation of magmas and their chemical and isotopic signatures:
   - partial melting and differentiation of magmas, element compatibility and the significance of trace elements
   - divergent plate boundaries, decompression melting and mid ocean ridge basalts
   - convergent plate boundaries, subduction and dehydration melting
   - intraplate volcanism, ocean island basalts
   - basics of isotope geochemistry, parent-daughter relations, e.g. Sm-Nd, W-Hf as example
   - geochemical mantle reservoirs and signatures of recycled crust

Prerequisites / notice

Enrolment ONLY for MSc students with an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enroll for this course unit.

Earth Sciences Master - Key for Type

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Key for Hours

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<td>exercise</td>
<td>seminar</td>
<td>colloquium</td>
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<td>independent project</td>
<td>diploma thesis</td>
<td>revision course / private study</td>
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ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Courses Offered

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<td>871-0240-00L</td>
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<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern, M. Rau</td>
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</tbody>
</table>

**Abstract**

This course looks into scientific theories and also empirical studies on human learning and relates them to the school.

**Objective**

Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the ways humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

**Content**

Thematic Schwerpunkte:
- Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen

Lernformen:

**Lecture notes**

Folien werden zur Verfügung gestellt.

**Literature**


**Prerequisites / notice**

This lecture is only apt for students who intend to enrol in the programs "Lehrdiplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.

**871-0238-01L**

Support and Diagnosis of Knowledge Acquisition Processes (EW3)

Enrolment only possible with matriculation in Teaching Diploma (except for students of Sport Teaching Diploma, who complete the sport-specific course unit EW3) and for students who intend to enrol in the "Teaching Diploma".

**Prerequisites:** successful participation in 871-0240-00L "Human Learning (EW1)".

**Abstract**

In this seminar students learn advanced techniques to support and to diagnose knowledge acquisition processes in school.

**Objective**

The main goals are:
- (1) You have a deep understanding about the cognitive mechanisms of knowledge acquisition.
- (2) You have a basic understanding about psychological test theory and can appropriately administer tests.
- (3) You know various techniques of formative assessment and can apply these to uncover students' misconceptions.

**Competencies**

Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed

Decision-making fostered

Media and Digital Technologies fostered

Problem-solving fostered

Social Competencies

Communication fostered

Cooperation and Teamwork fostered

Leadership and Responsibility fostered

Sensitivity to Diversity fostered

Personal Competencies

Creative Thinking fostered

Critical Thinking fostered

**Mathematics Education Master - Key for Type**

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**Key for Hours**

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<tr>
<td>K</td>
<td>colloquium</td>
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</table>

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
In this seminar students learn advanced techniques to support and to diagnose knowledge acquisition processes in school.

Hours
Teaching materials are available online on Moodle.

ECTS

Subject-specific Competencies fostered
Analytical Competencies
C. M. Thurn

4 credits
Communication
This course looks into scientific theories and also empirical
Selected biological topics, with a special focus on evolution, are dealt with under consideration of the special needs of persons involved in

Lecturers
Thematische Schwerpunkte:
- Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der
Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des
Wissens transferts; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle
Unterschiede in der Lernfähig und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen

Abstract
Theorien und wissenschaftliche Konstrukte werden zusammen mit ausgewählten wissenschaftlichen Untersuchungen in Form einer
Vorlesung präsentiert. Die Studierenden vertiefen nach jeder Stunde die Inhalte durch die Bearbeitung von Aufträgen in einem
elektronischen Lerntagebuch. Über die Bedeutung des Gelernten für den Schulalltag soll reflektiert werden. Ausgewählte
Tagebucheinträge werden zu Beginn jeder Vorlesung thematisiert.

Lecture notes
Foliow werden zur Verfügung gestellt.

Literature

Prerequisites / notice
This lecture is only apt for students who intend to enrol in the programs "Lehrdiplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.

Support and Diagnosis of Knowledge Acquisition Processes (EW3) 
Enrolment only possible with matriculation in Teaching Diploma, who complete the sport-specific course unit EW3) and for students who intend to enrol in the "Teaching Diploma".

Prerequisites: successful participation in 871-0240-00L
"Human Learning (EW1)"

Abstract
In this seminar students learn advanced techniques to support and to diagnose knowledge acquisition processes in school.

Objective
The main goals are:
(1) You have a deep understanding about the cognitive mechanisms of knowledge acquisition.
(2) You have a basic understanding about psychological test theory and can appropriately administer tests.
(3) You know various techniques of formative assessment and can apply these to uncover students’ misconceptions.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Sensitivity to Diversity

Personal Competencies
- Creative Thinking
- Critical Thinking

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Subject Didactics

<table>
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<td>Professional Exercises in Biology</td>
<td>W</td>
<td>2</td>
<td>2U</td>
<td>P. Faller</td>
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<tr>
<td>Abstract</td>
<td>Students conduct a series of &quot;classical&quot; biological school experiments and therefore gain practice and experience in this area.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Implementation of Subject Didactics I and II with the focus on conducting biological experiments in schools. This includes finding, testing and further developing suitable protocols for different subject areas of school biology. Working out how to didactically embed the experiments in lessons. Students can perform, off the cuff, 12 school experiments (which they have tested themselves), from the different subject areas, and conduct these correctly in technical terms. They can incorporate these experiments in their tuition in a didactically meaningful manner.</td>
<td></td>
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<tr>
<td>Lecture notes</td>
<td>Der Teil biologische Experimente findet im Rahmen von 7 Halbtagen statt.</td>
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</table>

<table>
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<td>3G</td>
<td>P. Faller</td>
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<tr>
<td>Abstract</td>
<td>- Basic conditions for tuition (MAR - recognition of Matura certificates - curricula, standards), selection of topics and reduction of the complexity of topics. - Application of teaching methods and techniques from educational science in biology classes. - Planning and preparation of lessons. - Assessing learning performance (forms of examination/assessment).</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Objective</td>
<td>- Students can discuss and put into practice in their teaching work the conditions and objectives set out in the regulations governing the school-leaving examination (Matura), the framework curriculum and the conditions and objectives specified by their school. - They are in a position to select learning objectives and formulate these on the basis of the target level model. They can plan and prepare lessons and can also develop appropriate learning assignments. - Students can reconstruct specialist contents in didactic terms and develop teaching modules suitable for the different levels from these on the basis of the subject structure and learner requirements. - They can reduce the complexity of subject-based specialist contents and present them in such a way that they are comprehensible and meaningful for learners. - They can select appropriate media for their work (e.g. school books) and use these. They can employ appropriate experiments. - The students can use different forms of examination for monitoring performance. - Students are in a position to implement and discuss the concepts of biology teaching and learning on the basis of specific topics covered in school biology.</td>
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<tr>
<td>Lecture notes</td>
<td>Wird laufend in der Vorlesung abgegeben.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Studierende müssen LE zusammen mit dem Einführungspraktikum - LE 551-0968-00L - belegen.</td>
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<tr>
<td>402-0091-00L</td>
<td>Teaching Science in Higher Education</td>
<td>W</td>
<td>3</td>
<td>1V</td>
<td>G. Schiltz</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course imparts fundamental didactic concepts that are relevant to teaching science in a Higher Education context. Students are able to characterize and to discuss the model of outcomes based education. Students are able to transfer the basic concepts of this model (ILO, TLA, assessment, constructive alignment) to science education.</td>
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(Please the Buch in der 5. Auflage von 2022 vor dem ersten Treffen erwerben!)
### Chemical Direction

#### Specialised Courses

#### Introductory Courses

#### Spec. Courses in Respective Subject with Educational Focus

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
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<tbody>
<tr>
<td>529-0962-00L</td>
<td>Fundamental Aspects of Chemistry with an Educational Focus I</td>
<td>W</td>
<td>4 credits</td>
<td>2V</td>
<td>C. Thilgen, R. Grass, A. Togni</td>
</tr>
</tbody>
</table>

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module CHE406 at UZH. Examination Registration only at ETH.

Please mind the ETH enrolment deadlines for UZH students: https://ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

Abstract
Selected topics in general chemistry:
1) The language of chemistry
2) Chirality and stereochemistry
3) Chemistry and sustainability.

Objective
In this course, participants acquire extended and more in-depth knowledge of selected chemistry topics. The selection is based to a large extent on the partial aspects of chemistry that are typically taught at high school. By gaining a broader understanding, teachers are put in a position where they can comprehend the topics that are to be taught in a wider and, to some extent, unconventional context and critically process these in respect of their teachability and learnability. At the same time, interrelationships between the classical sub-disciplines of chemistry are highlighted, along with the unique features of chemistry as one of the central natural sciences.

Content
The FV primarily conveys basic subject knowledge. Didactic aspects or even concrete suggestions for the design of grammar school lessons are possible, but not central.

Learning format: Lecture.

Thematic focus of FV I:
The language of chemistry: Concepts, formulas, aesthetics, and philosophical aspects
Stereochemistry: The Coupe du Roi and its chemical meaning, Cyclostereoisomerism, Origin of biomolecular homochirality
Chemistry and sustainability. The link between chemical products and energy consumption, life cycle assessments and chemical energy storage

Lecture notes
Slides and selected literature will be provided.

Literature
Selected articles from the primary literature are presented, commented on and recommended reading.

Prerequisites / notice
FV I (fall semester) and FV II (spring semester) do not build upon each other. The order in which they are taken is therefore indifferent.

#### Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
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<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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#### Subject Didactics

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<th>Lecturers</th>
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<tr>
<td>529-0950-00L</td>
<td>Subject Didactics Chemistry I</td>
<td>W</td>
<td>4 credits</td>
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<td>P. Aschwanden</td>
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</table>

Simultaneous enrolment in Introductory Internship Chemistry - course 529-0966-00L - is compulsory.

Abstract
Implementing findings from research into teaching and learning for chemistry lessons and coverage of subject-specific teaching and learning specialities.

Objective
The students have basic subject didactic knowledge for teaching chemistry at a secondary school. They are able to design lessons that are effective for learning, actively involve students in lessons, explain challenging concepts simply, use experiments for theory and reflect on teaching.
Content

- Auswahl gymnasiumsrelevanter Lerninhalte
- Didaktische Vereinfachung
- Modelle und chemischen Formeln zur Beschreibung von Aufbau und Umwandlung der Substanzen
- Wechselspiel zwischen Beobachtung in der realen Welt und Deutung auf Modell-Ebene
- Skizzen entwerfen und zur Erklärung von Reaktionen nutzen
- Chemie im 8. Schuljahr: Das Teilchenmodell erklärt viele Phänomene im Anfangsunterricht
- Atommodelle und chemische Bindung
- Radioaktivität und Kernspaltung
- Struktur und Eigenschaft
- Auswahl, Konzeption, Durchführung, Einbettung und Auswertung von Demonstrations-Experimenten

Lecture notes

Die Unterrichten sind auf der Plattform http://fdchemie.pbworks.com zugänglich

Literature

- E. Rossa: Chemie-Didaktik, Cornelsen Verlag, 2015
- H.-J. Bader et al: Konkrete Fachdidaktik Chemie, Oldenbourg Verlag, 2002

Prerequisites / notice


Anhand der Diskussion bewährter Beispiele und dem Entwurf eigener Unterrichtsbausteine soll die zukünftige Lehrperson befähigt werden, einen den spezifischen Rahmenbedingungen angepassten Unterricht zu entwickeln, der diesem hohen Qualitätsanspruch genügt.

402-0091-00L  Teaching Science in Higher Education  W  3 credits  1V  G. Schiltz

Abstract

This course imparts fundamental didactic concepts that are relevant to teaching science in a Higher Education context.

Objective

Students are able to characterize and to discuss the model of outcomes based education. Students are able to transfer the basic concepts of this model (ILO, TLA, assessment, constructive alignment) to science education.

Lecture notes

keines

Literature


(Bitte das Buch in der 5. Auflage von 2022 vor dem ersten Treffen erwerben!)
1. Introduction to Energy – what is it all about
2. Energy and making use of it – a short history of energy use and an overview on energy technologies
3. Coal, oil and natural gas – fossil fuels
4. Renewables I: Biomass, Hydropower, and Wind Energy – from traditional use to the modern concepts
5. Renewables II: Geothermal, Tidal power and Solar Technologies – new renewables to lead the change
6. Nuclear power, radioactivity and ultimate storage – the quest for a safe technology
7. Breeding and Nuclear Fusion – can it work at all?
8. Energy Storage – the need to increase capacity and for new technologies
9. Climate Change and Decarbonisation of the Energy Mix – how much time do we have?
11. Energy Systems – how everything can play together
12. Life Cycle Assessment of Energy Technologies – problems and possibilities
14. The Actual Energy Transition and Decarbonisation – How is your 2040, 2050?

Literatur
- The Physics of Energy, R.L. Jaffe, W. Taylor, 2018
- Clean Disruption of Energy and Transportation, T. Seba 2014
- Energy and Civilization: A History, V. Smil, 2018

Prerequisites / notice
- Basics of Physics applied to Energy and Energy Technology.
- Investigation on current problems (and possible solutions) related to the energy system and the environmental interactions.

Training of scientific and multi-disciplinary methods, approaches and their limits in the exercises and discussions.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

Subject Didactics

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<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0910-00L</td>
<td>Physics Didactics I: Special Didactics of Physics Teaching</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Mohr</td>
</tr>
</tbody>
</table>

Further information is available from the lecturer via email:
mamohr@ethz.ch

Simultaneous enrolment in Introductory Internship Physics - course 402-0920-00L - is compulsory for Teaching Diploma Physic

Objective
Die Studierenden verfügen über fachdidaktisches Grundwissen für den Physikunterricht an einer Mittelschule. Sie können eigene Lektionen unter Berücksichtigung der vielfältigen Rahmenbedingungen planen, durchführen und evaluieren. Sie reflektieren ihren Unterricht und sind bestrebt, ihn didaktisch und pädagogisch weiter zu entwickeln.

Die Studierenden kennen die Einsatzmöglichkeiten, Chancen und Schwierigkeiten verschiedener Unterrichtsmethoden und Hilfsmittel. Sie können die Eignung von Unterrichtsformen im Hinblick auf eine Lernsituation beurteilen. Sie bemühen sich in ihrem Unterricht, geeignete Methoden und Medien angepasst an die Klasse und das Thema einzusetzen.


Content
- Thematik: Schwerpunkte
- Fachspezifisches: Sachstrukturen der gängigen Unterrichtsthemen, Alltagsbezüge, Fehlvorstellungen, Demonstrations- und Schülerexperimente, Arbeitsmittel zu physikalischen Themen des Grundlagen- und Schwerpunktunterrichts
- Einsat von unterschiedlichen Unterrichtsmaterialien: Experimente, Computer, Taschenrechner, Video, Simulation
- Unterrichtsformen: Lernaufgabe, Werkstatt, Puzzle, Projekt, Gruppenarbeit, Praktikum

Lernformen
Interaktive Lehr-Lernveranstaltung mit Vorträgen und Demonstrationen des Dozenten, studentischer Einzel- und Kleingruppenarbeit, kurzen Präsentationen der Studierenden, Verarbeitung der Inhalte durch Bearbeitung von Aufträgen ausserhalb der Kontaktstunden

Lecture notes
Folien und weitere Unterlagen werden zur Verfügung gestellt

Prerequisite / notice
Die Veranstaltung ist zusammen mit dem Einführungspraktikum zu belegen

402-0091-00L Teaching Science in Higher Education

Objective
Students are able to characterize and to discuss the model of outcomes based education.

Lecture notes
keines

(Please buy the book in the 5th edition before the first meeting.)

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concept and Theories</th>
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<tbody>
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<td>Method-specific Competencies</td>
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Natural Sciences

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<tr>
<td>651-3001-00L</td>
<td>Dynamic Earth I</td>
<td>W</td>
<td>6</td>
<td>4V+2U</td>
<td>O. Bachmann, A. Galli, A. Fichtner, M. Schönbächler, S. Willett</td>
</tr>
</tbody>
</table>

Abstract
Provides a basic introduction into Earth Sciences, emphasizing different rock-types and the geological rock-cycle, as well as introduction into geophysics, plate tectonics and planetology.

Objective
Understanding basic geological and geophysical processes.

Content
Overview of the Earth as a system, with emphasis on plate tectonic theory and the geological rock-cycle. Provides a basic introduction to crystals and minerals and different rock-types. Lectures include processes in the Earth's interior, physics of the earth, planetology, introduction to magmatic, metamorphic and sedimentary rocks. Exercises are conducted in small groups to provide more in depth understanding of concepts and content of the lectures.

Literature
Grotzinger, J., Jordan, T.H., 2020, Understanding Earth, Macmillan Learning, 8th Ed.
https://doi.org/10.1007/978-3-662-48342-8

Prerequisites / notice
Exercises and short excursions in small groups (10-15 students) will be lead by student assistants. Specific topics in earth sciences will be discussed using examples and case studies. Hand samples of the major rock types will be described and interpreted. Short excursions in the region of Zurich will permit direct experience with earth science processes (e.g. earth surface processes) and recognition of earth science problems and solutions relevant for modern society (e.g. building materials, water resources). Working in small groups will allow for discussion and examination of actual earth science themes.

Science Education Master - Key for Type

| W+  | Eligible for credits and recommended |
| W   | Eligible for credits |
| E-  | Recommended, not eligible for credits |
| O   | Compulsory |
| Z   | Courses outside the curriculum |
| Dr  | Suitable for doctorate |

Key for Hours

| V   | lecture |
| G   | lecture with exercise |
| U   | exercise |
| S   | seminar |
| K   | colloquium |
| P   | practical/laboratory course |
| A   | independent project |
| D   | diploma thesis |
| R   | revision course / private study |

ECTS European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
The course “Didactic Basics for Student Teaching Assistants” enhances Student Teaching Assistants (Student TAs) to develop knowledge, capability and confidence in effectively plan and teach courses and exercises. Participants get trained to think critically about students’ learning and create learning situations in which students are actively engaged.

**Objective**
In this course Student Teaching Assistants will...
- reflect on their approach to teaching as well as their attitude towards teaching.
- understand the basics of teaching and learning in the context of their subject.
- consciously design the introduction of their course as well as the introduction of single teaching units.
- apply classroom assessment techniques as formative assessments to measure the current status of their students.
- develop a didactic concept according to the learning objectives.
- conduct interactive sequences as learning activities.
- give and get feedback from peers and self-reflect on their teaching practice.
- feel confident to use methods for active learning scenarios in their classes.

**Content**
The online course provides a range of relevant topics for developing teaching competences of Student Teaching Assistants:
- Overview about how learning works. Based on these fundamentals of learning participants reflect on their role as Student TAs to feel comfortable in their new role as a teacher.
- Plan an own lesson by introducing a class and locate it in the larger topic (methods: portal and informative introduction).
- Develop learning activities in order to activate students (active learning methods).
- Giving and also getting feedback. The participants integrate this topic also in their lesson plan.

While working through the online course, Student TAs have the chance to reflect, exchange ideas with peers and plan their own teaching accordingly so that they feel confident in their role.

**Prerequisites / notice**
Self-paced online course with a online/face-to-face consolidation workshop.
Consolidation Workshops take places online or in presence (you have the choice). Dates will be released at the beginning of the new semester.

**Competencies**
- **Method-specific Competencies**
  - Media and Digital Technologies
  - Communication fostered
  - Cooperation and Teamwork fostered
- **Social Competencies**
  - Critical Thinking fostered
- **Personal Competencies**
  - Self-awareness and Self-reflection fostered
  - Self-direction and Self-management fostered

**Prerequisites / notice**
This course takes place on the campus of ETH Zurich. The room for our meetings will be HG D18.1.

**Dates will be released soon.**
Military Psychology and Pedagogy I (Without Exercises)

Examine the fundamentals of the two sciences and establish links with military life. Discuss various schools of thought in psychology and pedagogy and their relationships with military practice. Focus on content and process theories of motivation, as well as knowing the possibilities and limitations of military education and deriving consequences.

**Subjects:**
- History of military psychology
- Introduction to psychological thinking
- Motivational theories
- Defence-, service-, operational- and combat motivation
- Swiss military pedagogy
- Education as a specific feature of pedagogical thinking and acting

**Literature:**
- Annen, H., Steiger, R. & Zwygart, U.: Gemeinsam zum Ziel, Huber, Frauenfeld 2004 (provided as PDF)
- Stadelmann, J.: Führung unter Belastung, Huber, Frauenfeld 1998 (provided as PDF)

*The lecture is supported by a virtual learning environment containing relevant documents (presentations and texts) and information to further literature.*

**Competencies**

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<thead>
<tr>
<th>Competencies</th>
<th>Problem-solving</th>
<th>Communication</th>
<th>Cooperation and Teamwork</th>
<th>Negotiation</th>
<th>Adaptability</th>
<th>Critical Thinking</th>
<th>Self-awareness and Self-reflection</th>
<th>Self-direction and Self-management</th>
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**Objective**

- Becoming acquainted with classic psychological views of human behaviour and experience
- Knowing content- and process theories of motivation and being able to transfer them to the military context
- Knowing the possibilities and limitations of military education and deriving consequences

**Content**

- Overall, the objective is to become acquainted with the basics of both scientific areas and to make references to military practice. Military psychology is a branch of applied psychology; consequently, selected aspects of psychological principles will be covered. Military pedagogy hasn't yet established itself firmly as an independent scientific discipline, it nevertheless can draw on a deep-seated tradition in Switzerland. Thus, the great importance that has been attached to the discussion of education in Swiss society and academia will be taken into account.

**Notice**

REQUIREMENT: teaching duties in the current semester

**Prerequisites / notice**

This programme is designed for ETH Doctoral Teaching Assistants with current teaching responsibilities (exercises, excursions, supervision of practicals, lectures, etc.) or those who will assume teaching tasks in the semester following the programme. No previous teacher training is required.
Leadership and Responsibility
Beside of the most important terms of sociology, demographic changes and the related value and structure change will be analysed.
M. M. Keupp, S. De Rosa, Military Sociology I

Analytical Competencies
Subject-specific Competencies
Concepts and Theories
assessed

Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving
assessed
assessed
assessed

Social Competencies
Leadership and Responsibility
assessed
Self-presentation and Social Influence
assessed

Personal Competencies
Critical Thinking
Self-awareness and Self-reflection
assessed
assessed

853-0063-02L Military History I (Without Exercises) Z 3 credits 2V M. Olsansky, T. Cubito, A. Wettstein

Abstract
The purpose of the lecture is to outline the development of the armed forces (assets regarding manpower, technology and armament), the concepts of warfare and the actual warfare in the 19th and 20th century.

Objective
- Distinguish between military history as a subject and historiography as a way of describing events;
- Analyse the modern developments regarding armed forces and warfare in the context of socio-economic changes;
- Based on the approach regarding revolution in military affairs, describe the evolution of the armed forces and of warfare;
- Exemplify the issues regarding the evolution of the combat (First and Second World War, Vietnam War and Algerian War).

Content
The lecture first examines the bases of the science of (military) history. It focuses on how military history developed from war history, on specific similarities and differences between military history and general historiography, the different ways of dealing with history in Switzerland, Germany, France and in the Anglo-Saxon cultural area (different approaches) as well as on institutions which deal with military history such as universities, military academies, national and international commissions and associations etc.

The lecture is structured along the lines of the concept of “Military Revolution” and starts with the formation of modern, European armed forces after the Oranian Army reform in the 17th century.

Based on the “Military Revolution” approach, the lecture examines the structural changes regarding the armed forces and the development of warfare from the 18th to the 20th century. Special emphasis will be put on how the battlefield was revolutionized due to the Napoleonic wars, the industrialization in the 19th century, the First World War, the mechanization and totalization during the Second World War and the period of the Cold War.

Literature

853-0064-00L Military Sociology I Z 3 credits 2V T. Szvircev Tresch, S. De Rosa, T. Ferst

Abstract
Beside of the most important terms of sociology, demographic changes and the related value and structure change will be analysed. The second part focuses on organizational sociology. Thirdly, the course examines to which extent armed forces can be considered as organizations like any other and to which extent they constitute a special case from an organizational and normative point of view.

Objective
- Recognize and explain current changes (social change) in modern society (individualisation, pluralisation); describe demographic changes in Switzerland; explain the structures of societies; define issues and fields of research in modern military sociology and explain the foundations of organisational sociology; explain the military in terms of organisational sociology and identify specific traits of the military as an organisation.
- Exemplify the issues regarding the evolution of the combat (First and Second World War, Vietnam War and Algerian War).
- Based on the approach regarding revolution in military affairs, describe the evolution of the armed forces and of warfare;
- Analyse the modern developments regarding armed forces and warfare in the context of socio-economic changes;
- Recognize and analyze planned economic systems;
- Understand the link between institutions, human action and economic results.

Literature
A reader with a set of texts will be handed out.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed
fostered

Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management
fostered
fostered
fostered
fostered
fostered

Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation
fostered
fostered
fostered
fostered
fostered
assessed
assessed
fostered

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management
assessed
fostered
assessed
fostered
fostered
fostered
fostered

853-0101-02L Defense Economics I Z 3 credits 2V M. M. Keupp, M. Bader, F. Muhly, C. Schulze

Abstract
In terms of structure and content, the event follows the lecturer's book “Militärokonomie” (Military Economics), which is available in two language versions:
- German language: ISBN 978-3-658-06146-3

Objective
* Recognizing parallels between business and military thinking;
* Recognize and analyze planned economic systems;
* Understand the link between institutions, human action and economic results.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1169 of 2653
The semester program of the course is divided into 14 modules of 90 minutes each, which combine lecture (teaching of analytical techniques) and exercise (application by means of concrete case studies).

The contents correspond to sections 1 to 2.2.5 of the above book. The following will be discussed:

1. fundamental military economic problems including historical introduction to the topic
2. the institutional foundations of a military organisation
3. the modern military as a planned economy system
4. actors and stakeholders in the system

Lecture notes
Lecture slides are given to the participants before the first lecture. In addition, the above mentioned book will be handed over to the participants. Participants of the lecture who are not professional officer candidates are requested to obtain the book from the library or bookstore.

Literature

Prerequisites / notice
none.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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<td>Concepts and Theories</td>
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<td>Cooperation and Teamwork</td>
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<td>fostered</td>
<td>assessed</td>
<td>Customer Orientation</td>
<td>fostered</td>
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<td>Problem-solving</td>
<td>Leadership and Responsibility</td>
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<td>Problem Management</td>
<td>Self-presentation and Social Influence</td>
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Abstract
The lectures "Leadership I" (WS) and "Leadership II" (SS) have been designed as a two-semester lecture series, but may also be followed independently of one another or in reverse order. "Leadership I" covers the following fields: leadership basics, leadership theories and leadership styles, the concept of leadership responsibility and the role of communication in practical leadership.

Objective
The aim of this lecture is to give students an introductory overview of relevant topics regarding leadership research and practice, thus enabling them to gain a deeper understanding of the leadership phenomenon. Students should understand different concepts of leadership in the complex interaction between individuals, groups, organizations, contexts, and situations. They should grasp the concept of leadership responsibility (leadership ethics) and be able to derive consequences for leadership in practical situations. They should recognize the fundamental importance of communication in leadership situations and receive input that enables them to communicate adequately in specific situations.

Competencies

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<tr>
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<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<td>Concepts and Theories</td>
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<td>Decision-making</td>
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Specialized Continuing Education

Special internal ETH courses offered by LET and the Teaching Specialists.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>999-9999-99L</td>
<td>EduApp Course</td>
<td>E-</td>
<td>0</td>
<td>1V+1U</td>
<td>B. Volk</td>
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This course unit is not a genuine ETH course unit. It is used by LET and the Teaching Specialists for EduApp demonstration purposes.
### Humanities, Social and Political Sciences (General Courses) - Key for Type

<table>
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<tr>
<th>Code</th>
<th>Description</th>
<th>Code</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
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</table>

### Key for Hours

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
### Educational Science

Course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>see Educational Science Teaching Diploma</td>
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<tr>
<td>871-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>R. Schumacher</td>
</tr>
</tbody>
</table>

**Abstract**

This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)".

**Objective**

- Get to know cognitively activating instructions in MINT subjects
- Get information about recent literature on learning and instruction

**Prerequisites / notice**

For eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.

| 871-0242-07L | Human Intelligence | W | 1 credit | 1S | E. Stern |

**Abstract**

The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.

**Objective**

- Understanding of research methods used in the empirical human sciences
- Getting to know intelligence tests
- Understanding findings relevant for education

| 871-0229-00L | Using Outdoor Education | W | 1 credit | 1S | R. Schumacher, P. Faller |

**Abstract**

In this seminar, future teachers will be trained to prepare and conduct excursions to out-of-school learning venues. For this purpose, excursions are offered at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf.

**Objective**

Future teachers will learn to prepare and conduct excursions to out-of-school learning venues.

**Content**

- Excursions at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf:
  - Dendrochronology: What annual rings tell
  - Photosynthesis/Climate change: The tracks in the forest
  - Forest Soil: The soil in the focus of the climate

### Subject Didactics in Geography

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4239-00L</td>
<td>Subject Didactics Geography I (University of Zurich)</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

**Limited number of participants.**

In addition to the course enrollment a registration by email is required at Dr. Stefan Hesske (E-Mail: stefan.hesske@ife.uzh.ch).


**Abstract**

Fundamentals (theory and practice) of specialist subject teaching for high-school geography lessons.

**Objective**

Die Studierenden lernen Theorie und Praxis im Unterricht zu verbinden, verschiedene Unterrichtsmethoden und -mittel einzusetzen sowie ihren Unterricht zu planen, durchzuführen und zu reflektieren.

**Prerequisites / notice**

A maximum of 12KP additional requirements in Geography may be open before registering for the didactics Geography.

Please provide the form [https://ethz.ch/content/dam/ethz/edu/education/Didaktik-Ausbildung/Files/Diverses/Form_Auflagen_bis%2012%20KP_291015.pdf](https://ethz.ch/content/dam/ethz/edu/education/Didaktik-Ausbildung/Files/Diverses/Form_Auflagen_bis%2012%20KP_291015.pdf) as a confirmation.

Besides the module registration at University of Zurich, the responsible lecturer of the course must be informed by mail by 1 September.

| 651-4124-00L | Examination Subject Didactics | O | 1 credit | 2G | S. Hesske, J. Rafflenbeul |

**Abstract**

Die Prüfung Fachdidaktik bildet den Abschluss der didaktischen Ausbildung und wird nach erfolgreichem Abschluss aller Ausbildungsbereiche der didaktischen Ausbildung abgelegt.
Content

Geprüft werden:
Fähigkeit, Geografie-Unterricht mit Bezug zur eigenen Praxis kritisch und unter verschiedenen Blickwinkeln (inhaltlich, methodisch-
didaktisch) zu betrachten. Lernarrangements mit Bezug zum heutigen Bildungs- und Schulfachverständnis zu gestalten und kritisch zu
hinterfragen sowie deren möglichen/ erzielten Wirkungen zu diskutieren und zu begründen; Unterrichtssituationen zu reflektieren und zu
evaluieren.

Unterlagen aus der fachdidaktischen Ausbildung

Lecture notes

Unterlagen aus der Fachdidaktik

Literature

3-06-065941-8

Prerequisites / notice

The Examination Didactics is completed at the end of studies and must be fulfilled together with both examination lessons I and II (651-
2520-01 und 651-2520-02). The responsible lecturers must be informed in advance so that the examination date (and place) can be
organized.

All of the following courses must be successfully completed: Geography Didactics I, II, III and the specialised courses in respective subjects
I, II and III as well as the Introductory Internship and Internship.

The examination didactics is an 15-minutes oral exam that takes place at the same day together with the examination lessons I and II.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed

Social Competencies

Communication assessed
Cooperation and Teamwork assessed
Customer Orientation assessed
Leadership and Responsibility assessed
Self-presentation and Social Influence assessed
Sensitivity to Diversity assessed

Personal Competencies

Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

651-4120-00L Subject Didactics Geography IV: Mentored Project ■ O 2 credits 4A S. Hesske, J. Rafflenbeul

Prerequisites: successful participation in Geography Didactics of Geography Teaching I, II, III

Abstract

Mentorierte Arbeit mit Bezug zur fachdidaktischen Ausbildung.

Objective

selbständige, theoriegestützte Auseinandersetzung mit konkreter, praxisbezogener Fragestellung zum Geographieunterricht.

Content

selbständige, mentorierte Arbeit zu einem Thema aus der Fachdidaktik mit direktem Bezug zur Lehrpraxis im Fach Geografie (z.B. zu
eigenen Übungslektionen und Praktikum oder zur Unterrichtsforschung). Das Thema wird zu Beginn mit der Mentorin/ dem Mentor festgelegt.

Literature


Prerequisites / notice

May be completed together with didactics III at the earliest.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assess
Project Management assessed

Social Competencies

Communication assessed
Cooperation and Teamwork assessed
Customer Orientation assessed
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies

Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

651-4118-00L Subject Didactics Geography III (University of Zurich) O 3 credits 2G University lecturers

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: 090GG3

Limited number of participants. In addition to the course enrollment a registration by email is required no later than September 1 for autumn semester, February 1 for spring.
University lecturers

4P

Die Fachdidaktik Geographie III ermöglicht eine vertiefte, anwendungsorientierte Auseinandersetzung in Bezug auf den Geographie-

Lesson Shadowing (University of Zürich)

The Lesson Shadowing is part of the practical education of the teacher training for Upper Secondary Schools and must be completed at the

Prerequisites / notice

Geography Didactics III may be completed in parallel with Geography Didactics II, but only after successful completion of Geography

Professional Training in Geography

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<td>Lesson Shadowing (University of Zürich)</td>
<td>O</td>
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<td>2P</td>
<td>University lecturers</td>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadline">https://www.uzh.ch/cmsssl/en/studies/application/deadline</a> s.html</td>
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<td>Prerequisites / notice</td>
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<td>The Lesson Shadowing is part of the practical training in the study program &quot;Teaching Diploma for Matura Schools&quot;. It must be completed at the beginning of the course - if possible in the 1st semester.</td>
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<td>The Lesson Shadowing can only be completed together with an accredited internship teacher of ETH Zurich (<a href="https://cms-author.ethz.ch/content/dam/ethz/special-interest/erdw/department/dokumente/cug/Praktikumslehrpersonen_LD_Geographie.pdf">https://cms-author.ethz.ch/content/dam/ethz/special-interest/erdw/department/dokumente/cug/Praktikumslehrpersonen_LD_Geographie.pdf</a>).</td>
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<tr>
<td>651-2519-02L</td>
<td>Lessons Training (University of Zurich)</td>
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<td>4P</td>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<td>The practice lessons help students to gain first experiences in teaching and is completed together with the didactics courses.</td>
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<td>The practice lessons for didactics must be completed within the didactic courses.</td>
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<td>Students register for the module at UZH ideally together with didactics II. ECTS will be assigned after having handed in all relevant documents to the lecturers, at the earliest upon completion of didactics II.</td>
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<tr>
<td>651-2517-00L</td>
<td>Teaching Internship I Geography (University of Zurich)</td>
<td>O</td>
<td>8 credits</td>
<td>17P</td>
<td>University lecturers</td>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<td></td>
<td>UZH Module Code: 090BPP1</td>
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<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadline">https://www.uzh.ch/cmsssl/en/studies/application/deadline</a> s.html</td>
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<td>Prerequisites / notice</td>
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<td></td>
<td>Prerequisites: Successful completion of Educational Science and Subject Didactics in Geography (FD I, II, III) as well as Spec. Courses in Resp. Subj. w/ Educ. Focus &amp; Further Subj. Didactics (PV I, II, III) plus completion of the introductory internship.</td>
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<td>The Introductory Internship can only be completed together with an accredited internship teacher of ETH Zurich (<a href="https://cms-author.ethz.ch/content/dam/ethz/special-interest/erdw/department/dokumente/cug/Praktikumslehrpersonen_LD_Geographie.pdf">https://cms-author.ethz.ch/content/dam/ethz/special-interest/erdw/department/dokumente/cug/Praktikumslehrpersonen_LD_Geographie.pdf</a>).</td>
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<tr>
<td>651-2520-01L</td>
<td>Examination Lesson I Geography ■</td>
<td>O</td>
<td>1 credit</td>
<td>2P</td>
<td>S. Hesske, J. Rafflenbeul</td>
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<td>To be completed together with Examination Lesson II 651-2520-02.</td>
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<td></td>
<td>Abstract</td>
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<td></td>
<td>In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.</td>
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<td>Objective</td>
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<td></td>
<td>On the basis of a specified topic, the candidate shows that they are in a position</td>
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<td>- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle</td>
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<td>- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.</td>
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</tbody>
</table>
Die Studierenden erfahren das Lektionsthema in der Regel 14 Tage vor dem Prüfungstermin. Von der zuständigen Lehrperson erhalten sie Informationen über den Wissensstand der zu unterrichtenden Klasse und können die Klasse einmal vor dem Prüfungstermin besuchen. Sie erstellen eine Vorbereitung gemäss Anleitung und reichen sie spätestens 2 Tage vor dem Prüfungstermin (bis 18 Uhr) den beiden Prüfungsexperten ein.

Die gehaltene Lektion wird kriteriumsbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/der Kandidatin über die gehaltene Lektion im Rahmen eines Kolloquiums (max. 15 min).

The following parts of the course must be passed: Subject Didactics I, Subject Didactics II, Subject Didactics III, Subject Didactics IV. In addition FWV I, FWV II and FWV III, introductory internship and internship (incl. internship journal).

- **Competencies**
  - **Subject-specific Competencies**
    - Concepts and Theories: assessed
    - Techniques and Technologies: assessed
  - **Method-specific Competencies**
    - Analytical Competencies: assessed
    - Decision-making: assessed
    - Media and Digital Technologies: assessed
    - Problem-solving: assessed
    - Project Management: fostered
  - **Social Competencies**
    - Communication: assessed
    - Cooperation and Teamwork: assessed
    - Customer Orientation: assessed
    - Leadership and Responsibility: assessed
    - Self-presentation and Social Influence: assessed
    - Sensitivity to Diversity: assessed
    - Negotiation: fostered
  - **Personal Competencies**
    - Adaptability and Flexibility: assessed
    - Creative Thinking: assessed
    - Critical Thinking: assessed
    - Integrity and Work Ethics: fostered
    - Self-awareness and Self-reflection: assessed
    - Self-direction and Self-management: assessed

- **Prerequisites / notice**
  - The examination lessons I and II are completed at the end of the training together with the subject didactics examination. The responsible lecturers must be informed in advance so that the examination date (and place) can be organized.

The following parts of the course must be passed: Subject Didactics I, Subject Didactics II, Subject Didactics III, Subject Didactics IV. In addition FWV I, FWV II and FWV III, introductory internship and internship (incl. internship journal).

- **Competencies**
  - **Subject-specific Competencies**
    - Concepts and Theories: assessed
    - Techniques and Technologies: assessed
  - **Method-specific Competencies**
    - Analytical Competencies: assessed
    - Decision-making: assessed
    - Media and Digital Technologies: assessed
    - Problem-solving: assessed
    - Project Management: fostered
  - **Social Competencies**
    - Communication: assessed
    - Cooperation and Teamwork: assessed
    - Customer Orientation: assessed
    - Leadership and Responsibility: assessed
    - Self-presentation and Social Influence: assessed
    - Sensitivity to Diversity: assessed
    - Negotiation: fostered
  - **Personal Competencies**
    - Adaptability and Flexibility: assessed
    - Creative Thinking: assessed
    - Critical Thinking: assessed
    - Integrity and Work Ethics: fostered
    - Self-awareness and Self-reflection: assessed
    - Self-direction and Self-management: assessed

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Using Outdoor Education

In the context of their first teaching practice, students compile a portfolio in which they analyse and document selected aspects of their teaching experience. Only for students of the Geography Teaching Diploma.

The semester paper must be completed together with the first teaching internship, the registration is therefore in the same semester.


<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4136-00L</td>
<td>Planning and Teaching Geography Fieldtrips (University of Zurich)</td>
<td>O</td>
<td>3 credits</td>
<td>6G</td>
<td>University lecturers</td>
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<tr>
<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<td></td>
<td>UZH Module Code: GEO992</td>
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<td>Mind the enrolment deadlines at UZH:</td>
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<td><a href="https://www.uzh.ch/cmsssl/en/studies/application/deadline">https://www.uzh.ch/cmsssl/en/studies/application/deadline</a> s.html</td>
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<tr>
<td>Abstract</td>
<td>Students transfer the content of their subject-specific, educational and didactic training into teaching practice. While teaching, they gain and reflect on experience in the design of subject-specific lessons, in classroom management and in performance assessment at all levels of the Matura school.</td>
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<tr>
<td>Content</td>
<td>The goal of the course is the content-based preparation and didactic conception of different &quot;learning locations&quot; in and around Zurich. The results are to be merged into an attractive excursion guide for teachers (secondary school II).</td>
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<tr>
<td>Objective</td>
<td>- Get to know and explore the catchment area of the Sihl River from different perspectives (e.g. urban geography, physical geography)</td>
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<td></td>
<td>- Content-based development and didactic implementation of &quot;learning places&quot; with different thematic focuses for school classes (Sek. II)</td>
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<td></td>
<td>- Reflection of the work results and processes</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The internship II has to be completed after the teaching internship I at the end of the program in the same semester. Prerequisite is the successful completion of all courses of the teaching diploma program.</td>
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</table>

Compulsory Elective Courses

Further course offerings from the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>871-0229-00L</td>
<td>Using Outdoor Education  ■ Enrolment only possible with matriculation in Teaching Diploma Biology and Geography.</td>
<td>W</td>
<td>1 credit</td>
<td>1S</td>
<td>R. Schumacher, P. Faller</td>
</tr>
<tr>
<td>Abstract</td>
<td>In this seminar, future teachers will be trained to prepare and conduct excursions to out-of-school learning venues. For this purpose, excursions are offered at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf.</td>
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<tr>
<td>Objective</td>
<td>Future teachers will learn to prepare and conduct excursions to out-of-school learning venues.</td>
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<tr>
<td>Content</td>
<td>Excursions at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf:</td>
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<td></td>
<td>- Dendrochronology: What annual rings tell</td>
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<td></td>
<td>- Photosynthesis/Climate change: The tracks in the forest</td>
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<td></td>
<td>- Forest Soil: The soil in the focus of the climate</td>
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<tr>
<td>860-0023-00L</td>
<td>International Environmental Politics</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>T. Bernauer</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined.</td>
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</table>
The objectives in this course are to (1) gain an overview of important questions pertaining to international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions in this policy area and how to address them in a conceptually and methodologically meaningful and insightful way; (3) gain an overview of important global and regional environmental problems and how they are or could be solved.

This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined, for example international efforts to reduce air pollution, manage international water resources, mitigate and adapt to global warming, protect the stratospheric ozone layer, address biodiversity challenges, deal with plastic waste, and prevent pollution of the oceans.

The course is open to all ETH students and visiting students from other universities. Participation does not require previous coursework in the social sciences or environmental policy. This course will take place on campus (ETH Main Building, HG F.3). There will be no live-streaming, and the course is NOT in hybrid (on-campus plus online) format. However, the lecture will be recorded and the recordings will be made available via the Moodle platform for this course a few days after the respective lecture for students who are unable to attend in person. All electronic correspondence will take place via the ETH mystudies system and Moodle, so please make sure you are properly registered there with a functioning email address/account.

Credits and Exam
After passing a written test at the end of the course (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test). Visiting students (e.g., from the University of Zurich, exchange students) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory. Students who obtain a grade of < 4.0 for the test will have a second chance (see table below). Students who did not participate in the test on 18 December 2023 will not have access to the repeat test unless they submit compelling and documented (e.g., medical, other exam in parallel at ETH) reasons for why they were unable to participate in the first test. It covers all contents of the lectures and the reading assignments. Visiting students (e.g., from the University of Zurich or other universities) are subject to the same conditions. Registration for the course in the mystudies system of ETH is compulsory. No separate registration for the exam is required, registration for the course as such covers everything. The exam will take place on campus, either in the F3 lecture hall or in a computer room. That is, you must be present in person at ETH Zurich on the exam date/time.

Objective
You will be able to present basic theoretical principles, facts and concepts on the following topics of human geography and apply them to simple examples:
- Society and space: basic perspectives of human geography, spatial concepts, forms of society, globalization.
- State in globalization: sovereignty, borders, nation, identity.
- Economy in the global age: commodity chains, labor relations and business strategies.
- Cities in the context of global transformations: Global urbanization processes, urban spatial developments, urban living conditions.

You know the basics of scientific work in human geography and can apply them in a small project. For example:
- Economy in the global age: commodity chains, labor relations and business strategies.
- State in globalization: sovereignty, borders, nation, identity.
- Economy in the global age: commodity chains, labor relations and business strategies.
- Cities in the context of global transformations: Global urbanization processes, urban spatial developments, urban living conditions.

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

Recommended prerequisite: Human Geography II (UZH Module Code: GEO122)

This course enables students to think through and about difference geographically: multi-scalar, critically, spatially. Students learn to understand selected theoretical perspectives in human geography.

Focusing on a chosen thematic area of human geography, they train using these perspectives to interpret empirical phenomena and raise questions about them.

Objective
- To understand selected theoretical perspectives in human geography that problematize questions of difference.
- To use these theoretical perspectives to interpret empirical phenomena of social difference and inequality and raise questions about them.
- To deepen knowledge on empirical phenomena of social difference in one specific topic of human geography.
- To write a seminar paper, using theoretical and empirical material.
Following an introductory lecture, students will split into four smaller seminar groups, focused on different thematic areas from urban, political and economic geography. Seminars will be based on a close reading of selected material and designed for interactive participation and discussion.

Each seminar consists of theory-oriented sessions, where students will gather first insights into selected theoretical perspectives of human geography. Using these perspectives, students develop their knowledge of each seminar group’s thematic area of focus and practice applying theory to empirical fields of research.

Prerequisites / notice
After the introductory lecture in week 1, students must enroll in one of four seminar groups via OLAT. Attendance of the introductory lecture is a prerequisite for participation in the first group session.

Modules of Choice

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-2603-00L</td>
<td>Geography. Matters. (University of Zurich)</td>
<td>W</td>
<td>4 credits</td>
<td>2V</td>
<td>University lecturers</td>
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<tr>
<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: GEO410</td>
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<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html">https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html</a></td>
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<td>The course aims are twofold. First, students will discuss urgent societal challenges (e.g. biodiversity loss, climate change, migration, urbanization, water scarcity) and outline how Geography as a whole can contribute tackling these challenges. Second, students are encouraged to reflect their individual interdisciplinary curricula.</td>
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<td>The thematic bracket opened at the beginning of the curriculum and introducing the interdisciplinary approach of geography will be closed. Practical guidance is provided allowing students to identify matching job advertisements, to develop and communicate own strengths, and to prepare application documents.</td>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>651-4088-03L</td>
<td>Physical Geography III (Geomorphology and Glaciology) (University of Zürich)</td>
<td>W</td>
<td>5 credits</td>
<td>1V+1U</td>
<td>University lecturers</td>
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<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: GEO231</td>
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<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html">https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html</a></td>
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<td></td>
<td>Das Modul bietet eine kurze Einführung in einige Komponenten und Prozesse des hydrologischen Kreislaufes. Dabei werden einzelne Wasserspeicher (Schnee-, Boden und Grundwasser) und Flüsse zwischen den Speichern (Verdunstung, Niederschlag und Abfluss) betrachtet. Übungen ergänzen die Vorlesung.</td>
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Part 3

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>651-2338-00L</td>
<td>Remote Sensing and Geographic Information Science III (University of Zürich)</td>
<td>W</td>
<td>5 credits</td>
<td>2V+3U</td>
<td>University lecturers</td>
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<tr>
<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: GEO233</td>
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<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html">https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html</a></td>
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<td>The course &quot;Grundlagen der Fernerkundung&quot; (Principles of Remote Sensing) introduces the underlying principles of remote sensing and a range of fundamental concepts for understanding, handling and manipulating remote sensing data and images. It provides first details on optical image geometries as well as image classification and time series analysis.</td>
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<td>The learning goals of this module comprise the following aspects:</td>
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<td>- Understanding and being able to explain fundamental concepts of remote sensing</td>
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<td>- Knowing basic image understanding techniques and being able to apply these to optical imagery.</td>
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<td>- Being able to choose and apply appropriate data analysis methods to solve a given remote sensing task</td>
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<td>- Being able to interpret data, critically discuss the results and draw reasonable conclusions</td>
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<tr>
<td>103-0214-00L</td>
<td>Cartography Fundamentals</td>
<td>W</td>
<td>5 credits</td>
<td>4G</td>
<td>L. Hurni</td>
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<td></td>
<td>Basic knowhow about communication with spatial information by using plans and maps, about the most important design rules and production methods for map graphics.</td>
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<td>Acquire basic knowhow about communication with spatial information by using plans and maps, about the most important design rules and production methods for map graphics. Ability to assess existing products with respect to their content-related and design quality. Ability to design proper plans and well designed legends for basic maps.</td>
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<td>Definitions &quot;map&quot; and &quot;cartography&quot;, map types, current tasks and situation of cartography, map history, spatial reference systems, map projections, map conception and workflow planning, map design, analog and digital map production technology, prepress technology, printing technology, topographic maps, map critics.</td>
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<td>Will be distributed module by module.</td>
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Literature

Prerequisites / notice
Further information at http://www.karto.ethz.ch/studium/lehrangebot.html

Competencies
<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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</thead>
<tbody>
<tr>
<td>Methods-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Social Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>assessed</td>
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<td>Problem-solving</td>
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<td>Critical Thinking</td>
<td>assessed</td>
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</tbody>
</table>

Geography Teaching Diploma - Key for Type

| O | Compulsory | E- | Recommended, not eligible for credits |
| W+| Eligible for credits and recommended | Z  | Courses outside the curriculum |
| W | Eligible for credits | Dr | Suitable for doctorate |

Key for Hours

| V | lecture |
| G | lecture with exercise |
| U | exercise |
| S | seminar |
| K | colloquium |
| P | practical/laboratory course |
| A | independent project |
| D | diploma thesis |
| R | revision course / private study |

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Geomatics Master

Master Studies (Programme Regulations 2022)

Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>103-0248-00L</td>
<td>Geospatial Research Methods</td>
<td>O</td>
<td>4</td>
<td>4G</td>
<td>M. Raubal</td>
</tr>
<tr>
<td>Abstract</td>
<td>The goal of this seminar-style course is to convey methods how to do research and communicate research results in the geospatial domain. The course further provides an overview of the types of research in the geospatial domain and the research life cycle.</td>
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<tr>
<td>Objective</td>
<td>Students will exercise important aspects when doing research, such as doing a literature search, writing and referencing, and presenting.</td>
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<tr>
<td>103-0249-00L</td>
<td>Geospatial Reference Systems</td>
<td>O</td>
<td>4</td>
<td>4G</td>
<td>M. Varga</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course is an advanced introduction to spatial and temporal reference systems for acquisition, analysis and communication of geospatial data. The course covers definitions, conventions and comprehensive real world examples of coordinate reference systems, time reference systems, their respective practical realization, and operations for changing data between them.</td>
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<tr>
<td>Objective</td>
<td>After this course the students should be able to describe the most important established national and international spatial and temporal reference systems; describe the techniques, processes, and institutions needed to establish and maintain reference frames; select appropriate reference systems and frames for specific geospatial modeling/analysis tasks; carry out coordinate transformations, conversions, and time operations on geospatial data, taking into account and quantifying the uncertainties; combine geospatial data originally referring to different reference frames into a single reference frame.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The course requires familiarity with linear algebra and analysis at the level of a BSc program in engineering or natural sciences.</td>
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<td>Personal Competencies</td>
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<tr>
<td>103-0250-00L</td>
<td>Geospatial Data Acquisition</td>
<td>O</td>
<td>4</td>
<td>4G</td>
<td>T. Medic</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course supports the students in acquiring an in-depth understanding of sensors, sensor systems and sensor networks for the acquisition of geospatial data. Emphasis is put on the prediction and assurance of data quality based on an understanding of key sensing principles, external influences, and data acquisition processes.</td>
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<tr>
<td>Objective</td>
<td>After this course the students should be able to describe main sensing principles for time, distance, angle, position, attitude, motion, temperature, optical imaging and spectrum; describe main performance criteria of sensors and sensor systems for static and dynamic geospatial applications; control sensors for geospatial data acquisition using a computer and self-written programs; predict the performance of sensors and sensor systems based on information from data sheets and documentation of sensor system architecture; assess the performance of sensors and sensor systems experimentally.</td>
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<tr>
<td>103-0251-00L</td>
<td>Computational Methods for Geospatial Analysis</td>
<td>O</td>
<td>4</td>
<td>4G</td>
<td>K. Schindler, J. A. Butt, O. Dietrich, B. Soja, N. Wiedemann</td>
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<tr>
<td>Abstract</td>
<td>Introduction to mathematical and statistical tools for geospatial data analysis.</td>
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<tr>
<td>Objective</td>
<td>The goal is to familiarise students with the principles and tools of geospatial data analysis, and to enable them to apply those tools to practical tasks.</td>
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<tr>
<td>Content</td>
<td>The course introduces basic methods of geostatistics and geospatial data analysis. Topics include spatial correlation, auto-correlation and the variogram; surface interpolation (kernel-based, kriging, parametric surface models); spatially adaptive filtering (bilinear, guided filter); spatial stochastic processes and random fields; time series models and spatio-temporal analysis.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Bachelor level mathematics: analysis, linear algebra, statistics and probability theory, parameter estimation. Basic knowledge of multivariate statistics and machine learning is recommended.</td>
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Core Electives

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0417-00L</td>
<td>Transport Planning Methods</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>E. Heinen</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis.</td>
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</tbody>
</table>
Objective
- Knowledge and understanding of statistical methods and algorithms commonly used in transport planning
- Comprehend the reasoning and capabilities of transport models
- Ability to independently develop a transport model able to solve / answer planning problem
- Getting familiar with cost-benefit analysis as a decision-making supporting tool

Content
The course provides the necessary knowledge to develop models supporting the solution of given planning problems and also introduces cost-benefit analysis as a decision-making tool. Examples of such planning problems are the estimation of traffic volumes, prediction of estimated utilization of new public transport lines, and evaluation of effects (e.g. change in emissions of a city) triggered by building new infrastructure and changes to operational regulations.

To cope with that, the problem is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/policy by means of cost-benefit analysis. Interim lab session take place regularly to guide and support students with the applied part of the course.

Lecture notes
Moodle platform (enrollment needed)

Literature


101-0427-01L

Public Transport Design and Operations

W 6 credits 4G  F. Corman

Abstract
This course aims at analyzing, designing, improving public transport systems, as part of the overall transport system. Public transport is a key driver for making our cities more livable, clean and accessible, providing safe, and sustainable travel options for millions of people around the globe. Proper planning of public transport system also ensures that the system is competitive in terms of speed and cost. Public transport is a crucial asset, whose social, economic and environmental benefits extend beyond those who use it regularly; it reduces the amount of cars and road infrastructure in cities; reduces injuries and fatalities associated to car accidents, and gives transport accessibility to very large demographic groups.

Goal of the class is to understand the main characteristics and differences of public transport networks. Their various performance criteria based on various perspective and stakeholders. The most relevant decision making problems in a planning perspective of point of view

At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate possible improvements to existing networks of public transport and the management of those networks; optimize the use of resources in public transport.

General structure:
- general introduction of transport, modes, technologies, system design and line planning for different situations,
- mathematical models for design and line planning
- timetabling and tactical planning, and related mathematical approaches
- operations, and quantitative support to operational problems,
- evaluation of public transport systems.

Content
Basics for line transport systems and networks
Passenger/Supply requirements for line operations
Objectives of system and network planning, from different perspectives and users, design dilemmas
Conceptual concepts for passenger transport: long-distance, urban transport, regional, local transport

Planning process, from demand evaluation to line planning to timetables to operations
Matching demand and modes
Line planning techniques
Timetabling principles

Allocation of resources
Management of operations
Measures of realized operations
Improvements of existing services

Lecture notes
Lecture slides are provided.

Literature
Ceder, Avi: Public Transit Planning and Operation, CRC Press, 2015, ISBN 978-1466563919 (English)


### Application Development in Cartography

**103-0227-00L**

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Methods-specific Competencies</th>
<th>Social Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
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</table>

**Objective**

Students acquire general knowledge about the foundations and best practices in 3D cartography and modern web application development. They learn to plan, design and implement an interactive and animated 3D web map.

**Content**

- 3D cartography
- Web mapping
- Data processing
- Animations and interactions
- Map and UI design
- Web application development
- Programming (JavaScript).

**Lecture notes**

Handouts of the lectures and exercise documents are available on Moodle.

**Prerequisites / notice**

Cartography II or Introduction to Web Cartography Part 1+2 (MOOC) or similar knowledge in mapping with JavaScript.

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### Image-based Mapping

**103-0287-00L**

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**Objective**

Learn how to apply photogrammetry, image analysis and machine learning to mapping tasks; hands-on experience in implementing automatic image analysis methods, and in judging their results.

**Content**

Preprocessing of satellite images, atmospheric correction; extraction of features (radiometric indices, texture descriptors, etc.) from raw image intensities; semantic image segmentation (e.g., cloud masking); physical parameter estimation (e.g., vegetation height); practical deployment of geometric and semantic computer vision and image analysis methods for mapping; assessment of prediction results.

**Prerequisites / notice**

Basic knowledge of photogrammetry, image processing and machine learning.

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### Basics and Principles of Radar Remote Sensing for Environmental Applications

**102-0617-00L**

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**Abstract**

The course will provide the basics and principles of Radar Remote Sensing (specifically Synthetic Aperture Radar (SAR)) and its imaging techniques for the use of environmental parameter estimation.

**Objective**

The course should provide an understanding of SAR techniques and the use of the imaging tools for bio/geophysical parameter estimation. At the end of the course the student has the understanding of:

1. SAR basics and principles,
2. SAR polarimetry,
3. SAR interferometry and
4. environmental parameter estimation from multi-parametric SAR data.
The rationale behind the structure of the course follows the idea that radar imaging and radar/SAR interferometry are closely related and students will get an understanding of the conception, structure and impact of cadastral systems and related concepts such as land registration. Additional reading material:


Lecture notes and Literature

100-0627-00L Applied Radar Remote Sensing 

<table>
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<tr>
<th>Physical Sciences</th>
<th>W 3 credits</th>
<th>2G</th>
<th>O. Frey</th>
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Abstract

This course provides an introduction to processing and interpreting radar and synthetic aperture radar (SAR) remote sensing data. The primary topics of the course are interferometric techniques and related applications such as topography mapping and mapping of surface displacements, with a strong emphasis on solving practical problems using MATLAB.

Objective

Understand the concepts and techniques required to process and to adequately interpret interferometric radar/SAR data for topographic mapping and surface displacement applications.

Content

At the end of the course the student is able to read, display, process, and interpret interferometric radar/SAR using MATLAB.

The course starts with the real-aperture radar case and a first introduction to the concept of radar interferometry with applications to topographic mapping and mapping of surface displacements.

Based on that, the 2-D imaging concept used in synthetic aperture radar imaging is treated.

Then, we expand further on radar and SAR interferometric (InSAR) concepts and processing steps for single interferograms and stacks of interferograms also using persistent scatterer interferometry (PSI) to measure deformation based on time series of interferometric SAR data.

Finally, the 3-D radar imaging case (SAR tomography) is put into context with PSI/InSAR time series as an extension of the more classical interferometric approaches thereby closing the circle around the strongly related concepts of SAR imaging and interferometry.

Lecture notes

Lecture notes/handouts for each topic will be provided online.

Literature

- ISBN: 978-0-306-47633-4
- https://doi.org/10.1007/0-306-47633-9

Prerequisites / notice

It is highly recommended that the student has previously taken the following courses:

- 100-0617-00L: Methodologies for Image Processing of Remote Sensing Data
- 100-0617-01L: Methodologies for Image Processing of Remote Sensing Data

103-0687-00L Cadastral Systems

<table>
<thead>
<tr>
<th>Physical Sciences</th>
<th>W 2 credits</th>
<th>2G</th>
<th>J. Lüthy</th>
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</table>

Abstract

Conception, structure and impact of cadastral systems such as property cadastre, PLR-cadastre, digital twin and related spatial data infrastructures (SDI) as well as their importance for civil society.

Objective

Students will get an understanding of the conception, structure and impact of cadastral systems and related concepts such as land administration, land registry, PLR-cadastre, spatial data infrastructures and Digital Twins. The link between cadastral systems, gender equality, economic prosperity and the contribution of property cadastre to achieving the United Nation Sustainable Development Goals (UN SDG) is discussed.

The Swiss cadastral system ("Amtliche Vermessung") as well as a number of international systems in developed as well as in developing countries are discussed.

The importance of the data from the property cadastre for the National Spatial Data Infrastructure (NSDI) and digital transformation will be investigated using various examples.

Content

Origin and purpose of cadastral systems
- Importance of cadastral systems as societal property due to the impact on the economy, society and the environment.
- Contribution of the cadastral system to achieving the SDGs in gender equality, poverty and food security.

Swiss cadastral system
- legal basis
- organisation
- Technical implementation
- Quality and integrity assurance
- profession
- Embedding cadastral data in the national spatial data infrastructure

Literature


Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1183 of 2653
Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies fostered
Problem-solving fostered

Social Competencies

Cooperation and Teamwork fostered
Customer Orientation fostered
Sensitivity to Diversity fostered

Personal Competencies

Critical Thinking fostered

851-0724-01L Real Estate Property Law W 3 credits 3V S. Stucki, R. Müller-Wyss

Particularly suitable for students of D-ARCH, D-BAUG, D-USYS.

Abstract

Real estate property law (esp. content, acquisition, restrictions under private and public law, transmission and loss). Legal presentation: land register, surveying, cadastre. Basic questions of contract and tax law.

Objective

The legal principles of real estate property law can be correctly interpreted and applied in daily life.

Content

Real estate property law (esp. content, acquisition, restrictions under private and public law, transmission and loss). Legal presentation: land register, surveying, cadastre. Basic questions of contract and tax law.

Lecture notes

Abgegebene Unterlagen: Skript in digitaler Form

Literature

- Adrian Mühlematter / Stephan Stucki: Grundbuchrecht für die Praxis, Zürich 2016
- Wolfgang Ernst / Samuel Zogg: Sachenrecht in a nutshell, Zürich 2020
- Jörg Schmid / Bettina Hürlimann-Kaup: Sachenrecht, Zürich 2017
- Meinrad Huser: Schweizerisches Vermessungsrecht, unter besonderer Berücksichtigung des Geoinformationsrechts und des Grundbuchrechts, Zürich 2014
- Meinrad Huser, Geo-Informationsrecht, Rechtlicher Rahmen für Geographische Informationssysteme, Zürich 2005
- Meinrad Huser, Darstellung von Grenzen zur Sicherung dinglicher Rechte, in ZBGR 2013, 238 ff.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies

Communication fostered
Cooperation and Teamwork assessed
Customer Orientation assessed
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity assessed
Negotiation assessed

Personal Competencies

Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management fostered

103-0187-01L Space Geodesy W 6 credits 4G B. Soja

Abstract


Objective

After this course, the students should be able to

• Describe the major observation techniques in space geodesy
• Describe the necessary modeling and analysis approaches to derive geodetic products of highest quality
• Select the appropriate space geodetic data for scientific investigations
• Analyze the space geodetic data for scientific purposes
• Interpret the scientific results

Content

Overview of GNSS, Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser Ranging (SLR/LLR), Satellite Radar Altimetry with the basic principles, the instruments and observation equations.

Modelling of the station motions and the estimation of station coordinates. Basics of wave propagation in the atmosphere. Signal propagation in the ionosphere and troposphere for the different observation techniques and the determination of atmospheric parameters.

Equation of motion of the unperturbed and perturbed satellite orbit. Osculating and mean orbital elements. General and special perturbation theory and the determination of satellite orbits.

Lecture notes

Script M. Rothacher “Space Geodesy”
### Complementary Electives

<table>
<thead>
<tr>
<th>Number</th>
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<td>103-0258-00L</td>
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<td>W</td>
<td>3</td>
<td>2G</td>
<td>J. Schito</td>
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**Abstract**

This course deepens the understanding of two main interoperability principles used in Geographic Information Science. Students will expand their knowledge of databases and the Swiss standard INTERLIS and will learn to use different tools and mechanisms to transform geodata between different systems: file-based, by web services, or using a model-based approach to define data meaning semantically.

**Objective**

1. Develop a comprehensive understanding of the key principles of integrability in Geographic Information Science and apply them to geospatial data.
2. Explore the principles of syntactic and semantic interoperability and apply them to geospatial data using a variety of tools.
3. Gain an in-depth understanding of geodatabases, UML, INTERLIS, and of the model-driven data transfer with restructuring and apply this knowledge to geodata.
4. Analyze the ontological spectrum of interoperability principles with varying levels of semantic expressiveness and different formalisms.
5. Examine the historical development of Geographic Information Systems interoperability, including the evolution of different approaches used across different countries.
6. Apprehend and foster research skills and improve competences in scientific writing and communication through completion of a voluntary project work.

**Content**

The aim of this course is to provide students with a deep understanding of two key interoperability principles in Geographic Information Science. Throughout the course, students will be exposed to a range of tools and mechanisms used to transform geospatial content across different file structures and databases. In particular, we will focus on the Conceptual Schema Language INTERLIS, which is used in Swiss surveying, while developing students’ abilities of interpreting, defining, and working with such models, also by using free and open-source tools.

Furthermore, we will explore the concept of integrability, which is fundamental to establishing higher levels of interoperability. We will examine how interoperability can span an ontological spectrum from OGC Web Services to semantic transformation, which may one day be understood by machines. By the end of this course, students will have gained a comprehensive understanding of the principles of interoperability and their applications in Geographic Information Science.

**Prerequisites**

Completed Bachelor course in GIS II or Geoinformationstechnologien und -analysen (GTA) and familiarity of working with a GIS and with geodatabases. Since we will primarily be using QGIS and PostgreSQL (pgAdmin), it would be beneficial if you could bring your own device with both applications pre-installed. Although not compulsory, it may also be useful to have Python/Anaconda and certain geospatial processing libraries installed.

**Competencies**

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Cooperation and Teamwork</td>
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<tr>
<td>103-0778-00L</td>
<td>GIS and Geoinformatics Lab</td>
<td>W</td>
<td>4</td>
<td>4P</td>
<td>P. Kiefer</td>
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</tbody>
</table>

**Abstract**

Independent study project with novel geoinformation technologies. Information on past projects: http://gis-lab.ethz.ch/

**Objective**

This lab focuses on presenting spatial, temporal, and open data in tangible ways. Students will learn how to work with novel geoinformation technologies such as virtual/mixed reality or mobile applications. They will engage in teamwork, application design, programming and presenting their results.
The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human machine interaction, as well as gaming technology.

This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are entrepreneurial understanding. A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases.

Typical lecture format (2h):
1. 15': Introduction
2. 60': Guest testimonial
3. 15': Discussion related to topic (in groups)
4. 10': Plenary discussion
5. 20': Q&A with (guest) lecturer

Lecture notes
- Lecture slides and case material

Competencies
- Subject-specific Competencies: Concepts and Theories, assessed
- Method-specific Competencies: Analytical Competencies, assessed
- Social Competencies: Communication, fostered
- Personal Competencies: Critical Thinking, assessed

Prerequisites / notice
- Prerequisites include:
  - Good programming skills (C# / C++ / Java etc.)
  - Computer graphics/vision experience: Students should have taken, at a minimum, Visual Computing. Higher level courses are recommended, such as Introduction to Computer Graphics, 3D Vision, Computer Vision.

This course is student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/graphics/HMI research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introduction to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course are student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/graphics/HMI research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

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Lecture slides and case material

Competencies
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Lecture slides and case material

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The projects teach the students in-depth specialist knowledge in the context of projects to be worked on independently in selected areas of Geomatics, promoting teamwork, project organisation and technical writing and presentation.

### Master’s Thesis

<table>
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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
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**Data: 15.06.2024 12:39**

Autumn Semester 2024

Page 1187 of 2653
Before starting the Master's thesis, students must have
a. obtained the Bachelor's degree;
b. fulfilled all specified admission conditions, if any;
c. acquired at least 90 credits in the Master's programme,
including 12 credits in the area of the interdisciplinary
project.

Abstract
The Master Programme concludes with the Master Thesis, which has to be done in one of the chosen Majors and has to be completed within 16 weeks. The Master Thesis is supervised by a professor and shall attest the students ability to work independently and to produce scientifically structured work.

Objective
To work independently and to produce a scientifically structured work.

Content
The topics of the Master Thesis are published by the professors. The Topic can be set also in consultation between the student and the professor.

Master Studies (Programme Regulations 2013)

Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
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<td>O</td>
<td>24 credits</td>
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</table>

Only for Geomatics MSc, Programme Regulations 2013.

Before starting the Master's thesis, students must have
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Objective
To work independently and to produce a scientifically structured work.

Content
The topics of the Master Thesis are published by the professors. The Topic can be set also in consultation between the student and the professor.

Electives
The entire course programs of ETH Zurich and the University of Zurich are open to the students to individual selection.

Recommended Electives of Master Degree Programme

No course offer.

Electives ETH Zurich

Course Catalogue of ETH Zurich

Science in Perspective

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-BAUG

Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

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<td>103-0132-AAL</td>
<td>Geodetic Metrology Fundamentals</td>
<td>E-</td>
<td>6 credits</td>
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</table>

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to the most important sensors, operation and calculation methods of Geodetic Metrology

Objective
Getting to know the most important sensors, operation and calculation methods of Geodetic Metrology

Content
Overview on the different domains of geodetic metrology
Geodetic instruments and sensors
Determination of 3D-coordinates with GNSS, total station and levelling
Calculation methods of geodetic metrology
Survey and staking-out methods

Lecture notes
Slides and additional material used in the associated regular course Geodätische Messtechnik GZ (in German) are provided in electronic form.

Literature

Prerequisites / notice
The field course is part of this lecture. Practical exercises complete the subjects taught during the semester.

If evidence of equivalent practical experience in surveying cannot be provided by the student, participation in the field course during the respective next available period (i.e. 1 week in the beginning of the summer holidays) is required.

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<tr>
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<td>103-0214-AAL</td>
<td>Cartography Fundamentals</td>
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<td>5 credits</td>
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Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.
Subject-specific Competencies
The students are capable of analysing measurements with appropriate methods. They can optimally extract model parameters from projections, map conception and workflow planning, map design, analog and digital map production technology, pressess technology, topographic map, map critics.

Lecture notes
Will be distributed module by module.

Literature

Prerequisites / notice
Further information at http://www.karto.ethz.ch/studium/lehrangebot.html

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Objective</th>
<th>Abstract</th>
<th>Content</th>
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</thead>
<tbody>
<tr>
<td>Subject-specific Competencies</td>
<td>Acquire basic knowhow about communication with spatial information by using plans and maps, about the most important design rules and production methods for map graphics. Ability to assess existing products with respect to their content-related and design quality. Ability to design proper plans and well designed legends for basic maps.</td>
<td>Definitions “map” and “cartography”, map types, current tasks and situation of cartography, map history, spatial reference systems, map projections, map conception and workflow planning, map design, analog and digital map production technology, pressess technology, printing technology, topographic map, map critics.</td>
<td>Definitions “map” and “cartography”, map types, current tasks and situation of cartography, map history, spatial reference systems, map projections, map conception and workflow planning, map design, analog and digital map production technology, pressess technology, printing technology, topographic map, map critics.</td>
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Prerequisites / notice
Further information at http://www.karto.ethz.ch/studium/lehrangebot.html


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<td>103-0253-AAL</td>
<td>Parameter Estimation</td>
<td>E- 4 credits</td>
<td>9R</td>
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<td>252-0846-AAL</td>
<td>Computer Science II</td>
<td>E- 4 credits</td>
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<td>406-0141-AAL</td>
<td>Linear Algebra</td>
<td>E- 5 credits</td>
<td>11R</td>
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<tr>
<td>406-0242-AAL</td>
<td>Analysis II</td>
<td>E- 7 credits</td>
<td>15R</td>
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</table>
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Mathematical tools of an engineer

Objective
Mathematics as a tool to solve engineering problems, mathematical formulation of problems in science and engineering. Basic mathematical knowledge of an engineer.

Content

Literature
Textbooks in English:
- J. Stewart: Multivariable Calculus, Thomson Brooks/Cole
- V. I. Smirnov: A course of higher mathematics. Vol. II. Advanced calculus
- M. Akveld, R. Sperb, Analysis II, vdf
- L. Papula: Mathematik für Ingenieure 2, Vieweg Verlag

406-0243-AAL
Analysis I and II
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Mathematical tools for the engineer

Objective
Mathematics as a tool to solve engineering problems. Mathematical formulation of technical and scientific problems. Basic mathematical knowledge for engineers.

Content
Complex numbers.
Calculus for functions of one variable with applications.
Simple Mathematical models in engineering.

Literature
Textbooks in English:
Textbooks in German:
- M. Akveld, R. Sperb: Analysis I, vdf
- M. Akveld, R. Sperb: Analysis II, vdf
- L. Papula: Mathematik für Ingenieure und Naturwissenschaftler, Vieweg Verlag
- L. Papula: Mathematik für Ingenieure 2, Vieweg Verlag

406-0603-AAL
Stochastics (Probability and Statistics)
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

Objective
The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

Content
From "Statistics for research" (online)
Ch 1: The Role of Statistics
Ch 2: Populations, Samples, and Probability Distributions
Ch 3: Binomial Distributions
Ch 6: Sampling Distribution of Averages
Ch 7: Normal Distributions
Ch 8: Student's t Distribution
Ch 9: Distributions of Two Variables

From "Introductory Statistics with R (online)"
Ch 1: Basics
Ch 2: The R Environment
Ch 3: Probability and distributions
Ch 4: Descriptive statistics and tables
Ch 5: One- and two-sample tests
Ch 6: Regression and correlation

Literature
- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
From within the ETH, this book is freely available online under:

From within the ETH, this book is freely available online under:
http://www.springerlink.com/content/m17578/
Physics I

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to the concepts and tools in physics: mechanics of point-like and rigid bodies, elasticity theory, elements of hydrostatics and hydrodynamics, periodic motion and mechanical waves.

Objective
Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve the latter.

The student should acquire an overview over the basic concepts in mechanics.

Content
Book:

Chapters:
1, 2, 3, 4, 5, 6 (without: 6-5, 6-6, 6-8), 7, 8 (without 8-9), 9, 10 (without 10-10), 11 (without 11-7), 13 (without 13-13, 13-14), 14 (without 14-6).

Literature
see "Content"

Friedhelm Kuypers
Physik für Ingenieure und Naturwissenschaftler
Band 1: Mechanik und Thermodynamik
Wiley-VCH Verlag, 2002
4th edition 2022

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies assessed
Problem-solving assessed

Personal Competencies
Self-direction and Self-management assessed

Physics II

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to the "way of thinking" and the methodology in Physics. The Chapters treated are Magnetism, Refraction and Diffraction of Waves, Elements of Quantum Mechanics with applications to Spectroscopy, Thermodynamics, Phase Transitions, Transport Phenomena.

Objective
Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve the latter.

The student should acquire an overview over the basic concepts used in the theory of heat and electricity.

Content
Book:

Chapters:

Literature
see "Content"

Friedhelm Kuypers
Physik für Ingenieure und Naturwissenschaftler
Band 2 Elektrizität, Optik, Wellen
Verlag Wiley-VCH, 2003
4th edition 2022

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies fostered
Problem-solving assessed

Personal Competencies
Self-direction and Self-management fostered

Computer Science

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.

Objective
Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens "behind the scenes" when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.
The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.

Lecture notes
Lecture slides and all other material will be made available for download on the course web page.

Literature
Bjarne Stroustrup, Einführung in die Programmierung mit C++, Pearson Studium, 2010
Andrew Koenig and Barbara E. Moo: Accelerated C++, Addison-Wesley, 2000

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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<th>Social Competencies</th>
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<td>Cooperation and Teamwork</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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103-2233-AAL GIS Basics
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
Fundamentals in geoinformation technologies: database principles, including modeling of spatial information, geometric and semantic models, topology and metrics; practical training with GIS software.

Objective
Know the fundamentals in geoinformation technologies for the realization, application and operation of geographic information systems in engineering projects.

Content
Modelling of spatial information
Geometric and semantic models
Topology & metrics
Raster and vector models
Databases
Applications
Labs with GIS software

Literature

Competencies

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<tr>
<th>Subject-specific Competencies</th>
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<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Cooperation and Teamwork</td>
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<td>Self-presentation and Social Influence</td>
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103-0187-AAL Satellite Geodesy
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract

Objective
Understanding the major observation techniques in space geodesy as modern methods applied in Earth system monitoring (geometry, rotation and gravity field of the Earth and the atmosphere), in national surveying and navigation.

Content
Overview of GPS, VLBI, Satellite and Lunar Laser Ranging (SLR/LLR), Satellite Radar Altimetry with the basic principles, the instruments and observation equations. Modelling of the station motions and the estimation of station coordinates. Basics of wave propagation in the atmosphere. Signal propagation in the ionosphere and troposphere for the different observation techniques and the determination of atmospheric parameters. Equation of motion of the unperturbed and perturbed satellite orbit. Oscillating and mean orbital elements. General and special perturbation theory and the determination of satellite orbits.

Literature
Script M. Rothacher “Space Geodesy”

401-0363-AAL Analysis III
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
Understanding the major observation techniques in space geodesy as modern methods applied in Earth system monitoring (geometry, rotation and gravity field of the Earth and the atmosphere), in national surveying and navigation.

Objective
Understanding the major observation techniques in space geodesy as modern methods applied in Earth system monitoring (geometry, rotation and gravity field of the Earth and the atmosphere), in national surveying and navigation.

Content
Overview of GPS, VLBI, Satellite and Lunar Laser Ranging (SLR/LLR), Satellite Radar Altimetry with the basic principles, the instruments and observation equations. Modelling of the station motions and the estimation of station coordinates. Basics of wave propagation in the atmosphere. Signal propagation in the ionosphere and troposphere for the different observation techniques and the determination of atmospheric parameters. Equation of motion of the unperturbed and perturbed satellite orbit. Oscillating and mean orbital elements. General and special perturbation theory and the determination of satellite orbits.

Literature
Script M. Rothacher “Space Geodesy”
Abstract
Introduction to partial differential equations. Differential equations which are important in applications are classified and solved. Elliptic, parabolic and hyperbolic differential equations are treated. The following mathematical tools are introduced: Laplace transforms, Fourier series, separation of variables, methods of characteristics.

Objective
Mathematical treatment of problems in science and engineering. To understand the properties of the different types of partial differential equations.

Content
Laplace Transforms:
- Laplace Transform, Inverse Laplace Transform, Linearity, s-Shifting
- Transforms of Derivatives and Integrals, ODEs
- Unit Step Function, t-Shifting
- Short Impulses, Dirac's Delta Function, Partial Fractions
- Convolution, Integral Equations
- Differentiation and Integration of Transforms

Fourier Series, Integrals and Transforms:
- Fourier Series
- Functions of Any Period p=2L
- Even and Odd Functions, Half-Range Expansions
- Forced Oscillations
- Approximation by Trigonometric Polynomials
- Fourier Integral
- Fourier Cosine and Sine Transform

Partial Differential Equations:
- Basic Concepts
- Modeling: Vibrating String, Wave Equation
- Solution by separation of variables; use of Fourier series
- D'Alembert Solution of Wave Equation, Characteristics
- Heat Equation: Solution by Fourier Series
- Heat Equation: Solutions by Fourier Integrals and Transforms
- Modeling Membrane: Two Dimensional Wave Equation
- Laplacian in Polar Coordinates: Circular Membrane, Fourier-Bessel Series
- Solution of PDEs by Laplace Transform

Literature

For reference/complement of the Analysis I/II courses:
Christian Blatter: Ingenieur-Analysis (Download PDF)

Prerequisites / notice
Up-to-date information about this course can be found at:
http://www.math.ethz.ch/education/bachelor/lectures/hs2013/other/analysis3_itet
Geomatics Master - Key for Type

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<tr>
<th>Key for Type</th>
<th>Description</th>
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<tr>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<td>Dr</td>
<td>Suitable for doctorate</td>
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Key for Hours

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<tr>
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<td>G</td>
<td>lecture with exercise</td>
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<td>U</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
History and Philosophy of Knowledge Master

Basic Courses

Lectures and Exercises

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>862-0050-00L</td>
<td>Theory and Methodology MAGPW</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>T. Bartoletti, N. Kirchner, D. Lucas</td>
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<td>Abstract</td>
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<td></td>
<td>Introduction to methods, theories and work techniques of the disciplines represented in the study programme.</td>
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<td></td>
<td>The interdisciplinary seminar is aimed exclusively at students of the master's program &quot;History and Philosophy of Knowledge&quot;. It is designed to give students an insight into the subjects represented in the degree program and their specific requirements, procedures, questions and working techniques.</td>
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<td>Dates: Thursday, 10-12</td>
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<tr>
<td>853-0725-00L</td>
<td>History Part One: Europe (The Cradle of Modernity, Britain, 1789-1914)</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>H. Fischer-Tiné</td>
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<td>A range of fundamental processes have transformed European societies in the course of the 19th and the 20th centuries. This lecture series looks at several key aspects of these modernization processes and asks about their continuing relevance for our times. The regional focus lies on Britain, where these processes took place for the first time.</td>
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<td>At the end of this lecture course, students can: (a) highlight the most important changes in the &quot;long nineteenth century&quot; in Britain (b) explain their long-term effects (also for other European countries); and (c) relate these changes to global developments today.</td>
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<td>The thematic foci include: Industrialization, urban growth, democratization and mass politics, shifting gender roles and ideals, and the emergence of consumerism and leisure culture.</td>
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<td>Lecture notes</td>
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<td>Power Point Slides and references will be made available in digital form during the course of the semester.</td>
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<td>Mandatory and further reading will be listed on the course plan that is made available from the first session.</td>
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<td>This lecture series does not build upon specific previous knowledge by the students.</td>
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<td></td>
<td>Critical Thinking</td>
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<tr>
<td>851-0360-00L</td>
<td>The Tower of Babel: From Babylon to Babel Fish</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>P. Gerard</td>
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<td>&quot;Will the vocabularies never cease clashing?/Werden die Wörterbücher immer streiten?/Will the bickerwords never grow silent.&quot;</td>
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<td>- Eugene Jolas, &quot;Babel: 1940&quot;</td>
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<td>To situate contemporary discussions of machine translation in relation to earlier literary and philosophical reflections on the problem of linguistic diversity.</td>
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<td>To gain familiarity with historical origins of machine translation and the stages of its development until the present.</td>
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<td>To draw historical, thematic, and conceptual connections between the emergence of machine translation in the middle of the twentieth century and the impulses driving post-war literary and theoretical texts.</td>
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<td>To apply information theory to the analysis of literary texts.</td>
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<td>To use literary texts to interrogate the operation of telecommunications systems and the assumptions on which those systems rest.</td>
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<td>Media and Digital Technologies</td>
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<td>Self-presentation and Social Influence</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
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<tr>
<td>851-0038-00L</td>
<td>Philosophical Ethics of Life and Death</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>N. Mazouz</td>
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<td>Abstract</td>
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<td>This course discusses ethical issues relating to life and death, e.g. reproductive technology, euthanasia, organ transplantation, genetic engineering, animal and nature conservation, human enhancement, animal welfare, nature conservation, biodiversity and our relation to nature more generally.</td>
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<td>Students will get an overview of different historical and contemporary approaches in bioethics. They are enabled to further developing their abilities to understand complex theories, to critically reflect on them and to put them up for discussion.</td>
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The aim is to evoke History as a source of creation for writers. The aim is to identify the bridges built by this transdisciplinarity, and to question the way in which History is "rewritten" by literature, after having been at its origin.

Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Decision-making
- Communication
- Cooperation and Teamwork
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

Competencies
- Literature and History
  - W 3 credits 2V
  - L.-P. Dalembert

Abstract
Literature and history have often coexisted, "dialogued". History is a recurring theme in many literary works. In this seminar, we will explore the relationship between literature and history.

Objective
The aim is to evoke History as a source of creation for writers. The aim is to identify the bridges built by this transdisciplinarity, and to question the way in which History is "rewritten" by literature, after having been at its origin.

Content
Literature and history have often coexisted, "dialogued". History is a recurring theme in many literary works. In this seminar, we will explore the relationship between literature and history. We'll look at several periods of world history, from America to Europe and Africa. The aim is to evoke History as a source of creation for writers. The aim is to identify the bridges built by this transdisciplinarity, and to question the way in which History is "rewritten" by literature, after having been at its origin. To illustrate our points, we will draw on 20th- and 21st-century novels by French, Haitian and Algerian authors...

- Rosalie L'Înflâme, Évelyne Trouillot
- Le Manuscrit de Port-Ebène, Dominique Bona
- L'Affaire de l'esclave Farcy, Mohammed Aïssouai
- Cris, Laurent Gaudé (First World War)
- Sigmarigen, Pierre Assouline (World War II)
- Avant que les ombres s'effacent, Louis-Philippe Dalembert (Second World War)
- Où j'ai laissé mon âme, Jérôme Ferrari (Second World War & Algerian War)

851-0015-00L Literature and History (c.1700-1950) W 3 credits 2V H. Fischer-Tiné

Abstract
Each session focuses on a particular commodity and explores how its production, trade and consumption was entangled with important political, social and cultural developments. Taken together, the case studies (ranging from agricultural crops, via chemically produced drugs to mechanical marvels such as the gramophone) provide a picture of major global transformations in the past 300 years.

Objective
On one level, the course aims to familiarise students with a currently much debated approach to the writing of global history, namely the history of commodities. Each case study is used to deepen the participants' understanding of complex historical developments by telling seemingly simple stories in a global frame. Thus, for instance, the session on sugar explores plantation economies in the Caribbean and the transatlantic slave trade as well as shifting patterns of diet and consumption in Europe. The session on rubber focuses on botanical expeditions in Latin America, the deployment of Chinese coolies on Malaysian rubber farms and the rise of the automobile mass production in the USA. By linking the familiar to the unfamiliar and 'exotic' the inter-cultural sensitivity of the students will be enhanced.

Content
A Sampler of Histories and Philosophies of Mathematics Particularly suitable for students D-CHAB, D-INFK, D-ITET, D-MATH, D-PHYS

Abstract
This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be selected for discussion depending on the students' interests.

Objective
The course aims are:
1. To introduce students to the historicity of mathematics
2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
3. To develop critical reflection concerning the nature of mathematical objects
4. To introduce various theoretical approaches to the philosophy and history of mathematics
5. To open the students' horizons to the plurality of mathematical cultures and practices

Competencies
- Concepts and Theories
- Analytical Competencies
- Creative Thinking
- Critical Thinking
- Sensitivity to Diversity
- Self-awareness and Self-reflection

851-0013-00L Truth and Historical Injustice: The Production of W 3 credits 2V S. M. Scheuzger
Knowledge about Past Mass Atrocities

Abstract
The course deals with the scientific production of knowledge about past mass atrocities. It looks at the interplay of different disciplines, methods and technological means that have been involved in this production over time. Further, it poses the question of what truth can mean in this context.

Objective
The students a) know the main features of the discussion about the truth in the reconstruction of past events; b) have an understanding of the interplay, but also the coexistence of different scientific methods and inter-disciplinary means in the multidisciplinary production of knowledge about past mass crimes; c) have knowledge of important processes of dealing with past mass crimes from the second half of the 20th century onwards.

Content
When discussing the truthfulness of the academic study of the past, politically and ideologically motivated mass crimes are often cited as historical events in order to substantiate the necessity of a claim to truth. In doing so, moral arguments can be made or historical truth can be asserted as a basic prerequisite for living together in a democratic society under constitutional conditions.

The production of knowledge about past atrocities has always been an endeavour in which various scientific disciplines have been involved. The multidisciplinary character of the production of knowledge about mass crimes has become even more accentuated since the second half of the 20th century, not least due to the emergence of new technological possibilities.

The course offers a brief introduction to the discussion about the meaning of truth about past events. It looks at how different scientific approaches - from the humanities to the natural sciences - have been involved in coming to terms with mass crimes and how they have been related to each other. It deals with the question of what role certain techniques and technologies have played in the production of knowledge about past atrocities and how this has changed over time. These techniques and technologies range from the evaluation of documents and the taking of testimonies to specialised database programs, genetic analysis or imaging techniques, to digital technologies for the procurement of information on social media and the internet or for the modelling of past events.

In addressing these questions, the course looks at processes of dealing with the past from the middle of the 20th century to the 21st century in Europe, Latin America and Africa.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: fostered
- Critical Thinking: fostered

Personal Competencies

851-0020-00L Gender and Science

Abstract
This lecture series offers an introduction to the relationship between gender and science, with a focus on the specific intersections with the sciences taught at ETH.

Objective
This lecture series is designed to acquaint students from all levels and departments with the various ways in which gender perspectives matter for specific scientific disciplines, as well as for science in general. Students will learn to recognize and analyse the specific ways in which scientific theories and methods are gendered. They will be able to discuss and reflect how these topics are connected to their own scientific disciplines.

Content
There is agreement across academic disciplines today that gender influences and structures the production of knowledge and that scientific knowledge production in turn shapes gender notions. Even within “hard” sciences such as mathematics, physics, engineering, etc., gender is a significant factor in determining what counts as “objective” knowledge, who can know it, what kind of knowledge is produced, or how this knowledge is acquired and justified. Feminist research aims to reveal how dominant conceptions of science and knowledge practices disadvantage women*, and other subordinate groups, with the goal of reforming these practices. An important part of feminist critique is to show that such efforts substantially improve the overall quality of research.

The semester will start with two introductory lectures acquainting students with research questions in the field of Gender and Science by summarizing its key concepts and methods. It will then continue as a series of weekly guest lectures by scholars from different scientific disciplines that provide accessible insights into the intersection between gender studies and the guest lecturer’s research field. Students will thereby be encouraged to learn from concrete examples rather than abstract theory. The goal is for students to understand how to apply concepts and methods of gender studies to their particular disciplines. Intermediate discussions with the students will provide a forum for critically reflecting the content of the lectures and the connections to their own academic fields and practices.

All lectures by the guest speakers will also be open to the broader ETH public, while the introductory and discussion sessions are only for registered course participants.

851-0157-28L Life and Death

Abstract
This course explores the relation between the scientific investigation of life and cultural notions of death from a historical perspective (assuming there is no such thing as the scientific investigation of death). While the course covers the times from antiquity up to the present, the main emphasis will be placed on the modern life sciences since the 19th century.

Objective
There is only one certainty in life: death. This brute fact has animated much thought and work in theology, art and philosophy - but also in the natural sciences, such as biology and medicine. Questions regarding health and disease, evacuation, extinction and immortality have played a crucial role in this connection.

Content
The course aims to explore above relations - the relations between the scientific investigation of life and cultural notions of death - from a historical perspective (assuming there is no such thing as the scientific investigation of death). While the course covers the times from antiquity up to the present, the main emphasis will be placed on the modern life sciences since the 19th century.

851-0202-00L Digital Humanities: Methods, Challenges, Perspectives

Abstract
In the 21st century, the humanities and the social sciences are undergoing a ground-breaking transformation: Data-driven, collaborative projects open up new opportunities. Which are the promises and the challenges of digital methods? The lecture series provides an overview of the latest developments.

Objective
- exploring the most important theoretical and methodological approaches since 2000
- understanding terms and procedures
- using digital texts, images and metadata
- reflecting on the conditions, opportunities and problems of digital methods

Content
The possibilities (Franco Moretti, Graphs, Maps, Trees, Verso 2005; Andrew Piper, Enumerations, Chicago UP 2018) and pitfalls (Franco Moretti, The Wrong Move, Konstanz UP 2022) of cultural history under digital conditions require critical reflection and evaluation. The lecture will explore showcases and pioneering work, annotated texts, images, metadata and interfaces provided by libraries, archives and museums. Research approaches and practical applications will be presented and evaluated.

851-0527-00L Introduction to the History of Technology: Concepts, and Current Debates

Abstract
Technology and society cannot be separated: No society functions without technology. The seminar offers a problem-oriented introduction to basic questions of the history of technology, introduces approaches to the history of technology and discusses selected, ongoing debates.

Objective
The course seeks to provide a critical introduction to the issues, methods, and selected areas of research in the history of technology.
851-0453-00L  Artificial Intelligence and Human Values  

W 3 credits  

M. Boenig-Liptsin, K. Wodajo  

Abstract  
This course introduces students to the ethical, political and legal debates and transformations in relation to Artificial Intelligence and provides students with concepts and methods from the constructivist and interpretive social sciences to work towards responsible and democratic human-technology futures.  

Objective  
The main objectives of the course are to enable students to 1) identify the ways in which human values and developments of AI technologies are entangled, 2) articulate what is significant about contemporary transformations in AI and society, and 3) participate and shape the relationship between human values and AI as citizens and professionals.  

Content  
The growing presence of AI tools for public use, for public administration, inside corporations and in scientific research raises many questions about the ethical, political, legal consequences of these technologies. This course is built around multiple sites of encounter among human values and AI, including bodies, persons, cities, labs, law, and environment. In each site, we inquire about what and whose values are being prioritized and with what consequences. The course also investigates existing best-practices around how to "align" human values with AI (e.g., human-centric design, alignment, reproducibility, transparency, explainability) and introduces students to regimes of ethics and governance of AI being proposed in jurisdictions around the world. Students learn to unpack the values and assumptions in existing techniques and frameworks for the design and governance of AI and to engage constructively with diverse stakeholders to shape the human-technology future towards aims that are reflexive, responsible, and democratic.  

851-0297-00L  Manipulation in Literature and Cultural History  

W 3 credits  

S. S. Leuenberger  

Abstract  
This lecture focuses on the manipulation and control of individuals and the masses. The power of manipulation is based on subtle use of persuasive linguistic elements and knowledge of the desires and fears of the intended audience. In addition to a theoretical overview, the lecture concentrates on the literary and discursive texts that dispute the control of protagonists.  

Objective  
Students will learn about manipulation as a linguistic and narrative phenomenon steeped in myth and classical rhetoric. Against the backdrop of cultural-historical developments, particularly with regard to major changes in media technology, we will examine how the reach of manipulation was extended from the individual to the masses. Students will be able to refine their critical discourse analysis skills and interdisciplinary abilities by studying texts from literature, politics, sociology, philosophy and psychoanalysis which reflect this shift in emphasis.  

Content  
Since the dawn of time mankind has tried to exert influence over others through the utilisation of certain techniques: initially for self-preservation – for example the interpretation of Sigmund Freud in Totem und Tabu. Later, desire became the driving force – centre stage: the desire for pleasure, power and control. Manipulation manifests itself in the form of characters and words, it is an authentically linguistic occurrence: classical antiquity, with the rhetoric, develops a system of verbal power of persuasion and, already then, questions were being raised in literary and discursive texts about how people could, or even should, manipulate. The exertion of influence and its impact will be clearly described, propagated, commented upon, criticised and ironised. In contrast to oppressive overpowering, the power of manipulation (in Latin, manus hand, plere fill) is on the one hand, based on the subtle use of persuasive linguistic elements – it is always a (literary) discourse, too – and on the other, on knowing precisely what the fantasies, desires and fears of the manipulated are. The discourse of manipulation has its beginnings in the age of sophists and their belief in an omnipotence of language and rhetoric. It underwent further transformation under political and psychological signs in the early modern period through Giordano Bruno and Niccolò Machiavelli and culminated in the 20th century in a critique of the deception strategies of the "culture industry" (T.W Adorno) and "psychotechnology" (B. Stiegler) in global capitalism. Nowadays social media is the "radicalisation machine" (J. Ebner) that present new challenges for society. Written in the 19th century, the Protocols of the Elders of Zion already gave indications of how present-day conspiracy theorists would manipulate their audience, and its impact can still be felt today. Since manipulation is a linguistic, narrative and also literary phenomenon, the central theme of the lecture is how in literature itself this often politically controversial and manipulative behaviour is picked up and reflected through poetry: such as in Tristan from Gottfried von Strassburg, Goethe's Wilhelm Meister, Friedrich Schiller's Die Verschwörung des Fiesco zu Genua or Heinrich von Kleist's Der zerbrochene Krug, the works of Edgar Allan Poe and Thomas Mann (Mario und der Zauberer) and, most recently in Eckhart Nickel's novel, Hysteria.  

Competencies  
Subject-specific Competencies  
- Concepts and Theories  
  - Techniques and Technologies  
Method-specific Competencies  
- Analytical Competencies  
  - Decision-making  
  - Media and Digital Technologies  
  - Problem-solving  
Social Competencies  
- Communication  
  - Cooperation and Teamwork  
  - Sensitivity to Diversity  
  - Negotiation  
Personal Competencies  
- Adaptability and Flexibility  
  - Creative Thinking  
  - Critical Thinking  
  - Integrity and Work Ethics  
  - Self-awareness and Self-reflection  
  - Self-direction and Self-management  

Seminar  
Readings in Environmental Thinking  
W 3 credits  
J. Ghazoul  

Abstract  
This course introduces students to foundational texts that led to the emergence of the environment as a subject of scientific importance, and shaped its relevance to society. Above all, the course seeks to give confidence and raise enthusiasm among students to read more widely around the broad subject of environmental sciences and management both during the course and beyond.  

Objective  
The course will provide students with opportunities to read, discuss, evaluate and interpret key texts that have shaped the environmental movement and, more specifically, the environmental sciences. Students will gain familiarity with the foundational texts, but also understand the historical context within which their academic and future professional work is based. More directly, the course will encourage debate and discussion of each text that is studied, from both the original context as well as the modern context. In so doing students will be forced to consider and justify the current societal relevance of their work.
The course will be run as a book reading club. The first session will provide a short introduction as to how to explore a particular text (that is not a scientific paper) to identify the key points for discussion.

Thereafter, in each week a text (typically a chapter from a book or a paper) considered to be seminal or foundational will be assigned by a course lecturer. The lecturer will introduce the selected text with a brief background of the historical and cultural context in which it was written, with some additional biographical information about the author. He/she will also briefly explain the justification for selecting the particular text.

The students will read the text, with two to four students (depending on class size) being assigned to present it at the next session. Presentation of the text requires the students to prepare by, for example:
- identifying the key points made within the text
- identifying issues of particular personal interest and resonance
- considering the impact of the text at the time of publication, and its importance now
- evaluating the text from the perspective of our current societal and environmental position

Such preparation would be supported by a mid-week tutorial discussion (about 1 hour) with the assigning lecturer.

These students will then present the text (for about 15 minutes) to the rest of the class during the scheduled class session, with the lecturer facilitating the subsequent class discussion (about 45 minutes). Towards the end of the session the presenting students will summarise the emerging points (5 minutes) and the lecturer will finish with a brief discussion of how valuable and interesting the text was (10 minutes). In the remaining 15 minutes the next text will be presented by the assigning lecturer for the following week.

The specific texts selected for discussion will vary, but examples include:
- Leopold (1949) A Sand County Almanach
- Carson (1962) Silent Spring
- Naess (1973) The Shallow and the Deep
- Jared Diamond (2005) Collapse

Discussions might also encompass films or other forms of media and communication about nature.

Competencies

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851-0039-00L Plural Perspectives on Rationality

Rationality has been treated as a “universal” character of human beings. But such understandings, though dominant, also came under androcentric and Eurocentric critiques. They point out that exclusion of women and people of color is not aberrant but scientific practices, but rather constituent of the principle modern science based on. This seminar offers plural perspectives on rationality.

Students will be introduced to theories of rationality from different philosophical traditions. Their ways of thinking shall be enriched and their sensibilities towards diversity improved. Students will participate in discussions, gain and sharpen their ability to understand complicated texts and identify arguments.

Understood as a distinctive human attribute, rationality has been treated as a “universal” character of human beings. But the course of philosophy has witnessed how dominant understandings of rationality came under androcentric and Eurocentric critique. Such reflections argue that exclusion of women and people of color is constituent of the principle modern science is based on rather than aberrant bad scientific practices.

What counts as reasonable? What is rational? These questions seem quintessential. We deal with them every day. Telling right from wrong, true from false is considered a basic ability of reasoning. For example, clarity and consistency are what we almost always strive for, while contradictions and ambiguities are what we try our best to avoid. Such tendency, which is to be found not only in everyday life but also in science of different kinds, seems to suggest that there is nothing valuable, nothing worth learning from ways of reasoning that do not share these standards – or even deny that they can count as rationality at all. Nevertheless, when taking into consideration the androcentric and Eurocentric critiques modernity has been receiving so far, it is questionable whether the standard of rationality can really (or justifiably) be so impoverished. How can we think about rationality otherwise? Can we learn anything valuable from, for example, contradictions and ambiguities? If so, how to think about these unconventional ways of reasoning? In this seminar we will read and discuss theories of rationality from diverse philosophical traditions.

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851-0622-00L Inequality and Injustice: Economic and Philosophical Perspectives

Globalization and technological progress in recent decades have on the one hand reduced inequality and led to new forms of inequality on the other hand. The question is whether these new forms of inequality lead to more inequality. This course provides an overview of the current philosophical and economic discourse on inequality and injustice.

Using philosophical and economic texts and discussions, students develop an understanding of the concepts, developments, causes, and consequences of inequality. Students will acquire the ability to participate in an informed discourse on the issues of inequality and injustice and to critically reflect on their actions and position in the world.
Content

In this seminar we will explore the issues of inequality and injustice. In doing so, we will explore the following questions: What is meant by inequality and injustice? Under what circumstances are inequalities unjust? Have inequalities and injustices increased or decreased over the last 50 years? What are the causes of increasing or decreasing inequality? What do these inequalities and injustices mean for our society? And what public and private measures are needed for more inclusive societies?

- Concepts of inequality and injustice
- Development of inequality over the last 50 years based on different dimensions of inequality: income, wealth, education, health, CO2 emissions, political participation
- Discrimination of women, people with physical disabilities, people of the "Global South"
- Causes of inequality: globalization, technological progress, political systems and institutions, economic system, social discrimination, stereotypes and norms.
- Consequences of inequality: justice, dignity, inefficiency
- Towards more inclusive societies: the role of policies, civil society, social movements and individual behavior.

The seminar is based on readings of economic and philosophical texts and is complemented by short presentations and discussions with scholars of philosophy and economics. In some cases, practitioners will also be invited to the seminar. Students will apply the concepts, theories and knowledge covered in the course to practical issues related to inequality and inequity.

862-0122-00L Science and Mysticism ■

Abstract

Mysticism and science appear to be the greatest possible opposites: mysticism is based precisely on the abandonment of knowledge, science on the overcoming of mysticism. Yet in fact, there are far-reaching connections between the two: skepticism, language criticism, experience, subjectivity, ecstasy, anomaly. We want to examine these using texts from medieval as well as modern neo-mysticism.

Objective

At first glance, mysticism and science appear to be the greatest possible opposites: mysticism is based precisely on the abandonment of knowledge, whereas science is based on overcoming mysticism. However, upon closer inspection it becomes clear that there are different and far-reaching mediations between the two. Because what characterizes the mysticism developed in different religions in the Middle Ages (if it can even be defined in general terms) is the criticism of a certain, namely dogmatic, knowledge, in contrast to which something that seems surprisingly modern is emphasized: subjective experience. The emphatic theory of experience, the subject (and its dissolution), but also language (and its criticism) are among the reasons for the rediscovery of mysticism in modern times around 1900 in philosophy and literature, in science and politics. In the MAGPW seminar we will examine the complex relationship between mysticism and science using theoretical problems, including "negative theology" and anti-science (ignorance), (radical) skepticism, language criticism, experience, subject dissolution, ecstasy, anomaly. We start from concrete texts, on the one hand from the interreligious spectrum of medieval mysticism (such as Eckhart, Abulafia, Al-Gazali), and on the other hand and above all from modern neo-mysticism around 1900 (such as Gustav Landauer, Martin Buber, Wittgenstein, Robert Musil, Hermann Broch).

851-0037-00L Ethics of Building ■

Abstract

Building practices have often been associated with utopian visions and promises of a more just way of living together. But to what extent can the built environment contribute to a better society? What role can mathematical models or data analyses play in questions of distributive justice in the city? Is it ever possible to build sustainably, or is building always also destroying the environment?

Objective

Students will learn about contemporary debates in architectural and urban planning ethics. We will discuss the positions against the background of their historical predecessors and current contexts. Students will work on small case studies in which they will ethically analyze the construction of a building, a district or a city. The seminar includes a student-co-led expedition through Zurich.

Content

Throughout history, there have always been utopian visions and promises tied to construction, be it of individual objects, such as towers, or of entire cities. For example, thanks to their geometric shapes, modern cities are supposed to enable more equality among people, even the equal distribution of sunshine, as Le Corbusier once dreamed. But to what extent is it even possible to create more equality by designing living spaces? A wall automatically excludes by protecting the interior. Building cities always means defining the far and the near, the center and the periphery, the upper and the lower. These orientations translate into social relations for example of those who have to commute far and those who are at the center of the action. Who determines how and what is built and whose perspective is not taken into account? To whom does a built landscape afford agency and to whom not? Mathematical models can predict the probabilities of commuting far and those who are at the center of the action. We start from concrete texts, on the one hand from the interreligious spectrum of medieval mysticism (such as Eckhart, Abulafia, Al-Gazali), and on the other hand and above all from modern neo-mysticism around 1900 (such as Gustav Landauer, Martin Buber, Wittgenstein, Robert Musil, Hermann Broch).

851-0067-00L Science Studies between economic growth, social needs and critique

Abstract

Science has become a subject of research in its own right since the 20th century: the field of "science studies" examines the organization of science, its social benefits, its contribution to economic growth or its impact on people and nature. The seminar introduces the history of this research and sheds light on its applied and critical dimensions.

Objective

Using historical sources from the field of science studies, students learn to understand societal expectations and criticisms of the sciences in the 20th and 21st centuries.
The value of science for social and economic development has been an issue of debate since the 20th century. At the same time, science became a subject of research in its own right: the sociology of science in the 1930s dealt with the social benefits (“Science for Social Needs”) and the organization of science. Since the 1950s, the research field of the “Science of Science” has quantified scientific publications (“Science Citation Index”) and attempted to measure the relationship between research and innovation, between education and economic growth (OECD studies). Science seemed to promise scientific and technical progress, innovation and economic growth both in the industrialized countries and, with the help of “technology transfer”, to the then so-called “developing countries”. At the same time, in the field of “technology assessment”, the sciences were criticized for causing risks and damages to humans and nature (e.g. through pesticides or biotechnology) or entailing effects of social inequality.

The fact that the sciences have been the subject of debate since the 20th century is not only a matter of general public interest. It is also the effect of the development and funding of research fields that deal with measures to increase innovation or with the benefits and risks of science. The seminar deals with the history of this research in its political and economic contexts as well as in its applied and critical function. It examines the knowledge on which historical and current expectations of science in politics and society are based.

**Literature Sources (selection):**
- J.D. Bernal: The Social Function of Science (1939)
- Derek de Solla Price: Little Science, Big Science (1963)
- Hilary Rose & Steven Rose: Science and Society (1969)
- Christopher Freeman: Economics of Research and Development (1977)
- Ziauddin Sardar, Dawud G. Rosser-Owen: Science Policy and Developing Countries (1977)
- Donna Haraway: Class, Race, Sex, Scientific Objects of Knowledge (1982)

**Secondary literature (selection):**
- Gerardo Ienna: The Double Legacy of Bernalism in Science Diplomacy (2022)
- Elena Aronova: Scientometrics and with and without Computers: The Cold War Transnational Journeys of the Science Citation Index (2016)
- Elena Aronova & Simone Turchetti: Science Studies During the Cold War and Beyond (2017)

**Competencies**
- Subject-specific Competencies: Fostered
  - Concepts and Theories
  - Analytical Competencies
  - Communication
  - Cooperation and Teamwork
  - Sensitivity to Diversity
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection

**Content**

851-0281-00L  **The Knowledge of Poetry**  
*W* 3 credits  
2V  
C. Jany  

**Abstract**
Novals once described poetry as “the mind’s inherent way of acting”. Thinking takes place in verses and images, rather than concepts and formulas. If this were true, every spontaneous cognition would amount to poetry and each thought essentially to a poem -- a structure combining and concentrating ideas, perceptions, and emotions. Knowledge and poetry would be one.

**Objective**
Such is the promise literature has made since its inception, a promise we will examine in this class by considering mainly lyrical compositions in verse, from the beginnings to the present. The central question is: What do poems know and what is the relationship between thinking in verse and technical and scientific knowledge?

851-0077-00L  **Philosophy of War**  
*W* 3 credits  
2S  
O. Del Fabbro  

**Abstract**
In the course we read classical texts from the field of philosophy of war (Clausewitz, Sun Tzu, Tolstoy, Machiavelli, Kant) and focus on questions such as: what is war? Strategy and tactics in war? Ethics of war? War and Politics?

**Objective**
Students learn about the different types of argumentative texts and their historical, social, political and ethical context. They learn to understand the descriptive and critical value of texts in regard to the topic of war.

851-0019-00L  **Insect Histories: Bugs that Made the Modern World**  
*W* 3 credits  
2S  
T. Bartoletti  

**Abstract**
The seminar explores insects as historical actors and their diverse interactions with human societies over time and space. It offers an overview of recent approaches in environmental history and multispecies ethnography while providing an analytical framework to understand global processes of natural resource exploitation, knowledge formation, and imperialism.

**Objective**
The objective is to analyze human-insect interactions by identifying key historical factors (economic, scientific, political). Students will integrate current frameworks in the study of environmental history through the combination of primary sources and interdisciplinary research. They will develop skills rooted in their interest in insects and learn to translate them into feedback to peers.

**Content**
Scholars typically approach Nature-related histories by focusing on environmental change, the commodification of resources, and the legacy of natural history collections. Examples of this approach include studies on deforestation, dam constructions, the rubber boom, and the colonial history of European museums. In contrast to these commonly explored topics, insects are often underrepresented in historical research, both as living creatures and metaphors. Addressing this gap, the seminar explores human-insect interactions from a global historical perspective between 1600 and 2000. This exploration encompasses a critical and relational understanding of the history of the scientific study of insects (entomology) and the processes of imperial expansion and global territorialization. To achieve this, students will learn how human-insect interactions led to radical transformations in diverse environments, reflecting a particular modern conception of nature influenced by control anxieties related to economic profit and tropical diseases. Moreover, students will examine how ways of knowing about insects and the environment were influenced by broader correlated economic and imperial factors. Focusing on insect (hi)stories, the aim of this seminar is to apply new methodologies for non-human agencies and source analysis on both micro and macro scales in global and environmental histories.

851-0304-00L  **Science Fiction**  
*W* 3 credits  
2S  
A. Klischer, S. Lohmann  

**Abstract**
Literature in general can be seen as fundamentally concerned with the forms and functions of knowledge and (sometimes scientific) understanding, but the genre of science fiction is unique in that it literalizes this approach in a far-reaching fashion as the future of science and technology. We will explore knowledge, and the “science of literature” through a diverse range of science fiction texts.

**Objective**
- Concept and history of science fiction
- Theory of science fiction and related forms (e.g. utopia, fantasy)
- Contexts of the history of knowledge and technology in the 19th and 20th centuries.
- Potential of science fiction to criticize technology and society
Content
This course introduces students to the various forms and functions of knowledge and science in literature, particularly within the realm of science fiction, the genre that most directly epitomises this fundamental connection within literary texts. In analysing how it shifts our understanding of ourselves and of supposedly inalterable facts about the reality we inhabit, we will examine how science fiction demonstrates that fiction is neither fundamentally in conflict with scientific knowledge, as previously supposed, nor a mere vehicle for its celebration, as still commonly presumed of science fiction. Instead, the genre, with its radical investigations into other forms of being, fearing and hoping, plays a crucial role in the social formation, order and negotiation of knowledge. As such, science fiction also represents a vital thought experiment regarding the "science of fiction", i.e. the development of a knowledge of literature and the many fascinating ways in which it helps us to know our own world better, in turn.

In this course, we will take a systematic and theory-based approach to a deeper understanding of science fiction, particularly concerning its historical background, unique aesthetic/narrative tools, and relationship with the critical and technocultural contexts that shape it. Employing contemporary theoretical approaches, we will discuss a variety of themes within primary texts alongside diverse critical sources, all of which ultimately relate to knowledge and knowability. Particular areas of focus may include: other worlds and alien existences; altered temporality and alternate history; utopia and dystopia; climate fiction and the Anthropocene; posthumanist and cyborg identities; robots and AI; and alternative futures. Moreover, the course will thereby also engage with the fundamental (and at times overlooked) role of order and presentation of knowledge, i.e. its aesthetic and narrative forms, within science and literature.

851-0456-00L Research in Ethics, Technology and Society  W 2 credits 2S  M. Boeji-Liptsin, G. Dorthe
Abstract
Through thematic discussions of readings, presentation and workshop of writing-in-progress, and discussions with invited guests, this course brings together advanced students doing research in science, technology and society to develop their knowledge and projects in community with peers, postdoctoral fellows, and faculty.
Objective
The objective of the course is to provide students doing their own research on topics in science, technology and society with focused peer-feedback and tailored theoretical and methodological discussions to support the development of their projects.
Content
The course is focused on content fromSTS and moral and political theory and develops empirical, qualitative, and interpretive social science methods, such as ethnography/participant observation, historical archival research, discourse and document analysis, and semi-structured interviews. Specific thematic, reading, methodological foci are determined by the group to meet the specific needs of each participant.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
Method-specific Competencies
- Analytical Competencies assessed
Social Competencies
- Communication fostered
Personal Competencies
- Adaptability and Flexibility fostered
- Critical Thinking assessed

851-0455-00L Science, Trust and Politics  W 3 credits 2S  G. Dorthe
Abstract
The seminar aims to inspire a nuanced understanding of the dynamics of expertise in society. Cross-fertilizing literatures from science and technology studies (STS) and from activists’ movements, it focuses on contemporary controversies around emerging technologies and climate policy, where trust in science is said to be undermined (e.g. climate skepticism or anti-vaccine movements).
Objective
1) Introduce to the role and functions of expertise in democratic societies. 2) Familiarize with assumptions about science and society embedded in contemporary controversies. 3) Inspire critical perspectives on (dis)trust in science through activists’ movements on contested environmental and technological issues. 4) Develop a creative position on the relations between science, trust and politics.
Content
Engineers and scientists often pursue their studies and research in the hope that their knowledge can contribute to make a better world, inform democratic deliberation and help public understanding of complex issues. Yet this special status of science and technology is being increasingly contested by marginalized publics, lobbies, exposed populations, and by members of the scientific communities themselves. Climate skepticism or vaccine hesitancy are some of the most vivid examples of this confusing situation. In this seminar, students will learn to reflect on expertise as a form of scientific engagement in the messiness of democratic deliberation and public life, beyond the noble but outdated ideal of “speaking truth to power”.
The exercise of expertise is stumbling upon several conundrums. Which knowledge is relevant in which situation? How to make sure that some crucial perspectives are not left in the shadows? How to identify representative experts and make sure that they speak on behalf of a structured community? Whose voices are being silenced? On the other side of the spectrum, the public is often said to lack proper understanding of science and thus in need of being educated or disciplined. Or it is suspected of being manipulated by lobbies or foreign hostile powers, or of being too attached to its own privileges and unwilling to act in favor of the common good. Whose agency is being acknowledged in sociotechnical controversies and whose agency is being denied and why? The seminar will provide a deep understanding of these perspectives, by putting them in a broader historical and epistemological context. Students will thus learn to critically assess their strengths as well as their blind spots.

Whereas opposing technological developments (anti 5G or anti-vaccine activists) or pushing to act according to science (pro climate movements such as Extinction Rebellion or Scientist Rebellion), activists’ movements make up for a rich field of investigation on the dynamics of expertise and of how various publics can make sense of scientific knowledge. Cross-fertilizing activist’s texts and experiences with literature in science and technology studies and anthropology, this class will be organized as a structured conversation and a collective mapping of actors and key concepts of sociotechnical controversies. Over the course of the semester, students will learn not only to navigate some of the most heated contemporary debates, but also to articulate their own position on an issue of their choice.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
Method-specific Competencies
- Analytical Competencies assessed
Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Sensitivity to Diversity fostered
Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking assessed
- Self-awareness and Self-reflection assessed

851-0454-00L AI Personhood, Social Justice, and Cross-Cultural Dialogues in the Digital Age  W 3 credits 2S  K. Wodajo
Abstract
The course fosters critical, culturally conscious reflection on AI development and regulation by 1) exploring cross-cultural assessment of the concept of personhood and collective in digital society and how these concepts are reflected in AI development and regulation. 2) inspiring reflection on social justice issues stemming from major misconceptions of personhood in AI development and governance
Objective
- Understand and differentiate various concepts of personhood and collective in digital societies
- Critically evaluate emerging regulations in the field of AI
- Examine the implications of these regulatory frameworks and their conception of personhood for the AI human future
- Develop creative & culturally conscious analytical skill on issues of social justice in
On 13 March 2024, the European Parliament voted in favour of the long-awaited EU AI Act. On October 30, 2023, the US passed an Executive Order on the safe, secure, and trustworthy development and use of AI. Meanwhile, China has been adopting regulations: the 2021 regulation on recommendation algorithms, 2022 rules for deep synthesis (synthetically generated content), and draft rules on generative AI on August 15, 2023. In the face of this race to develop and regulate AI across various legal, regulatory, and cultural settings, this course exposes students to the overarching question: How can we envision an AI-human future that accommodates a pluriverse and ensures a just future?

In everyday life, from education, policy deliberation, planning and prediction, governance of the human behavior and the beyond human, to social and private life, and entertainments, AI systems and AI-enabled products play a significant role. At the very center of this sociotechnical system is the human, often referred to as the ‘data subject’. This raises foundational questions: Who or what is this ‘data subject’? What warrants its protection or what makes it worthy of protection – is it the human dignity, autonomy, rationality, legally protected rights or something beyond and within all these? Who/what is considered a protected ‘data subject’, and who/what is not? While these questions might seem new, they revisit old ethical dilemmas.

However, there is no one-fits-all answer to these questions. Responses vary greatly depending on local and cultural contexts across different jurisdictions and societies. The way AI development and regulatory practices conceptualize the subject of protection – that is, the human and its environment – varies. This leads to varying interpretations of personhood and what warrants protection. What personhood means and what is protected and not are not only matters of policy or legislative interpretations and standardization but a matter of social justice.

With this consideration, the course invites and encourages students to explore the concept of personhood from a cross-cultural perspective, incorporating epistemologies from the ‘South’, including Afro-communitarianism, pluriverse theories, and Confucianism. Students are then guided to critically examine personhood and community within the context of competing AI regulatory frameworks, such as those as the EU, China, Brazil, and the US, as well as in their own interactions with AI systems. By identifying conceptual limitations in current understandings of personhood and the centrality of the collective within contemporary AI regulation and practice, students can address core social justice issues. These include the overemphasis on individualism, which overlooks the communal and relational aspects of existence (including human and the beyond human), the instrumentalization of the environment, and exploitative business models.

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**Objective**

On the one hand, students learn to know Walter Benjamin’s most influential ideas, such as his views on art criticism, history and culture, as well as his methods of interpretation (Deutung) to architectural works and the Benjaminian texts themselves. With this consideration, the course invites and encourages students to explore the concept of personhood from a cross-cultural perspective, incorporating epistemologies from the ‘South’, including Afro-communitarianism, pluriverse theories, and Confucianism. Students are then guided to critically examine personhood and community within the context of competing AI regulatory frameworks, such as those as the EU, China, Brazil, and the US, as well as in their own interactions with AI systems. By identifying conceptual limitations in current understandings of personhood and the centrality of the collective within contemporary AI regulation and practice, students can address core social justice issues. These include the overemphasis on individualism, which overlooks the communal and relational aspects of existence (including human and the beyond human), the instrumentalization of the environment, and exploitative business models.

**Content**

This seminar deals with writings by Walter Benjamin. On the one hand, his most famous and influential essays and fragments on critique, history and experience will be read and discussed, and on the other, a special focus will be placed on his thinking on architectural themes.

**Abstract**

The seminar examines the history of materials science. Why and how were materials characterized, developed and tested? How did things as diverse as wood, concrete, ceramics and polymers become objects of a single discipline? How did social imaginaries and technical conditions affect scientific work with and on materials?

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**Objective**

Students learn to critically read and interpret different types of texts. They will be familiarised with the interdependencies of technical, scientific and social change. They reflect on (material) scientific practices.

**Content**

The seminar discusses the socio-technical conditions and effects of materials research from a historical perspective in the 20th century. We observe physicists, chemists and engineers, as well as concrete, foams and electron microscopes, in research laboratories and materials testing institutes, in articles and patents.

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**Objective**

Students gain an overview of the current ethical debates surrounding the legitimacy of homicide-rescue-cases in specific types of situations. They will be enabled to interpret complex texts, identify the argumentation, to reflect it critically and to put it up for discussion.

**Content**

First, the relevant literature on moral justifications in trolley cases will be discussed (Foot, Thomson, Kamm, Otsuka, Kagan). Second, neuropsychological research on trolley cases (Greene, Haidt, Berker, Kamm) and third, applications of such moral reasoning in cases potentially arising in autonomous robots (Rahwan, Nyholm and Smids, Wolkenstein) will be considered.

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Killing innocents is generally thought to be morally impermissible – or so it seems from an intuitive point of view. However, there are situations where people can only be saved if less others are killed, for example in some traffic cases, in some cases in natural disasters, medical emergencies, terrorist attacks or humanitarian interventions. In some of these situations our intuitions stay clear and disapproving: it is not permissible to kill, even in order to save many lives, for example, to take the vital organs of one patient in order to save many more other patients. In other scenarios, the intuitions are less clear or even revert for most of us, like in the famous trolley-bystander case, in which a bystander can divert an out-of-control trolley heading towards five to a track where one person is trapped. How are these moral intuitions to be justified, if they are? In this seminar the relevant literature on moral justifications in such trolley cases will be reviewed as well as on methodological problems pertaining to the role of intuitions in moral justifications. Neuropsychological research on such cases as well as critique of the methods and normative presuppositions used in that research will be debated. Finally, attempts to apply such moral reasoning on allegedly analogous cases arising in autonomous robots will be discussed.

862-0124-00L
Friedrich Nietzsche: Life and Work
W 3 credits
A.-A. E. Särkelä

Abstract
In this reading group we deal intensively with Friedrich Nietzsche's philosophy. We analyze topics such as morality, power and criticism of science based on jointly selected works. The aim is to explore philosophical approaches and their influence on modernity to understand and critically reflect on culture and science.

Objective
In our reading group we focus on an in-depth examination of Friedrich Nietzsche's philosophy. By jointly selecting and analyzing his works, we particularly focus on central themes such as morality, power and criticism of science. Our goal is to develop and discuss Nietzsche's philosophical approaches in collective discussions. We strive to jointly reflect and critically question the influence of his ideas on modern culture and science. This cooperative approach not only promotes the understanding of Nietzsche's work, but also the creative development and deepening of one's own thoughts and interpretations within the group.

Semester Report

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<td>862-0006-00L</td>
<td>Seminar Report</td>
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<tr>
<td>Abstract</td>
<td>The report is a critical selfassessment of the students development during the last semester.</td>
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<td>Objective</td>
<td>The report should lead to the competence to judge the relation between curricula design and fostered or prevented learning processes.</td>
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<td>Content</td>
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Semester Paper

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Major Courses

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<tr>
<td>Abstract</td>
<td>The term paper allows students to explore a topic of their choice in greater depth, applying the fundamental knowledge they have acquired so far.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>The development of a research question, the careful handling of the secondary literature and an increased source-critical competence form the learning objective.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>The development of a research question, the careful handling of the secondary literature and an increased source-critical competence form the learning objective.</td>
<td></td>
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</tr>
</tbody>
</table>
In each subject of the master reading lists are handed out. The books on these lists are the subject of the tutorials one has to attend with the teachers that are named in the Leitfaden. In three subjects essays are to be written about works on these lists.

### Essay on Readings in History of Technology (HS)
- **Number:** 862-0021-00L
- **Title:** Essay on Readings in History of Technology (HS)  
- **Type:** W  
- **ECTS:** 10 credits  
- **Hours:** 21A  
- **Lecturers:** Lecturers

**Abstract:** This essay is the outcome of an individual teaching and learning process during several terms and draws upon representative books and articles in history of technology. It has to consider the state of the art in the field.

**Objective:** Writing this essay aims to become acquainted with methods, tools, and concepts relevant for the students' master thesis.

### Essay on Readings in Science Research (HS)
- **Number:** 862-0023-00L
- **Title:** Essay on Readings in Science Research (HS)  
- **Type:** W  
- **ECTS:** 10 credits  
- **Hours:** 21A  
- **Lecturers:** Lecturers

**Abstract:** This essay is the outcome of an individual teaching and learning process during several terms and draws upon representative books and articles in history of technology. It has to consider the state of the art in the field.

**Objective:** Writing this essay aims to become acquainted with methods, tools, and concepts relevant for the students' master thesis.

### Essay on Readings in Theoretical Philosophy (HS)
- **Number:** 862-0025-00L
- **Title:** Essay on Readings in Theoretical Philosophy (HS)  
- **Type:** W  
- **ECTS:** 10 credits  
- **Hours:** 21A  
- **Lecturers:** Lecturers

**Abstract:** This essay is the outcome of an individual teaching and learning process during several terms and draws upon representative books and articles in history of technology. It has to consider the state of the art in the field.

**Objective:** Writing this essay aims to become acquainted with methods, tools, and concepts relevant for the students' master thesis.

### Essay on Readings in Practical Philosophy (HS)
- **Number:** 862-0027-00L
- **Title:** Essay on Readings in Practical Philosophy (HS)  
- **Type:** W  
- **ECTS:** 10 credits  
- **Hours:** 21A  
- **Lecturers:** Lecturers

**Abstract:** This essay is the outcome of an individual teaching and learning process during several terms and draws upon representative books and articles in history of technology. It has to consider the state of the art in the field.

**Objective:** Writing this essay aims to become acquainted with methods, tools, and concepts relevant for the students' master thesis.

### Essay on Readings in Literature and Culture (HS)
- **Number:** 862-0029-00L
- **Title:** Essay on Readings in Literature and Culture (HS)  
- **Type:** W  
- **ECTS:** 10 credits  
- **Hours:** 21A  
- **Lecturers:** Lecturers

**Abstract:** This essay is the outcome of an individual teaching and learning process during several terms and draws upon representative books and articles in history of technology. It has to consider the state of the art in the field.

**Objective:** Writing this essay aims to become acquainted with methods, tools, and concepts relevant for the students' master thesis.

### Essay on Readings in History of the Modern World (HS)
- **Number:** 862-0031-00L
- **Title:** Essay on Readings in History of the Modern World (HS)  
- **Type:** W  
- **ECTS:** 10 credits  
- **Hours:** 21A  
- **Lecturers:** Lecturers

**Abstract:** This essay is the outcome of an individual teaching and learning process during several terms and draws upon representative books and articles in history of technology. It has to consider the state of the art in the field.

**Objective:** Writing this essay aims to become acquainted with methods, tools, and concepts relevant for the students' master thesis.

### Essay on Readings in History and Philosophy of Mathematical Sciences (HS)
- **Number:** 862-0035-00L
- **Title:** Essay on Readings in History and Philosophy of Mathematical Sciences (HS)  
- **Type:** W  
- **ECTS:** 10 credits  
- **Hours:** 21A  
- **Lecturers:** Lecturers

**Abstract:** One-to-one supervisions form the basis for an essay covering the paradigmatic texts studied over several semesters.

**Objective:** The instructor will work one-to-one with the student to hone the skills and fundamental topics that are relevant for the Master's thesis.

### Essay on Readings in Ethics, Technology and Society (HS)
- **Number:** 862-0037-00L
- **Title:** Essay on Readings in Ethics, Technology and Society (HS)  
- **Type:** W  
- **ECTS:** 10 credits  
- **Hours:** 21A  
- **Lecturers:** Lecturers

**Abstract:** One-to-one supervisions form the basis for an essay covering the paradigmatic texts studied over several semesters. This essay should also take recent research into account.

**Objective:** The instructor will work one-to-one with the student to hone the skills and fundamental topics that are relevant for the Master's thesis.

#### Seminars

In the seminars, topics from the introductory courses are taught in more detail. Topics for essays are to be arranged with the teachers of the courses.

### Research Colloquium

#### Number
- **Title:** Research Colloquium Philosophy for Master Students and PhD (HS 2024)
- **Type:** W  
- **ECTS:** 2 credits  
- **Hours:** 1K  
- **Lecturers:** N. Mazouz, R. Wagner

**Abstract:** Ph.D. students, post docs, members of staff, and senior colleagues from other philosophy departments will report on their work in progress. Furthermore, promising new philosophical articles and parts of new philosophical books will be studied.

**Objective:** The instructor will work one-to-one with the student to hone the skills and fundamental topics that are relevant for the Master's thesis.

#### Number
- **Title:** Research Colloquium. Extra-European History and Global History (HS 2024)
- **Type:** W  
- **ECTS:** 2 credits  
- **Hours:** 1K  
- **Lecturers:** H. Fischer-Tiné, M. Dusinberre

**Abstract:** The fortnightly colloquium provides a forum for PhD students and postdoctoral researchers to present and discuss their current work. Half of the slots are reserved for presentations by invited external scholars.

**Objective:** PhD students will have an opportunity to improve their presentation skills and obtain an important chance to receive feedback both from peers and more advanced scholars.

**Prerequisites / notice:** The venue changes each semester alternately between UZH and ETH.

#### Number
- **Title:** Research Colloquium Science Studies (HS 2024)
- **Type:** W  
- **ECTS:** 2 credits  
- **Hours:** 1K  
- **Lecturers:** M. Hagner, M. Boenig-Liptsin

**Abstract:** This colloquium is devoted to the introduction into the theory and practice of scientific work. The schedule can be found on the institute's website - http://www.wiss.ethz.ch/en/teaching/

**Objective:** This colloquium is devoted to the introduction into the theory and practice of scientific work.

**Prerequisites / notice:** Lectures may be held either in English or German. Students receive 2 credit points for submitting a brief, written commentary on one of the presented topics (approx. 5 pages).

#### Number
- **Title:** Advanced Colloquium in Literary Studies (HS 2024)
- **Type:** W  
- **ECTS:** 2 credits  
- **Hours:** 1K  
- **Lecturers:** A. Kilcher

**Abstract:** The colloquium addresses advanced and graduate students. First, it offers participants the opportunity to present their own research projects (work in progress); and, second, it provides a most fruitful space to discuss methodological, theoretical and systematic complex issues.
Objective
The colloquium addresses advanced and graduate students. First, it offers participants the opportunity to present their own research projects (work in progress); and, second, it provides a most fruitful space to discuss methodological, theoretical and systematic complex issues.

Master’s Thesis
The work on the master-thesis is supervised by one of the teachers that are allowed to offer tutorials for it, named in the Leitfaden.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>862-0500-00L</td>
<td>Master’s Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

A student is only permitted to commence the Master thesis if
a. the Bachelor degree programme has been completed
b. any additional requirements for admission to the degree programme have been fulfilled
c. all credits have been acquired in the categories basic courses and major courses and at least 6 credits have been acquired in the category research colloquium

Abstract
The Master's thesis gives a thorough historical, philological or philosophical analysis of a topic related to the experimental or formal sciences or to technology. It incorporates the relevant research literature on this topic as well as first attempts at original research.

Objective
The master thesis gives a thorough historical, philological or philosophical analysis of a topic related to the experimental or formal sciences or to technology. It incorporates the relevant research literature on this topic as well as first attempts at original research.

History and Philosophy of Knowledge Master - Key for Type

<table>
<thead>
<tr>
<th>Key for Type</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

Key for Hours

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Type</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
This course teaches the basic principles of evolution, cell biology, molecular biology, genetics and developmental biology using the example of humans.

1. Students can explain the importance of evolution for the development of humans and diseases.
2. The students know the cell as the smallest unit of the body. They can explain how the functions of the cell are disturbed in certain diseases and where therapies intervene. They can describe the multiplication of cells in the body and show how errors in this multiplication can lead to diseases.
3. The students know DNA as the basis of life. They can explain how the DNA information is stored and how this information can be reproduced and protected from damage. They can describe how the information is read and translated into proteins. They can explain which mechanisms at the level of DNA, RNA and proteins can cause diseases.
4. Students can explain which technologies can be used to diagnose and treat diseases.
5. Students can explain how people differ genetically and know the molecular basis of these differences. They can explain how these differences can lead to diseases and why some of these differences do not affect diseases.
6. The students know the molecular causes of the most common hereditary diseases and can determine the probability of occurrence and transmission to offspring.
7. Students can explain the biochemical and molecular basis of human reproduction and know the basic principles of human embryonic development. The students can explain which mechanisms can be disturbed by a faulty development.

Lecture notes
See Moodle

Literature
"Biology - How life works", Morris et al.
"Evolutionary Analysis", Herron & Freeman
"Genetics: From Genes To Genomes", Goldberg & Fischer
"Molecular Biology of the Cell", Alberts et al.

Prerequisites / notice
The course is accompanied by exercises on Moodle, group projects and mid-terms (learning elements). Upon successful completion of the learning elements (at least 80% of the total possible points must be achieved), students can receive bonus points, which can be credited towards the grade of the final examination. Acquiring points from the group projects and the mid-terms requires on-site participation (no online participation possible). Acquiring bonus points is not a prerequisite for taking part in the final exam.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed
Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Personal Competencies
Creative Thinking fostered
Critical Thinking assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

529-1001-03L General Chemistry (for HST) O 6 credits 4V+2U J. Cvengros
Abstract
The lecture deals with a number of basic chemistry concepts. These include (amongst others) chemical reactions, energy transfer during chemical reactions, properties of ionic and covalent bonds, Lewis structures, properties of solutions, kinetics, thermodynamics, acid-base equilibria, electrochemistry and properties of metal complexes.

Objective
The course is designed to provide an understanding of the basic principles and concepts of general and inorganic chemistry.

Literature
Weiterführende Literatur:
Catherine Housecroft, Edwin Constable, CHEMISTRY: AN INTRODUCTION TO ORGANIC, INORGANIC AND PHYSICAL CHEMISTRY, 3. Auflage, Prentice Hall, 2005.(englisch)

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

252-0852-00L Foundations of Computer Science O 4 credits 2V+2U M. Dahinden, L. E. Fässler
Abstract
This course provides selected computer science concepts for interdisciplinary projects.

The following topics are covered: introduction to programming, sequence analysis, modeling and simulations, introduction matrices, managing data with with relational databases.
Students learn to...
- encode a problem into a program, test the program, and correct errors.
- understand and improve existing code.
- deal with the complexity of real data.
- store data in a suitable data structure.
- query databases and understand and evaluate the corresponding database model.
- implement models from the natural sciences as a simulation.
- run random experiments and interpret the results.
- explain and apply standard algorithms and evaluate their efficiency.

<table>
<thead>
<tr>
<th>Content</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1. Variables, data types</td>
<td></td>
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<tr>
<td>2. Control structures, logic</td>
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</tr>
<tr>
<td>3. Sequential data types, search- and sort algorithms, sequence analysis</td>
<td></td>
</tr>
<tr>
<td>4. Functions, modules, simulation and animation</td>
<td></td>
</tr>
<tr>
<td>5. Manage data with a relational database</td>
<td></td>
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<tr>
<td>6. Matrices, random experiments, cellular automata</td>
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</tbody>
</table>

| Lecture notes | All materials for the lecture are available at www.gdi.ethz.ch |

This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

<table>
<thead>
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<tr>
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<tr>
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<tr>
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<td>Problem-solving</td>
</tr>
<tr>
<td>Project Management</td>
<td>fostered</td>
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<tr>
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</tr>
<tr>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<td>Adaptability and Flexibility</td>
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<tr>
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<tr>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
<td>Self-direction and Self-management</td>
</tr>
</tbody>
</table>

376-0003-00L Introduction to Health Sciences and Technology I O 4 credits 2V+2U R. Müller

Abstract
Students should know the terms, models and classification systems used in health and disease; in addition, they should understand the methods of scientific working.

Objective
- Health: health models, diagnostics, epidemiology, therapy, prevention.
- Technology: mechanics, measurement technology, control loops.
- Science: ethics, literature search, study design, tests, data analysis, data presentation

Content
- Introduction to Health Sciences and Technology I
- Personal Competencies
- Social Competencies
- Subject-specific Competencies

<table>
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<td>Self-direction and Self-management</td>
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</table>

First Year Examinations Part 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-1011-00L</td>
<td>Organic Chemistry I (for Biol./Pharm.Sc./HST)</td>
<td>O</td>
<td>4 credits</td>
<td>4G</td>
<td>C. Thilgen</td>
</tr>
</tbody>
</table>

Abstract
Fundamentals of Organic Chemistry: molecular structure. Bonding and functional groups; nomenclature; resonance and aromaticity; stereochemistry; conformation; bond strength; organic acids and bases; basic reaction thermodynamics and kinetics; reactive intermediates: carbanions, carbenium ions and radicals.

Objective
Understanding the basic concepts and definitions of organic chemistry. Knowledge of the functional groups and classes of compounds that are important in biological systems. Foundations for the understanding of the relationship between structure and reactivity.

Content

Lecture notes
Lecture notes are available (pdf file). Exercises, answer keys and other handouts can be downloaded from the Moodle course "Organic Chemistry I" of the current semester (https://moodle-app2.let.ethz.ch).

Literature

Prerequisites / notice
The course consists of lectures (36 hours) and problem-solving lessons (20 hours, groups of ca. 25 people). In addition, online exercises are available in the e-learning environment Moodle (Course OC I).
Mathematics I

Abstract
Mathematics I/II is an introduction to one- and multidimensional calculus and linear algebra emphasizing on applications.

Objective
Students understand mathematics as a language for modeling and as a tool for solving practical problems in natural sciences.

Students can analyze models, describe solutions qualitatively or calculate them explicitly if need be. They can solve examples as well as their practical applications manually and using computer algebra systems.

Content

## Eindimensionale diskrete Entwicklungen ##
- linear, exponentiell, begrenzt, logistisch
- Fixpunkte, diskrete Veränderungsrate
- Folgen und Grenzwerte

## Funktionen in einer Variablen ##
- Reproduktion, Fixpunkte
- Periodizität
- Stetigkeit

## Differentialrechnung (I) ##
- Veränderungsrate/-geschwindigkeit
- Differentialquotient und Ableitungsfunktion
- Anwendungen der Ableitungsfunktion

## Integralrechnung (I) ##
- Stammfunktionen
- Integrationstechniken

## Gewöhnliche Differentialgleichungen (I) ##
- Qualitative Beschreibung an Beispielen: Beschränkt, Logistisch, Gompertz
- Stationäre Lösungen
- Lineare DGL 1. Ordnung
- Trennung der Variablen

## Lineare Algebra ##
- Erste Arithmetische Aspekte
- Matrizenrechnung
- Eigenwerte / -vektoren
- Quadratische LGS und Determinante

Lecture notes
In Ergänzung zu den Vorlesungskapiteln der Lehrveranstaltungen fassen wir wichtige Sachverhalte, Formeln und weitere Ausführungen jeweils in einem Vademecum zusammen.

Dabei gilt:
* Die Skripte ersetzen nicht die Vorlesung und/oder die Übungen!
* Ohne den Besuch der Lehrveranstaltungen verlieren die Ausführungen ihren Mehrwert.
* Details entwickeln wir in den Vorlesungen und den Übungen, um die hier bestehenden Lücken zu schliessen.
* Prüfungsrelevant ist, was wir in der Vorlesung und in den Übungen behandeln.

Literature
Siehe auch Lernmaterial > Literatur

**Th. Wihler**
Mathematik für Naturwissenschaften, 2 Bände: Einführung in die Analysis, Einführung in die Lineare Algebra; Haupt-Verlag Bern, UTB.

**H. H. Storrer**
Einführung in die mathematische Behandlung der Naturwissenschaften I; Birkhäuser. Via ETHZ-Bibliothek:
https://link.springer.com/book/10.1007/978-3-0348-8598-0

**Ch. Blatter**
Lineare Algebra; VDF und als Skript in der PolyBox

**A. Caspar, N. Hungerbühler**
Mathematische Modellierung in den Life Sciences, Springer. Via ETH-Bibliothek:
## Übungen und Prüfungen ##
+ Die Übungsaufgaben (Handaufgaben, Khan-Aufgaben, Multiple-Choice) sind ein wichtiger Bestandteil der Lehrveranstaltung.
+ Es wird erwartet, dass Sie mindestens 9 von 13 der wöchentlichen Serien bearbeiten und zur Korrektur einreichen.
+ Der Prüfungstoff ist eine Auswahl von Themen aus Vorlesung und Übungen. Für eine erfolgreiche Prüfung ist die konzentrierte Bearbeitung der Aufgaben unerlässlich.

### Competencies

#### Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

#### Method-specific Competencies

- Analytical Competencies
- Decision-making
- Problem-solving

#### Social Competencies

- Communication
- Cooperation and Teamwork

#### Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-direction and Self-management

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### Second and Third Year Core Courses

#### Examination Blocks

##### Examination Block A

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0151-00L</td>
<td>Human Physiology I</td>
<td>O</td>
<td>5 credits</td>
<td>4V</td>
<td>W. Langhans, M. Willecke, to be announced</td>
</tr>
</tbody>
</table>

**Abstract**
Dieser Kurs vermittelt die Grundlagen der Physiologie und Anatomie des menschlichen Körpers.

**Objective**
Der Schwerpunkt dieses Kurses liegt auf dem Verständnis der physiologischen Mechanismen des menschlichen Körpers. Im Mittelpunkt steht dabei der gesunde Mensch, ergänzt um Beispiele für klinisch wichtige Funktionsstörungen/Krankheiten. Im Sinne einer integrativen Betrachtungsweise wird beizu- Funktion jeweils der Bogen von den molekularen Mechanismen bis zum komplexen Zusammenspiel der Organe im Gesamtorganismus gespannt. Die Anatomie wird dort speziell besprochen, wo sie für das Verständnis der Funktion notwendig oder hilfreich ist.

Der Kurs umfasst das Herbst- (Teil I) und das Frühjahrsemester (Teil II). Im Teil I werden Kern-Konzepte der Physiologie vermittelt, also die grundlegenden Mechanismen, die für das Verständnis aller physiologischen Prozesse notwendig sind. Die Studierenden werden dadurch befähigt, diese allgemeinen Prinzipien auf die Funktionen aller Organsysteme und deren Zusammenspiel anzuwenden. Im Teil I werden zudem die allgemeinen Aspekte des Nervensystems und des endokrinen Systems eingeführt, da alle Organfunktionen letztlich unter nervaler und endokriner Kontrolle stehen.

**Content**

- **Humanphysiologie I (HS)**
  - «Kern-Konzepte» in der Physiologie
  1. Struktur und Funktion
  2. Energietransfer, -speicherung und -nutzung
  3. Informationsfluss, -speicherung und -nutzung
  4. Homöostase
  5. Evolution
  - Allgemeine Endokrinologie und endokrines System
  - Allgemeine Neurophysiologie und Neuroanatomie
  - Die chemischen Sinne, Geschmack und Geruch
  - Ernährung und Verdauung
  - Leber und Stoffwechsel
  - Energiehomöostase
  - Flüssigkeitshomöostase und Niere
  - Reproduktion, Entwicklung und Altern

- **Humanphysiologie II (FS)**
  - Sinnesphysiologie
  - Muskelphysiologie
  - Neuronale Kontrolle von Haltung und Bewegung
  - Höhere zentralnervöse Hirnfunktionen
  - Atmung und Lunge
  - Herz und Kreislauf
  - Blut
  - Immunologie
  - Thermoregulation/Fieber
  - Stress

**Lecture notes**
Online-Material wird im Laufe des Kurses zur Verfügung gestellt.

**Literature**
Wird im Kurs bekannt gegeben.

**Competencies**

- Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies

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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>401-0293-00L</td>
<td>Mathematics III</td>
<td>O</td>
<td>5 credits</td>
<td>3V+2U</td>
<td>A. Caspar, N. Hungerbühler</td>
</tr>
</tbody>
</table>

**Abstract**
Vertiefung der mehrdimensionalen Analysis mit Schwerpunkt in der Anwendung der partiellen Differentialgleichungen, Vertiefung der linearen Algebra und Einführung in die Systemanalyse und Modellbildung.

**Objective**
Die Studierenden
- verstehen Mathematik als Sprache zur Modellbildung und als Werkzeug zur Lösung angewandter Probleme in den Naturwissenschaften.
- können anspruchsvolle Modelle analysieren, Lösungen qualitativ beschreiben oder allenfalls explizit berechnen: diskret/kontinuierlich in Zeit, Ebene und Raum.
- können Beispiele und konkrete arithmetische und geometrische Situationen aus Anwendungen mit Methoden der höheren Mathematik interpretieren und bearbeiten.
Content

Einführung Modellbildung

- SIR-Modelle: Ausbreitung von Krankheiten bei Epidemien
- Pocken-Modell: Was ist der Effekt von Impfungen?

Lineare Modelle

- Vektorräume
- Lösungsraum eines Linearen DGL-Systems
- Diagonalisierbarkeit und Normalformen
- Exponential einer Matrix

Fourier-Reihen

- Euklidische Vektorräume
- Orthogonale Projektion
- Anwendungen

Nichtlineare Modelle

- Stationäre Lösungen, Qualitative Aussagen
- Mehrdimensionale Modelle: Räuber-Beute, Lotka-Volterra

Partielle Differentialgleichungen: Vorgänge, die von Raum und Zeit anhängen

- Einführung, Repetition, Beispiele
- Fourier-Methoden: Wärmeleitung, Laplace, Wellengleichung, Filter, Computertomographie

Laplace-Transformation

- Definition und Notation
- Rechenregeln
- Anwendungsbeispiele

Lecture notes

- Buch: "Mathematische Modellbildung in den Life Sciences", A. Caspar und N. Hungerbühler

Literature

- Buch: "Mathematische Modellbildung in den Life Sciences", A. Caspar und N. Hungerbühler

Prerequisites / notice

Vorlesungen Mathematik I/II

Competencies

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Analytical Competencies
Decision-making
Problem-solving

Social Competencies

Cooperation and Teamwork

Personal Competencies

Critical Thinking

Statistics II

401-0643-13L

O 3 credits 2V+1U J. Dambon

Abstract

Vertiefung von Statistikmethoden. Nach dem detaillierten Fundament aus Statistik I liegt nun der Fokus auf konzeptueller Breite und konkreter Problemlösungsfähigkeit mit der Statistiksoftware R.

Objective


physics I

402-0083-00L

O 4 credits 3V+1U K. S. Kirch

Abstract

This course is an introduction to classical physics, with special focus on applications in medicine.

Objective

Obtain an understanding of basic concepts in classical physics and their application (using mathematical pre-knowledge) to the solution of simple problems, including certain applications in medicine.

Obtain an understanding of relevant quantities and of orders of magnitude.

Content

General introduction; Positron-Emission-Tomography as appetizer, including ionising radiation; kinematics of a point mass; dynamics of a point mass (Newton's axioms and forces); physical work, power and energy; conservation of linear and angular momentum; oscillations and waves; mechanics of a rigid body; fluid mechanics; introduction to electricity.

Lecture notes

Will be distributed at the start of the semester.

Literature

"Physik für Mediziner, Biologen, Pharmazeuten", von Alfred Trautwein, Uwe Kreibig, Jürgen Hüttermann; De Gruyter Verlag.

Prerequisites / notice

Voraussetzung Mathematik I-II (Studiengänge Gesundheitswissenschaften und Technologie bzw. Humanmedizin) / Mathematik-Lehrveranstaltungen des Basisjahres (Studiengänge Chemie, Chemieingenieurwissenschaften bzw. Interdisziplinäre Naturwissenschaften)
This course will provide insight into various aspects of medical device design such as patient needs assessment, product specification, software development and hardware utilization in robotics.

Objective

The course aims at teaching and solidifying following topics:
- CAD
- FEM
- Product optimization
- Mechanical testing
- Software development
- Hardware usage in robotics

Content

The course is aimed at improving the students' knowledge on certain topics such as programming in python and biomechanics, but also teaches new skills such as using CAD software, FEM and mechanical testing. The course is split into 6 sessions, which will be completed in groups. The students will be assigned to groups at the beginning of the semester. 4 of the experiments will be geared towards the use case of designing a bone plate to bridge a critical size gap of a femur. The experiments are therefore 1) using CAD to reconstruct the initial condition and the bone plate 2) running a FEM in order to analyze the performance of the bone plate 3) with the knowledge of the FEM, optimizing the bone plate and 4) testing of the designed bone plate, the bone plate will be 3D printed. The remaining 2 experiments will 1) focus on programming a robotic arm used in rehabilitation engineering and 2) on the hardware usage of the robotic arm including force sensors and EMG.

Lecture notes

Each of the 6 sessions has its own tutorial and will be handed out to the students.

Prerequisites / notice

Only motivation and curiosity is required.

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**Focus Courses**

#### Human Movement Sciences and Sports

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>376-0203-00L</td>
<td>Movement and Sport Biomechanics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>W. R. Taylor, R. List</td>
</tr>
</tbody>
</table>

**Abstract**

Learning to view the human body as a (bio-) mechanical system. Making the connections between everyday movements and sports activity with injury, discomfort, prevention and rehabilitation.

**Objective**

Students are able to describe the human body as a mechanical system. They analyse and describe human movement according to the laws of mechanics.

**Content**

Movement- and sports biomechanics deals with the attributes of the human body and their link to mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.

**Lecture notes**

Available within the Moodle

**Competencies**

- Subject-specific Competencies: Concepts and Theories assessed
- Techniques and Technologies fostered
- Method-specific Competencies: Analytical Competencies fostered
- Problem-solving fostered
- Critical Thinking fostered

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**Exercise Physiology**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>376-0207-00L</td>
<td>Exercise Physiology</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>C. Spengler, F. Gabe Beltrami</td>
</tr>
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</table>

**Abstract**

This course provides an overview over molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interactions of the different systems influencing factors, e.g. genetics, gender, age, altitude/depth, heat/cold, with respect to performance and health.

**Objective**

The aim of this course is to understand molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interaction of the different systems regarding health-relevant aspects and performance in healthy people and persons with selected diseases. Furthermore, students will understand the influence of genetics, gender, age, altitude/depth, heat and cold on the named factors.

**Content**

History of Exercise Physiology, research methods, fibertype heterogeneity and its functional significance, neural control of muscle force, molecular nad cellular mechanisms of muscle adaptation to resistance, endurance and stretching exercise, interindividual variability in the response to training, cardiorespiratory and metabolic responses to acute and chronic exercise, sex differences relevant to exercise performance, exercise in heat and cold environment, children and adolescents, in sport and exercise, exercise at altitude and depth, aging and exercise performance, exercise for health, exercise in the context of disease.

**Lecture notes**

Online material is provided during the course.

**Literature**

Wird in der Vorlesung bekannt gegeben.

**Prerequisites / notice**

Anatomy and Physiology I + II
Develop and realize a project from A-Z in a team! Applying and deepening existing knowledge, working in teams and independently, fosters Concepts and Theories. The Focus-Project Human Movement Science and Sport emphasizes focus on the origins and prevention of different physical, sensory, and mental impairments, their treatments, and methods of assistance in public and home environments. Rehabilitation is put into a larger context providing insights into healthcare systems, health economy, accessibility, barrier-free architecture, para-sports, legal & regulatory aspects, disability policy, and inclusion.

**Objective**
With this lecture, we want to not only transfer a broad knowledge about rehabilitation and inclusion, but also raise awareness about the challenges and needs of people with impairments, the economy and the overall society. Students should learn about the complex and multi-faceted interaction of care, treatment, assistance, reimbursement, accessibility, legal regulation, and social inclusion. This knowledge and awareness should be presented in a multi-modal way using interactive tools and organizing group/plenary discussions.

**Content**
The course will cover the following topics:
- Introduction: definition of terms, historical and legal background, role of the UNO, WHO, ICRC
- Origins: reasons and origins of physical, sensory and mental impairments; surgical and pharmaceutical treatments
- Therapy: physical therapy, occupational therapy, speech therapy, psychotherapy
- Technological support: Robot-aided therapy, Virtual Reality, muscle stimulation, Brain-Computer Interfaces (BCIs)
- Home therapy: personal assistance, mobile health systems, tele-monitoring, tele-therapy
- Assistive technologies: gait assistance, prosthesis, orthoses, seeing/hearing aids, etc.
- Social inclusion: definition of normality and belongingness, social behaviours, UN-BRK, etc.
- Accessibility: national and international aspects of accessibility
- Health economy in rehabilitation: public and private cost models, health insurance, SUVA, IV
- Barrier-free building and living: environmental obstacles, norms in architecture, inclusive design
- Parasports: history of Olympics and Paralympics, Special Olympics, Deaflympics, Cybathlon
- Policy: health, social, equal opportunity, disability
- Regulatory affairs: ethics committees, Swissmedic, Bundesamt für Gesundheit (BAG), law and disability
- Prevention: primary and secondary prevention, social prevention

**Competencies**
**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Leadership and Responsibility: fostered
- Sensitivity to Diversity: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

**Prerequisites**
Prerequisites for the focus projects:
- a. First year examinations successfully passed
- b. Blocks A, B and C successfully passed by project start

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**Medical Technology**

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>227-0386-00L</td>
<td>Biomedical Engineering</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the basic vocabulary of biomedical engineering and getting familiar with concepts that govern common medical instruments and the most important organs from an engineering point of view.

**Objective**
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.
Content

History of BME and the role of biomedical engineers. Ethical issues related to BME.
Biomedical sensors both wearable and also biochemical sensors.
Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices.
Bioinformatics: genomic and proteomic tools, databases and basic calculations.
Equations describing basic reactions and enzyme kinetics.
Medical optics: Optical components and systems used in hospitals.
Basic concepts of tissue engineering and organ printing.
Biomaterials and their medical applications.
Function of the heart and the circulatory system.
Transport and exchange of substances in the human body, compartment modeling.
The respiratory system.
Bioimaging.
Orthopedic biomechanics.

Prerequisites

No specific requirements, BUT

HEST and BIOL students will have to learn a lot of new words related to biochemistry, biology and medicine, while

ITET, MAVT, PHYS students will have to learn a lot of new words related to biochemistry, biology and medicine, while

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

Abstract

Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective.
Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Objective

Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Content

Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

Lecture notes

Introduction to Biomedical Engineering
by Enderle, Banchard, and Bronzino

AND

moodle page of the course

Lecture notes

Introduction into methodology used in biomaterials research and application.
Introduction into different material classes in use for medical applications.

376-0021-00L

Materials and Mechanics in Medicine
W 4 credits 3G M. Zenobi-Wong, J. G. Snedeker

Abstract

Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective.
Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Objective

Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Content

Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

Lecture notes

course website on Moodle

Literature

Introduction to Biomedical Engineering, 3rd Edition 2011,
Autor: John Enderle, Joseph Bronzino, ISBN 9780123749796
Academic Press

376-1714-00L

Biompatible Materials
W 4 credits 3V K. Maniura, M. Rottmar, M. Zenobi-Wong

Abstract

Introduction into molecular used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

Objective

The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Content

Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.
A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Lecture notes

Handouts are deposited online (moodle).

Literature


(available online via ETH library)

Handouts and references therin.
The course will cover the following topics:

- Introduction: definition of terms, historical and legal background, role of the UNO, WHO, ICRC
- Origins: reasons and origins of physical, sensory and mental impairments; surgical and pharmaceutical treatments
- Therapy: physical therapy, occupational therapy, speech therapy, psychotherapy
- Technological support: Robot-aided therapy, Virtual Reality, muscle stimulation, Brain-Computer Interfaces (BCIs)
- Home therapy: personal assistance, mobile health systems, tele-monitoring, tele-therapy
- Assistive technologies: gait assistance, prosthesis, orthoses, seeing/hearing aids, etc.
- Social inclusion: definition of normality and belongingness, social behaviours, UN-BRK, etc.
- Accessibility: national and international aspects of accessibility
- Health economy in rehabilitation: public and private cost models, health insurance, SUVA, IV
- Barrier-free building and living: environmental obstacles, norms in architecture, inclusive design
- Parasports: history of Olympics and Paralympics, Special Olympics, Deaflympics, Cybathlon
- Policy: health, social, equal opportunity, disability
- Regulatory affairs: ethics committees, Swissmedic, Bundesamt für Gesundheit (BAG), law and disability
- Prevention: primary and secondary prevention, social prevention

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies

- Communication
- Cooperation and Teamwork
- Leadership and Responsibility

Personal Competencies

- Adaptability and Flexibility
- Critical Thinking
- Sensitivity to Diversity

Assessed

- Fostered

Prerequisites for the focus projects:

- First year examinations successfully passed
- Blocks A, B and C successfully passed by project start

Molecular Health Sciences

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>376-1348-00L</td>
<td>Cellular Ageing</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>G. Shivashankar</td>
</tr>
</tbody>
</table>

Abstract

Cells undergo major functional alterations as we age. In this course, we will discuss the basic molecular and cell biological mechanisms of cellular ageing. We will also discuss diseases related to cellular ageing and current rejuvenation and therapeutic strategies for cellular ageing in health and disease.

Objective

- Basic molecular and cell biological mechanisms of cellular ageing;
- Diseases related to cellular ageing;
- current rejuvenation and therapeutic strategies for cellular ageing in health and disease.

Content

Lecture-1: Hallmarks of cellular ageing
Lecture-2: Cellular microenvironment & extra-cellular matrix
Lecture-3: Cell morphometric changes & cytoskeletal remodeling
Lecture-4: Proteostasis
Lecture-5: Mitochondrial dysfunction
Lecture-6: Endo-membrane signaling
Lecture-7: Nuclear signaling & epigenetic alternations
Lecture-8: Chromatin remodeling & gene expression
Lecture-9: Genomic integrity
Lecture-10: Ageing cell genome and cellular homeostasis
Lecture-11: Diseases associated with cellular ageing
Lecture-12: Cellular rejuvenation strategies
Lecture-13: Therapeutic interventions to cellular ageing
Lecture-14: Concluding lecture
Abstract
Develop and realize a project from A-Z in a team! Applying and deepening existing knowledge, working in teams and independently, learning to structure problems, identifying solutions, system analysis and simulations, as well as presentation and documentation techniques.

Objective
- Synthesizing and deepening the theoretical knowledge from the basic courses of semesters 1-4
- Team organization, working in teams, improvement of interpersonal skills
- Independence, initiative, independent learning of new topic contents
- Problem structuring, solution identification in indistinct problems definitions, searching for information
- System description and simulation
- Presentation techniques, creating documentation
- Decision-making ability, implementation skills
- Expanding and recess of special knowledge

Content
In teams of 3-8 students, the students are integrated into a research group at D-HEST, where they work independently on a project.

Prerequisites / notice
Prerequisites for the focus projects:
a. First year examinations successfully passed
b. Blocks A, B and C successfully passed by project start

551-0309-00L Concepts in Modern Genetics
Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
In teams of 3-8 students, the students are integrated into a research group at D-HEST, where they work independently on a project.

Prerequisites / notice
Prerequisites for the focus projects:
a. First year examinations successfully passed
b. Blocks A, B and C successfully passed by project start

551-0317-00L Immunology I

Abstract
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Objective
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Content
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Lecture notes
Electronic access to the documentation will be provided. The link can be found at “Lernmaterialien”

Literature
Kuby, Immunology, 9th edition, Freemen + Co., New York, 2020

Prerequisites / notice
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making fostered
- Problem-solving fostered
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered

Personal Competencies
- Self-direction and Self-management fostered
- Critical Thinking fostered
- Creative Thinking fostered
- Adaptable and Flexible fostered
- Self-awareness and Self-reflection fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies fostered
- Decision-making fostered
- Problem-solving fostered
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Self-direction and Self-management fostered

551-0317-00L Immunology II

Abstract
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Objective
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Content
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Lecture notes
Electronic access to the documentation will be provided. The link can be found at “Lernmaterialien”

Literature
Kuby, Immunology, 9th edition, Freemen + Co., New York, 2020

Prerequisites / notice
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies fostered
- Decision-making fostered
- Problem-solving fostered
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Self-direction and Self-management fostered

551-0317-00L Immunology III

Abstract
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Objective
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Content
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Lecture notes
Electronic access to the documentation will be provided. The link can be found at “Lernmaterialien”

Literature
Kuby, Immunology, 9th edition, Freemen + Co., New York, 2020

Prerequisites / notice
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies fostered
- Decision-making fostered
- Problem-solving fostered
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Critical Thinking fostered
- Self-direction and Self-management fostered
The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases is discussed.

Key skills
- On successful completion of the module the student should be able to interpret and critically evaluate original research reports.
- apply knowledge and relate experimental approaches from molecular, cellular and developmental biology to the developing nervous system.

Content
The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases is discussed.

Lecture notes
Must be downloaded from OLAT: https://www.olat.uzh.ch/olat/dmz/
as BIO344

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on OLAT.

Prerequisites / notice
The course is mandatory for the following study programmes:
- BIO142 Developmental Biology
- BIO143 Neurobiology
- Neurosciences

ECTS
3 credits

W. von der Behrens, J. Winterer

University lecturers
Abstract
The course covers the physiology of nerve cells, from the single cell through the neuronal network to the systemic level. The focus is on molecular and cellular mechanisms – synaptic transmission, signal transduction, gene expression, synaptic plasticity.

Objective
Based on an understanding of molecular and cellular mechanisms, the aim is to provide a deepened insight into neurophysiological processes underlying complex brain functions – learning/memory, sleep, sensory.

Content
First, basic molecular and cellular mechanisms in nerve cells (excitability, neurotransmission, signal transduction, gene expression, synaptic plasticity) are introduced. Afterwards, their significance for selected neurophysiological processes (learning/memory, sleep, sensory) will be illuminated.

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on Moodle.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Method-specific Competencies
Analytical Competencies assessed

551-0309-00L Concepts in Modern Genetics
Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed
Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Self-presentation and Social Influence fostered
Personal Competencies
Creative Thinking assessed
Critical Thinking fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Bachelor Studies (Programme Regulations 2017)
Second Year Compulsory Courses
Examination Blocks
Examination Block 2

Number: 376-0151-00L
Title: Human Physiology I
Type: O
ECTS: 5
Hours: 4V
Lecturers: W. Langhans, M. Willecke, to be announced

Abstract
Dieser Kurs vermittelt die Grundlagen der Physiologie und Anatomie des menschlichen Körpers
Objective

Der Schwerpunkt dieses Kurses liegt auf dem Verständnis der physiologischen Mechanismen des menschlichen Körpers. Im Mittelpunkt steht dabei der gesunde Mensch, ergänzt um Beispiele für klinisch wichtige Funktionsstörungen/ Krankheiten. Im Sinne einer integrativen Betrachtungsweise wird bezüglich Funktion jeweils der Bogen von den molekularen Mechanismen bis zum komplexen Zusammenspiel der Organe im Gesamtkörper gespannt. Die Anatomie wird dort speziell besprochen, wo sie für das Verständnis der Funktion notwendig oder hilfreich ist.

Der Kurs umfasst das Herbst- (Teil I) und das Frühjahrsemester (Teil II). Im Teil I werden Kern-Konzepte der Physiologie vermittelt, also die grundlegenden Mechanismen, die für das Verständnis aller physiologischen Prozesse notwendig sind. Die Studierenden werden dadurch befähigt, diese allgemeinen Prinzipien auf die Funktionen aller Organsysteme und deren Zusammenspiel anzuwenden. Im Teil I werden zudem die allgemeinen Aspekte des Nervensystems und des endokrinen Systems eingeführt, da alle Organfunktionen letztlich unter nervaler und endokriner Kontrolle stehen.

Content

Humanphysiologie I (HS)

- «Kern-Konzepte» in der Physiologie
  1. Struktur und Funktion
  2. Energietransfer, -speicherung und -nutzung
  3. Informationsfluss, -speicherung und -nutzung
  4. Homöostase
  5. Evolution
- Allgemeine Endokrinologie und endokrines System
- Allgemeine Neurophysiologie und Neuroanatomie
- Die chemischen Sinne, Geschmack und Geruch
- Ernährung und Verdauung
- Leber und Stoffwechsel
- Energiemangel
- Flüssigkeits- und Nierenhomöostase
- Reproduktion, Entwicklung und Alter

Humanphysiologie II (FS)

- Sinnesphysiologie
- Muskelphysiologie
- Neuronale Kontrolle von Haltung und Bewegung
- Höhere zentralnervöse Hirnfunktionen
- Atmung und Lunge
- Herz und Kreislauf
- Blut
- Immunologie
- Thermoregulation/Fieber
- Stress

Lecture notes

Online-Material wird im Laufe des Kurses zur Verfügung gestellt.

Literature

Wird im Kurs bekannt gegeben.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Conceptual and Theoretical Competencies</th>
<th>Method-specific Competencies</th>
<th>Analytical and Theoretical Competencies</th>
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<tbody>
<tr>
<td>401-0293-00L Mathematics III</td>
<td>O 5 credits 3V+2U</td>
<td>A. Caspar, N. Hungerbühler</td>
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</table>

Abstract

Vertiefung der mehrdimensionalen Analysis mit Schwerpunkt in der Anwendung der partiellen Differentialgleichungen, Vertiefung der Linearen Algebra und Einführung in die Systemanalyse und Modellbildung.

Objective

Die Studierenden

- verstehen Mathematik als Sprache zur Modellbildung und als Werkzeug zur Lösung angewandter Probleme in den Naturwissenschaften.
- können anspruchsvolle Modelle analysieren, Lösungen qualitativ beschreiben oder allenfalls explizit berechnen: diskret/kontinuierlich in Zeit, Ebene und Raum.
- können Beispiele und konkrete arithmetische und geometrische Situationen aus Anwendungen mit Methoden der höheren Mathematik interpretieren und bearbeiten.
Content

Einführung Modellbildung
- SIR-Modelle: Ausbreitung von Krankheiten bei Epidemien
- Pocken-Modell: Was ist der Effekt von Impfungen?

Lineare Modelle
- Vektorräume
- Lösungsraum eines Linearen DGL-Systems
- Diagonalisierbarkeit und Normalformen
- Exponential einer Matrix

Fourier-Reihen
- Euklidische Vektorräume
- Orthogonale Projektion
- Anwendungen

Nichtlineare Modelle
- Stationäre Lösungen, Qualitative Aussagen
- Mehrdimensionale Modelle: Räuber-Beute, Lotka-Volterra

Partielle Differentialgleichungen: Vorgänge, die von Raum und Zeit anhängen
- Einführung, Repetition, Beispiele
- Fourier-Methoden: Wärmeleitung, Laplace, Wellengleichung, Filter, Computertomographie

Laplace-Transformation
- Definition und Notation
- Rechenregeln
- Anwendungsbeispiele

Lecture notes
- Buch: "Mathematische Modellbildung in den Life Sciences", A. Caspar und N. Hungerbühler

Literature
- Buch: "Mathematische Modellbildung in den Life Sciences", A. Caspar und N. Hungerbühler

Prerequisites / notice
- Vorlesungen Mathematik I/II

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Cooperation and Teamwork

Personal Competencies
- Creative Thinking
- Critical Thinking

401-0643-13L Statistics II O 3 credits 2V+1U J. Dambon

Abstract
Vertiefung von Statistikmethoden. Nach dem detaillierten Fundament aus Statistik I liegt nun der Fokus auf konzeptueller Breite und konkreter Problemlösungsfähigkeit mit der Statistiksoftware R.

Objective

Examination Block 3

Number Title Type ECTS Hours Lecturers
402-0083-00L Physics I O 4 credits 3V+1U K. S. Kirch

Abstract
This course is an introduction to classical physics, with special focus on applications in medicine.

Objective
Obtain an understanding of basic concepts in classical physics and their application (using mathematical pre-knowledge) to the solution of simple problems, including certain applications in medicine.
Obtain an understanding of relevant quantities and of orders of magnitude.

Content
General introduction; Positron-Emission-Tomography as appetizer, including ionising radiation; kinematics of a point mass; dynamics of a point mass (Newton's axioms and forces); physical work, power and energy; conservation of linear and angular momentum; oscillations and waves; mechanics of a rigid body; fluid mechanics; introduction to electricity.

Lecture notes
Will be distributed at the start of the semester.

Literature
"Physik für Mediziner, Biologen, Pharmazeuten", von Alfred Trautwein, Uwe Kreibig, Jürgen Hüttermann; De Gruyter Verlag.

Prerequisites / notice
Voraussetzung Mathematik I-II (Studiengänge Gesundheitswissenschaften und Technologie bzw. Humanmedizin) / Mathematik-Lehrveranstaltungen des Basisjahres (Studiengänge Chemie, Chemieingenieurwissenschaften bzw. Interdisziplinäre Naturwissenschaften)

Competencies

Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Problem-solving

Method-specific Competencies
- Communication

Social Competencies
- Cooperation and Teamwork

Personal Competencies
- Creative Thinking

Focus Courses

Human Movement Science and Sport

Number Title Type ECTS Hours Lecturers
The course will cover the following topics:

- Is available within the Moodle
- W. R. Taylor, R. List
- Concepts in Modern Genetics, R. List
- Concepts and Theories, A. Hajnal, O. Voinnet
- Moving and Sport Biomechanics, R. R. Taylor
- Adaptability and Flexibility
- Critical Thinking
- Subject-specific Competencies
- Method-specific Competencies
- Personal Competencies

### 376-0203-00L Movement and Sport Biomechanics

**W 4 credits 3G** W. R. Taylor, R. List

**Abstract**
Learning to view the human body as a (bio-)mechanical system. Making the connections between everyday movements and sports activity with injury, discomfort, prevention and rehabilitation.

**Objective**
Students are able to describe the human body as a mechanical system. They analyse and describe human movement according to the laws of mechanics.

**Content**
Movement- and sports biomechanics deals with the attributes of the human body and their link to mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.

**Lecture notes**
Is available within the Moodle

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### 376-0207-00L Exercise Physiology

**W 4 credits 3G** C. Spengler, F. Gabe Beltrami

**Abstract**
This course provides an overview over molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interactions of the different systems influencing factors, e.g. genetics, gender, age, altitude/depth, heat/cold, with respect to performance and health.

**Objective**
The aim of this course is to understand molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interaction of the different systems regarding health-relevant aspects and performance in healthy people and persons with selected diseases. Furthermore, students will understand the influence of genetics, gender, age, altitude/depth, heat and cold on the named factors.

**Content**
History of Exercise Physiology, research methods, fibertype heterogeneity and its functional significance, neural control of muscle force, molecular and cellular mechanisms of muscle adaptation to resistance, endurance and stretching exercise, interindividual variability in the response to training, cardiorespiratory and metabolic responses to acute and chronic exercise, sex differences relevant to exercise performance, exercise in hot and cold environment, children and adolescents in sport and exercise, exercise at altitude and depth, aging and exercise performance, exercise for health, exercise in the context of disease.

**Lecture notes**
Online material is provided during the course.

**Literature**
Wird in der Vorlesung bekannt gegeben.

**Prerequisites / notice**
Anatomy and Physiology I + II

### 376-1220-00L Rehabilitation and Inclusion

**W 3 credits 2G** R. Rienier

**Abstract**
This course presents origins and prevention of different physical, sensory, mental impairments, their treatments, and methods of assistance in public and home environments. Rehabilitation is put into a larger context providing insights into healthcare systems, health economy, accessibility, barrier-free architecture, para-sports, legal & regulatory aspects, disability policy, and inclusion.

**Objective**
With this lecture, we want to not only transfer a broad knowledge about rehabilitation and inclusion, but also raise awareness about the challenges and needs of people with impairments, the economy and the overall society. Students should learn about the complex and multi-faceted interaction of care, treatment, assistance, reimbursement, accessibility, legal regulation, and social inclusion. This knowledge and awareness should be presented in a multi-modal way using interactive tools and organizing group/plenary discussions.

**Content**
The course will cover the following topics:

- Introduction: definition of terms, historical and legal background, role of the UNO, WHO, ICRC
- Origins: reasons and origins of physical, sensory and mental impairments; surgical and pharmaceutical treatments
- Therapy: physical therapy, occupational therapy, speech therapy, psychotherapy
- Technological support: Robot-aided therapy, Virtual Reality, muscle stimulation, Brain-Computer Interfaces (BCIs)
- Home therapy: personal assistance, mobile health systems, tele-monitoring, tele-therapy
- Assistive technologies: gait assistance, prosthesis, orthoses, seeing/hearing aids, etc.
- Social inclusion: definition of normality and belongingness, social behaviours, UN-BRK, etc.
- Accessibility: national and international aspects of accessibility
- Health economy in rehabilitation: public and private cost models, health insurance, SUVA, IV
- Barrier-free building and living: environmental obstacles, norms in architecture, inclusive design
- Paraplegics: history of Olympics and Paralympics, Special Olympics, Deaflympics, Cybathlon
- Policy: health, social, equal opportunity, disability
- Regulatory affairs: ethics committees, Swissmedic, Bundesamt für Gesundheit (BAG), law and disability
- Prevention: primary and secondary prevention, social prevention

**Competencies**

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### Molecular Health Sciences

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<tr>
<td>551-0309-00L</td>
<td>Concepts in Modern Genetics</td>
<td>W</td>
<td>6 credits</td>
<td>4V</td>
<td>Y. Barral, A. Hajnal, O. Voinnet, University lecturers</td>
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Information for UZH students: Enrollment to this course unit only possible at ETH. No enrolment to module BIC0348 at UZH.
Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

**Abstract**

Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Objective**

This course focuses on the concepts of classical and modern genetics and genomics.

**Content**

The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Lecture notes**

Scripts and additional material will be provided during the semester.

**Competencies**

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Problem-solving

Social Competencies

- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence

Personal Competencies

- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

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**551-0317-00L Immunology I**

**Abstract**

Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

**Objective**

Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

**Content**

- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

**Lecture notes**

Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"

**Literature**

- Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020

**Prerequisites / notice**

For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

**Competencies**

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Project Management

Social Competencies

- Communication
- Cooperation and Teamwork

Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-direction and Self-management

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**376-1348-00L Cellular Ageing**

**Abstract**

Cells undergo major functional alterations as we age. In this course, we will discuss the basic molecular and cell biological mechanisms of cellular ageing. We will also discuss diseases related to cellular ageing and current rejuvenation and therapeutic strategies for cellular ageing in health and disease.

**Objective**

- Basic molecular and cell biological mechanisms of cellular ageing;
- Diseases related to cellular ageing;
- current rejuvenation and therapeutic strategies for cellular ageing in health and disease.
Content
Lecture-1: Hallmarks of cellular ageing
Lecture-2: Cellular microenvironment & extra-cellular matrix
Lecture-3: Cell morphometric changes & cytoskeletal remodeling
Lecture-4: Proteostasis
Lecture-5: Mitochondrial dysfunction
Lecture-6: Endo-membrane signaling
Lecture-7: Nuclear signaling & epigenetic alternations
Lecture-8: Chromatin remodeling & gene expression
Lecture-9: Genomic integrity
Lecture-10: Ageing cell secreteme and cellular homeostasis
Lecture-11: Diseases associated with cellular ageing
Lecture-12: Cellular rejuvenation strategies
Lecture-13: Therapeutic interventions to cellular ageing
Lecture-14: Concluding lecture

Medical Technology

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<tr>
<th>Number</th>
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<tr>
<td>227-0386-00L</td>
<td>Biomedical Engineering</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
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</table>

Abstract
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the basic vocabulary of biomedical engineering and getting familiar with concepts that govern common medical instruments and the most important organs from an engineering point of view.

Objective
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs.

In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

Content
History of BME and the role of biomedical engineers. Ethical issues related to BME.
Biomedical sensors both wearable and also biochemical sensors.
Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices.
Bioinformatics: genomic and proteomic tools, databases and basic calculations.
Equations describing basic reactions and enzyme kinetics.
Medical optics: Optical components and systems used in hospitals.
Basic concepts of tissue engineering and organ printing.
Biomaterials and their medical applications.
Function of the heart and the circulatory system.
Transport and exchange of substances in the human body, compartment modeling.
The respiratory system.
Bioimaging.
Orthopedic biomechanics.
Lectures (2h), discussion of practical exercises (1h) and homework exercises.

Lecture notes
Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

AND

moodle page of the course

Prerequisites / notice
No specific requirements, BUT ITET, MAVT, PHYS students will have to learn a lot of new words related to biochemistry, biology and medicine, while HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.).

Competencies

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Materials and Mechanics in Medicine

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<td>376-0021-00L</td>
<td>Materials and Mechanics in Medicine</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Zenobi-Wong, J. G. Snedeker</td>
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Abstract
Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Objective
Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Content
Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

Lecture notes
course website on Moodle
Biocompatible Materials

**Abstract**
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

**Objective**
The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

**Content**
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Lecture notes**
Handouts are deposited online (moodle).

**Literature**

(available online via ETH library)

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Rehabilitation and Inclusion

**Abstract**
This course presents origins and prevention of different physical, sensory, mental impairments, their treatments, and methods of assistance in public and home environments. Rehabilitation is put into a larger context providing insights into healthcare systems, health economy, accessibility, barrier-free architecture, para-sports, legal & regulatory aspects, disability policy, and inclusion.

**Objective**
With this lecture, we want to not only transfer a broad knowledge about rehabilitation and inclusion, but also raise awareness about the challenges and needs of people with impairments, the economy and the overall society. Students should learn about the complex and multi-faceted interaction of care, treatment, assistance, reimbursement, accessibility, legal regulation, and social inclusion. This knowledge and awareness should be presented in a multi-modal way using interactive tools and organizing group/plenary discussions.

**Competencies**
- Concepts and Theories
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Sensitivity to Diversity
- Adaptable and Flexible
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

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### Neurosciences

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0007-01L</td>
<td>Advanced Neuroanatomy and Neurophysiology</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>M. Willecke, S. Meissner, D. P. Wolfer</td>
</tr>
</tbody>
</table>

**Abstract**
Advanced knowledge of anatomy and physiology of the nervous system.
Objective

The course equips students with advanced knowledge of the anatomical structure and function of the most important structures of the central nervous system. They will understand pathophysiological mechanisms and identify explanations for the occurrence of specific symptoms in neurological diseases. They will also be able to apply their knowledge to describe the mechanism of action of drugs. In addition, they learn the most important methods for analyzing the functions of the nervous system and will be able to use this knowledge to evaluate experimental data.

Content

1. Anatomy: How is the central nervous system structured?

2. Motor control: which structures are involved in voluntary and involuntary movements?

3. Sensory, somatosensory and sensorimotor integration: how is information from different systems integrated and interpreted by the brain?

4. Higher brain functions: What specializations enable us to speak and process emotions and feelings?

Prerequisites / notice


Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies fostered

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

Abstract

The lecture will cover molecular and cellular processes underlying the development of the nervous system (neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation). The importance of these processes in the context of developmental diseases is discussed.

Objective

On successful completion of the module the student should be able to
- relate structure and function of the nervous system to its development - apply principles of molecular, cellular, and developmental biology to the development of the nervous system
- identify key steps in development underlying neurological syndromes and diseases

Key skills
On successful completion of the module the student should be able to
- interpret and critically evaluate original research reports
- apply knowledge and relate experimental approaches from molecular, cellular and developmental biology to the developing nervous system.

Content

The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.

Lecture notes

Must be downloaded from OLAT: https://www.olat.uzh.ch/olat/dmz/ as BIO344

Literature

The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on OLAT.

Prerequisites / notice

BI0142 Developmental Biology, BI0143 Neurobiology

376-1305-00L Development of the Nervous System (University of Zurich)

Autumn Semester 2023

W 3 credits 2V University lecturers

376-1305-01L Molecular Neurophysiology: From Molecules to Systems

Autumn Semester 2023

W 3 credits 2V G. Schratt, R. Fiore, W. von der Behrens, J. Winterer

Information for UZH students:
Enrolment to this course unit only possible at ETH. Please mind the ETH enrolment deadlines for UZH students: https://ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html

Abstract

The course covers the physiology of nerve cells, from the single cell through the neuronal network to the systemic level. The focus is on molecular and cellular mechanisms – synaptic transmission, signal transduction, gene expression, synaptic plasticity.
Objective
Based on an understanding of molecular and cellular mechanisms, the aim is to provide a deepened insight into neurophysiological processes underlying complex brain functions – learning/memory, sleep, sensory.

Content
First, basic molecular and cellular mechanisms in nerve cells (excitability, neurotransmission, signal transduction, gene expression, synaptic plasticity) are introduced. Afterwards, their significance for selected neurophysiological processes (learning/memory, sleep, sensory) will be illuminated.

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on Moodle.

Competencies
Subject-specific Competencies
Concepts and Theories
Analytical Competencies
Method-specific Competencies

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0309-00L</td>
<td>Concepts in Modern Genetics</td>
<td>W</td>
<td>6 credits</td>
<td>4V</td>
<td>Y. Barral, University lecturers</td>
</tr>
<tr>
<td></td>
<td>Information for UZH students:</td>
<td>Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.</td>
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<tr>
<td></td>
<td>Please mind the ETH enrolment deadlines for UZH students: <a href="https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html">https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html</a></td>
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</table>

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.

Competencies
Subject-specific Competencies
Concepts and Theories
Analytical Competencies
Method-specific Competencies
Social Competencies
Communication
Cooperation and Teamwork
Self-presentation and Social Influence
Personal Competencies
Creative Thinking
Critical Thinking
Self-awareness and Self-reflection
Self-direction and Self-management

Electives

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>511-0575-01L</td>
<td>Signals and Systems</td>
<td>W</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>A. Carron</td>
</tr>
<tr>
<td>Abstract</td>
<td>Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to signals and produce other signals. In this course, we explore how signals can be represented and manipulated, and their effects on systems. We further explore how we can discover basic system properties by exciting a system with various types of signals.</td>
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<tr>
<td>Objective</td>
<td>Master the basics of signals and systems. Apply this knowledge to problems in the homework assignments and programming exercise.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes available on course website.</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Control Systems I is helpful but not required.</td>
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</tbody>
</table>

511-0604-00L | Microrobotics | W | 4 credits | 3G | B. Nelson |
| Abstract   | Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination. |
| Objective  | The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field. |
| Content    | Main topics of the course include:  
- Scaling laws at micro/nano scales  
- Electrostatics  
- Electromagnetism  
- Low Reynolds number flows  
- Observation tools  
- Materials and fabrication methods  
- Applications of biomedical microrobots |
| Lecture notes | The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically. |
| Prerequisites / notice | The lecture will be taught in English. |

511-0917-00L | Mass Transfer | W | 4 credits | 2V+2U | M. Tibbitt, V. Mavrantzas, C.-J. Shih |
| Abstract   | This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore, the application of these principles to important engineering problems is demonstrated. |
| Objective  | This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore, the application of these principles to important engineering problems is demonstrated. |
Content

Fick's laws; application and significance of mass transfer; comparison of Fick's laws with Newton's and Fourier's laws; derivation of Fick's 2nd law; diffusion in dilute and concentrated solutions; rotating disk; dispersion; diffusion coefficients, viscosity and heat conduction (Pr and Sc numbers); Brownian motion; Stokes-Einstein equation; mass transfer coefficients (Nu and Sh numbers); mass transfer across interfaces; Analogies for mass-, heat-, and momentum transfer in turbulent flows; film-, penetration-, and surface renewal theories; simultaneous mass, heat and momentum transfer (boundary layers); homogeneous and heterogeneous reversible and irreversible reactions; diffusion-controlled reactions; mass transfer and first order heterogeneous reaction. Applications.

Literature


Prerequisites / notice

Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Sensitivity to Diversity: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Objective

Introduction to mathematical signal processing and system theory.

Content


Lecture notes

Lecture notes, problem set with solutions.

227-0045-00L  Signals and Systems I

Abstract


Content


Literature

- H.-Bölcskei

Competencies

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed

Prerequisites / notice

HST: Possible from the 5th semester on.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: assessed
- Problem-solving: assessed

Social Competencies
- Cooperation and Teamwork: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed

Objective

Conduct physical performance tests and measurements that are typically used to assess performance of athletes and/or patients and that deepen the understanding of physiological processes in response to physical exertion.

Objective

Gain hands-on experience in exercise physiology and consolidate knowledge on physiological adaptations to different types and degrees of physical activity and climatic influences. Learn fundamental assessment techniques of the muscular system, the cardio-respiratory system and of whole-body performance, learn scientifically correct data analysis and interpretation of results. Insight into today's Sports Medicine.

376-0130-00L  Laboratory Course in Exercise Physiology

Abstract

HST: Possible from the 5th semester on.

Objective

Conduct physical performance tests and measurements that are typically used to assess performance of athletes and/or patients and that deepen the understanding of physiological processes in response to physical exertion.

Objective

Gain hands-on experience in exercise physiology and consolidate knowledge on physiological adaptations to different types and degrees of physical activity and climatic influences. Learn fundamental assessment techniques of the muscular system, the cardio-respiratory system and of whole-body performance, learn scientifically correct data analysis and interpretation of results. Insight into today's Sports Medicine.
Content

Laboratory course:
Various exercise tests assessing human performance and assessments of physiological responses to activity (examples are VO2max-test, Conconi-Tests. Determination of anaerobic threshold, Cooper-Test, 1-repetition maximum test, lactate minimum test), dynamometry, mechanography, body composition etc.). Insight into measurements in Sports Medicine.

Lecture notes

Tutorial on Laboratory Experiments in Exercise Physiology
(Editor: Exercise Physiology Lab)

Literature

Schmidt/Lang/Heckmann: Physiologie des Menschen, Springer-Verlag, Heidelberg
Kenney/Wilmore/Costill: Physiology of Sport and Exercise, Human Kinetics

Prerequisites / notice

Prerequisite:
Anatomy and physiology classes and lab course in physiology successfully completed (BWS students please contact C. M. Spengler)

Desirable:
Exercise Physiology Lecture (concomitantly or passed; is selection criterion in case of more applications than lab spaces)

376-1033-00L History of Sports

W 2 credits 2V M. Gisler

Abstract

Comprehension for development and changes of sports from the ancient world to the present. Description of sports in services of national idea, from education and health promotion from the middle of the 18th century till this day.

Objective

Understanding for the development and adaptation of sports from the ancient world to present times.

Content


Lecture notes

Ein Skript für die aktuelle Veranstaltung wird abgegeben.

Literature


376-1107-00L Sport Pedagogy

W 2 credits 2V C. Herrmann

Abstract

The teacher-student interaction presents a complex psychosocial event, demonstrating the need for a psychological extension of the classical social science / sports pedagogical perspective. Therefore, this lecture will be focused on "pedagogical-psychological aspects of competence development in the context of a multi-perspective physical education".

Objective

Development of pedagogical-psychological competences for the optimisation of future teaching activities.

Content

- Subject area of educational psychology
- Motivating students in physical education
- Building self-efficacy and strengthen the self-concept
- Promoting positive emotions and a positive attitude to anxiety
- Encouraging self-directed learning
- Leading classes and promoting cooperation
- Communicating with students efficiently
- Reflecting your own expectations critically
- Handling gender issues sensitively
- Promoting inclusion / Strengthening social and moral development
- Dealing with difficult students
- Evaluating achievements of students

Lecture notes

Teaching materials for the individual lectures are provided to the students via moodle.

Literature

Primärliteratur:

376-1117-00L Sport Psychology

W 2 credits 2V H. Gubelmann

Abstract

This lecture is intended as an introduction to sport psychology and imparts knowledge on selected areas of the subject.

Objective

Students are given insight into different work areas of sport psychology. In order to understand what «sport psychology» is, it is necessary to explain the essence and tasks of sport psychology and what it relates to, and to work out an underlying basis for key topics, such as cognition and emotions. Students' expertise is furthered by presenting and providing more in-depth treatment of additional topics of sport psychology. Selected intervention forms are intended to provide insight into applied sport psychology and ensure that mental processes and their impact in sport can be recognised. Case studies and practical exercises (e.g. objective training) are intended to prompt students to reflect to a greater extent on the forms in which sport psychology can be applied in their practice of sports and to integrate these in their teaching.

Content

Main Topics
- Introduction to sport psychology
- Cognitions in sports: mental rehearsal and mental training
- Emotions and stress
- Motivation: goal-setting in sports
- Career and career transition in elite sport
- Coach-Athlete-Interaction
- Psychological aspects of sport-injury rehabilitation
- Group dynamics in sport

Lecture notes

Instructional materials for each course will be made available to students. All lecture materials will be available to students on Moodle.

Literature


376-1122-00L Introduction to Public Health - Selected Topics and Specific Risks

W 2 credits 2G O. Hämmig

Abstract

In addition to particularly relevant public health topics and major social health risks, the course teaches the thinking and approach of the multidiscipline of public health. Its focus is not only on disease but also on health and more on prevention instead of cure as well as on social groups and their living conditions instead of individuals and individual risk factors.

Objective

The students learn about important and particularly health-relevant public health topics, phenomena and problems and how to deal with corresponding, public health related questions and problems.
Content
From a public health perspective, there are a number of social circumstances that have a high potential for disease and even increased risk of mortality for the affected populations.

These major social health risks include the following:
- unemployment and social decline
- poverty and social deprivation
- loneliness and social isolation
- migration and social discrimination
- over-indebtedness and social marginalization
- risky behavior and unhealthy social lifestyles

Such living conditions and behaviors have been shown to cause increased health risks, but do not necessarily mean that all those affected have comparably poor health or low life expectancy.

Potentially affected individuals, however, do fundamentally represent health risk groups, which include the following groups of people:
- (long-term) unemployed, disenrolled, welfare recipients, etc.
- those at risk of and affected by poverty, including homeless, low-income, working poor, single parents, etc.
- lonely or solitary people and the socially disintegrated
- refugees, immigrants, foreigners, secondos, etc.
- heavily indebted, insolvent people, people affected by wage garnishment, private bankruptcy, etc.
- addicts (incl. drug, alcohol, gambling and work addicts), underweight or overweight and obese, sedentary and physically inactive people, etc.

Prerequisites / notice
Willingness to regularly attend and actively participate in the course.

<table>
<thead>
<tr>
<th>376-1127-00L</th>
<th>Sociology of Sport</th>
<th>W</th>
<th>2 credits</th>
<th>2V</th>
<th>R. Bürgi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>These lectures deal with the current changes in society and sport and provide an overview of the many different problems and perspectives of sport sociology.</td>
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<tr>
<td>Objective</td>
<td>The lectures set out to: present the different dimensions, functions and interrelationships of present-day sport provide an introduction to the central theories and models of sport sociology show how far sport reflects society and how it changes and becomes more differentiated in the process take current examples to highlight the sociological view of sport.</td>
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<tr>
<td>Content</td>
<td>Sport and social change: developments and trends The economy and the media: commercialisation, logic, dependencies Social inequalities and distinctions: social impact, health and sport, sport and gender</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Social Competencies</td>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
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</table>

A detailed program with additional references will be delivered at the beginning of the lecture.

<table>
<thead>
<tr>
<th>376-1581-00L</th>
<th>Cancer: Fundamentals, Origin and Therapy</th>
<th>W</th>
<th>2 credits</th>
<th>2G</th>
<th>H. Nägeli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Students are able to describe selected chemicals, biological and molecular processes that occur in cells spontaneously or after physical or chemical exposure and resulting in a tumor. They are able to list important cancer-inducing agents and explain the respective mechanism of action. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies.</td>
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<tr>
<td>Content</td>
<td>The lecture deals with problems of tumor epidemiology (causes, mortality, incidence). Cancer is delineated as a multi-step process. Classes of chemical compounds that induce cancer are discussed as well as the reactive metabolites that may be built from. Covalent binding to DNA is discussed and different types of mutations resulting thereof. A selection of proto-oncogenes and tumor suppressor genes is presented. Their function will be discussed as well as the changes which are found in these genes in tumor cells, starting from single nucleotide exchanges up to large deletions. The reason for genetic predisposition to cancer will be discussed as well as cancer relevant aspects of cell cycle regulation. The role of tumor microenvironments and phenomena like angiogenesis and metastasis are presented as well as the mechanisms that protect the genome from mutagenic damage. Further subjects address old and new strategies of cancer treatment. Personalised cancer treatment.</td>
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<tr>
<td></td>
<td>additional information is given during the lecture</td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>The lecture requires an active participation of the students. All students will participate in individual or group work focussing on specific subject of the lecture. Students will have ample time for preparation during lecture time.</td>
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</tbody>
</table>
This course is tailored to students who want to become familiar with the analysis of ethical issues in all the different domains of life sciences and biotechnology. The course aims at equipping students with the necessary knowledge and analytic skills to understand, discuss and address the ethical aspects of science and technology in the domain of human health. The specific learning objectives of this course are:

A. Identify ethical issues in in life sciences and biotechnology.
B. Analyze and critically discuss ethical issues in life sciences and biotechnology.
C. Become aware of relevant legal and public policy frameworks.
D. Distinguish different ethical approaches and argumentative strategies in applied ethics.
E. Recognize how ethical issues relate to different accounts of technology and innovation.
F. Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
G. Autonomously anticipate ethical issues.
H. Propose and communicate solutions to ethical challenges and dilemmas.

The course starts off with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain of applied ethics. The students will also be introduced to current theoretical accounts of technology and will start to appreciate the relevance of ethics especially with respect to new and emerging technologies. Usable analytic tools will also be provided, thus enabling the students to engage with the discipline in a practical way from the very onset of the semester.

The course will continue with thematic sessions covering a broad variety of topics all of which are relevant to the different study tracks offered by the department. In particular, the course will cover the following domains: digital health technologies and medical AI; food, nutrition and healthy longevity; biomedical engineering; genetics; neuroscience and Neurotechnologies; medical robotics; disability and rehabilitation; environmental ethics. The course will also include sessions on cross-cutting ethically relevant aspects of health sciences and technologies, namely: access to innovation, translational research, and the relation between science and public policy.

All the topics of the course will be illustrated and interactively discussed through many case studies, offering the students the opportunity to prepare and present them, and to use them in individual as well as group exercises. Throughout the course, the students will have multiple opportunities to experiment with ethical argumentation and to practice their evolving skills.

This semester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their technological application. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences.

This course provides a thorough exploration of drug development and involved ethical issues as well as critical analysis of ethical challenges and practical skills to resolve them. It includes elements of drug discovery, preclinical and clinical research ethics, alternative regulatory pathways and ethics of drug pricing and develops a solid grasp of ethical complexity as well as practical skills.
This course is tailored to D-HEST students who want to become familiar with pharmaceutical development and its ethical implications. By the end of this course, students will have developed a comprehensive understanding of the ethical complexities and challenges in drug development. They will be equipped with the knowledge and analytical skills to navigate ethical reasoning and contribute to the responsible advancement of pharmaceutical research. The specific learning objectives of the course are:

- Discuss relevant legal and public policy frameworks in drug development, ensuring an understanding of the broader regulatory context within which policy and regulatory decisions are made.
- Recognize and identify ethical dilemmas inherent to drug development, fostering a heightened awareness of ethical considerations across various stages of the process.
- Identify and discuss ethical issues in drug development in light of recent advances in the field of artificial intelligence.
- Critically analyze ethical challenges within drug development, enabling them to discuss complex issues, evaluate competing ethical perspectives, and form reasoned judgments.
- Understand the ethical theories and principles that underpin drug regulation.
- Evaluate the ethical implications of alternative pathways, such as Accelerated Approval and Compassionate Use, equipping students to assess potential benefits, risks, and societal consequences.
- Assess the ethical dimensions of drug pricing decisions and their impact on equity and accessibility, encouraging thoughtful reflection on the broader societal implications of pricing strategies.

### Content

**Basics of Exercise Therapy**

**Objective**

Students learn the assessments to plan an exercise-therapy-treatment.

**Content**

- Principles of biomedical ethics and how they relate pharmaceutical innovation
- Introduction to drug development, with a focus on the Swiss regulatory ecosystem
- Current trends and impediments to effective drug development, including the use of AI in drug discovery
- Translational medicine and its ethical implications
- Ethical Aspects of pre-clinical research, including animal replacement technologies like organoids and organ chips
- Ethical aspects of clinical research
- Special regulatory pathways: expanded access / compassionate use
- Special regulatory pathways: accelerated approval
- Drug development and public health. emergency use of new drugs
- Drug pricing: introduction to its regulatory and ethical aspects

**Literature**

- Schulz / Huber: Grundlagen der Sporttherapie, Deutscher Ärztetverlag 2012
- Deimel et al.: Neue aktive Wege in Prävention und Rehabilitation, Deutscher Ärztetverlag, 2007

**Prerequisites / notice**

90% of the lections students must be present.

open-book-test in the last sessions at 20.12.2017

**Applied Basics in Sports and Exercise Therapy**

**Objective**

Students are familiar with a specific method of psychoregulation.

**Content**

- Biomechanik (v.a. Gelenke), Pathophysiologische Grundlagen, Modelle der Methodik und Didaktik, Lektionsplanung

**Prerequisites / notice**

The courses “Exercise and Sports Therapy 1 and 2” have been completed successfully.

One seminar day in an institution/company specialized in reintegration of clients into the workforce.

**Spinal Cord Injury and Exercise**

**Objective**

The following issues will be discussed: Epidemiology and etiology of spinal cord injury; complications and consequences of spinal cord injury; trainability/exercise physiology and spinal cord injury; history and organisation of wheelchair sports; elite sport and spinal cord injury.
General literature:

H.G. Koch, V. Geng
Querschnittlähmung verständlich erklärt (Band 1 und Band 2)
Mohr Siebeck, 2009
ISBN 978-3-16-153380-3 (Band 1) und 978-3-16-153381-0 (Band 2)

G.A. Zäch, H. G. Koch
Paraplegie - ganzheitliche Rehabilitation
Karger-Verlag, 2006
ISBN 3-8055-7980-2

V. Goosey-Tolfrey
Wheelchair sport: A complete guide for athletes, coaches and teachers
Human Kinetics, 2010

Y.C. Vanlandewijck, W.R. Thompson
The Paralympic Athlete
Wiley-Blackwell, 2011
ISBN 978-1-4443-3404-3

Liz Broad
Sports Nutrition for Paralympic Athletes, Second Edition
CRC Press 2019

Y.C. Vanlandewijck, W.R. Thompson
Training and Coaching the Paralympic Athlete
ISBN 978-1-119-04433-8

Voraussetzung: Vorlesung Anatomie/Physiologie besucht!

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Abstract

Introduction to Python Programming provides an overview of the basic programming blocks needed to translate a problem, stated in textual form, into an algorithm that solves it. The course provides an introduction to python programming and covers basics but also Bash scripting, version controlling and an introduction to the use of computer infrastructure such as EULER.

Objective

- understand and use variables
- work with common Python data types like integers, floats, strings, characters, lists, dictionaries, as well as pandas DataFrames
- use and implement basic flow control, including for loops and conditionals
- write Python code according to standard style guidelines
- use common python packages and set-up of a coding environment
- manipulate and extract data from pandas DataFrames
- interpret and handle simple error messages with the help of online resources
- have a general understanding of the coding workflow and typical code blocks, data and contained types

Content

- General Introduction, installation, IDEs, (virtual) environment setup
- Interpreting and handling error messages, debugging, using online documentation
- Data types, data containers and basic mathematical computations
- Branching and looping
- Writing and reading files
- Writing and using functions
- Data manipulation in pandas
- Data visualization (seaborn, matplotlib)
- Version controlling (git) and cluster submissions, simple bash scripts, slurm submission system

Prerequisites / notice

Students should bring a laptop

Introduction to Python Programming
- Registration only possible for BSc HST students in 5th semester (or further).
- This course is a required prerequisite for the 'Foundations of Data Science' class in the 6th semester.

Prerequisites / notice

Note for BSc Biology students: Only one of the two

Nucleic Acids and Carbohydrates

376-1725-00L
4 credits
2G
D. S. Roqueiro, S. Brüningk, C. Jutzeler

529-0731-00L
6 credits
3G
K. Lang, M. Frei, P. A. Kast, H. Wennemers
Medicinal Chemistry I

Abstract
Structure, function and chemistry of nucleic acids and carbohydrates, DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNA; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Objective
Structure, function and chemistry of nucleic acids and carbohydrates, DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNA; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Content
Structure, function and chemistry of nucleic acids and carbohydrates, DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNA; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Lecture notes
No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).

Literature
Mainly based on original literature, a detailed list will be distributed during the lecture

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Social Competencies
Communication assessed
Cooperation and Teamwork assessed

Personal Competencies
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

535-0230-00L Medicinal Chemistry I W 2 credits 2V J. Hall

Abstract
The lectures give an overview of selected drugs and the molecular mechanisms underlying their therapeutic effects in disease. The historical and modern-day methods by which these drugs were discovered and developed are described. Structure-function relationships and the biological rules underlying ligand-target interactions will be discussed and illustrated with examples.

Objective
Basic understanding of therapeutic agents with respect to molecular, pharmacological and pharmaceutical properties.

Content
Molecular mechanisms of action of drugs. Structure function and biophysical basis of ligand-target interactions

Lecture notes
Will be provided in parts before each individual lecture.

Literature

Prerequisites / notice
Requirements: Knowledge of physical and organic chemistry, biochemistry and biology.

Pharmacology and Toxicology I

Abstract
This two-semester lecture course provides a detailed understanding of the fundamentals of drug action and the therapeutic use of important classes of drugs. The lectures are intended for students of pharmaceutical sciences.

Objective
The lectures provide a comprehensive survey of pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathological and clinical aspects.

Content
Topics include disease-relevant macroscopic, microscopic, pathobiochemical and functional disturbances of specific organs and organ systems. The lectures integrate disease pathology with mechanisms of drug action, usage, metabolism, pharmacokinetics, side effects, toxicity, contraindications and dosage of relevant drugs. Basic principles of clinical pharmacology and pharmacotherapy will be covered.

Lecture notes
A script is provided for each lecture. Scripts define important course contents but do not replace the lectures.

Literature
Recommended reading:
- "Allgemeine und spezielle Pharmakologie und Toxikologie. 13. Auflage (2022)"
- "Urban & Fischer (Elsevier)"
- ISBN: 978-3-437-42622-3

The classic textbook in Pharmacology:
- "Goodman and Gilman’s The Pharmacological Basis of Therapeutics"
- Laurence Brunton, Bjorn Knollman.
- 14th edition (2022)
- ISBN-10: 1264258070

Prerequisites / notice
Voraussetzungen: Abschluss Grundstudium
Gene Technology

Abstract
The course gives a description and summary of the field of gene technology and its pharmaceutical applications. The course focuses on important methods and technologies and their application for genomic, transcriptomic and proteomic analyses in human biology.

Objective
The course gives an overview of current state-of-the-art and advancement in the fields of gene technology. Herein, the course focuses on genomic, transcriptomic and proteomic analysis and their uses in drug discovery and biomedical applications. The course is structured into lectures and practical examples drawn from the research field. Upon completion, the students are familiar and know current state-of-the-art of methods and applications, but are also able to classify, contrast and apply different strategies and methods within the field of gene technology. The course is suited for advanced undergraduate and early graduate students in pharmaceutical sciences or related fields.

Content
I) Genomics and transcriptomics

Methods and Techniques:
• Recombinant DNA technology
• Next generation sequencing methods, sequencing of genomes
• CRISPR technology
Application to human biology:
• Functional genomics/transcriptomics
• Principles of cancer, genetic diseases
• Therapies: cell-based therapies/gene therapies/DNA and RNA vaccination

II) Proteomics

Methods and Techniques:
• Protein cloning and expression
• The antibody molecule
• Measurement and determination of biomolecular interactions
• Protein characterization and engineering
• Modifications and radioactive labelling
Application to human biology:
• Protein therapeutics
• Proteomic approaches for identification of novel disease-related targets and biomarkers

III) Drug discovery: Protein-based libraries

• Immune repertoire mining
• Display and selection technologies
  1. antibody phage display
  2. other polypeptide display technologies
  3. small-molecules display: DNA-encoded chemical libraries

Lecture notes
The lecture series follows the above-described content, and the students are provided with the lecture slides and additional notes. The additional notes are needed for the in-depth study of the individual topics, and to set the frame and content of the in-class group work of the chosen examples.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility assessed
Self-presentation and Social Influence fostered
Sensitivity to Diversity assessed
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered
551-0319-00L Cellular Biochemistry (Part I) W 3 credits 2V U. Kutay, F. Allain, T. Kleele, I. Zemp

Abstract

Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterization of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Content

Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Lecture notes

Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biolog.ethz.ch)

Literature

Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice

To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

Competencies

Subject-specific Competencies: Concepts and Theories - assessed
Techniques and Technologies - assessed

376-1987-00L Physiology of Eating W 3 credits 2V W. Langhans

Abstract

This course was offered as 752-6302-00 up to spring semester 2022 and cannot be chosen again by students who have already received credits for the old course.

Objective

Introduction to the basic knowledge necessary for an understanding of the physiology and pathology of hunger, satiation, satiety, and body weight regulation, how this knowledge is generated, and how it helps improve nutritional advice for healthy people as well as nutritional guidelines for patients.

This course requires basic knowledge in physiology. The course covers psychological and physiological determinants of food selection and amount eaten. The aim is to introduce the students to (a) the basic knowledge necessary for an understanding of the physiology and pathology of hunger, satiation, satiety, and body weight regulation, (b) how new scientific knowledge in this area is generated, (c) how this basic knowledge helps improve nutritional advice for healthy people as well as nutritional guidelines for patients. Major topics are: Basic scientific concepts for the physiological study of eating in animals and humans; the psychopharmacology of reward; endocrine and metabolic controls of eating; the neural control of eating; psychological aspects of eating; eating behavior and energy balance: exercise, eating and body weight; popular diets and their critical evaluation; epidemiology: clinical features and the treatment of psychiatric eating disorders; epidemiology, clinical features and the treatment of obesity, including related aspects of non-insulin dependent diabetes; mechanisms of cachexia and anorexia during illness; exogenous factors that influence eating, including pharmaceutical drugs, alcohol, coffee, etc.

Lecture notes

Handouts will be provided.

Literature

Lecture notes will be discussed in class.

Competencies

Subject-specific Competencies: Concepts and Theories - assessed
Techniques and Technologies - assessed
Method-specific Competencies: Analytical Competencies - fostered
Problem-solving - fostered
Social Competencies: Self-presentation and Social Influence - fostered
Personal Competencies: Creative Thinking - fostered
Critical Thinking - fostered

752-2120-00L Consumer Behaviour I W 2 credits 2V M. Siegrist, A. Bearth, A. Berthold

Abstract

Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior

Objective

Students will be able to,
- explain the decision-making processes underlying the purchasing process
- describe the factors that have an influence on consumer behavior
- develop strategies to influence purchasing behavior

Competencies

Subject-specific Competencies: Concepts and Theories - assessed
Method-specific Competencies: Analytical Competencies - assessed
Decision-making - assessed
Social Competencies: Cooperation and Teamwork - fostered
Customer Orientation - assessed
Sensitivity to Diversity - assessed
Personal Competencies: Critical Thinking - assessed

752-4005-00L Food Microbiology I W 3 credits 2V M. Loessner, A. Harms

Abstract

This lecture is the first part of a one-year course. It offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts and molds present in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.

Objective

The lecture offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts, molds and protozoa in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.

The focus of this first part of the two part lecture (Food Micro II is offered in the FS) will be on the organisms, but also on the factors which determine spoilage and foodborne disease.
Content
1. History of Food Microbiology
   1.1. Short synopsis of foodborne microorganisms
   1.2. Spoilage of Foods
   1.3. Foodborne Disease
   1.4. Food Preservation
   1.5. VIP’s of Food Microbiology
2. Overview of Microorganisms in Foods
   2.1 Origin of foodborne Microorganisms
   2.2. Bacteria
   2.3. Yeasts
   2.4. Molds
3. Microbial Spoilage of Foods
   3.1. Intrinsic and Extrinsic Parameters
   3.2. Meats, Seafoods, Eggs
   3.3. Milk and Milk Products
   3.4. Vegetable and Fruit Products
   3.5. Miscellaneous (baked goods, nuts, spices, ready-to-eat products)
   3.6. Drinks and Canned Foods
4. Foodborne Disease
   4.1. Significance and Transmission of Foodborne pathogens
   4.2. Staphylococcus aureus
   4.3. Gram-positive Sporeformers (Bacillus & Clostridium)
   4.4. Listeria monocytogenes
   4.5. Salmonella, Shigella, Escherichia coli
   4.6. Vibrio, Yersinia, Campylobacter
   4.7. Brucella, Mycobacterium
   4.8. Parasites
   4.9. Viruses and Bacteriophages
   4.10. Mycotoxins
   4.11. Bioactive Amines
   4.12. Miscellaneous (Antibiotic-resistant Bacteria, Biofilms)

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download.

Literature
Recommendations will be given in the first lecture.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management assessed

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Self-presentation and Social Influence fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Introduction to Nutritional Science
752-6001-00L
W 3 credits 2V I. Hertter-Aeberli, K. Giller, C. Wolfrum

Abstract
This course introduces basic concepts of micro- and macronutrient nutrition. Micronutrients studied include fat-soluble and water-soluble vitamins, minerals, and trace elements. Macronutrients include proteins, fat, and carbohydrates. Special attention is given to nutrient digestion, bioavailability, metabolism, and excretion with some focus on energy metabolism.

Objective
To introduce the students to both macronutrients and micronutrients in relation to food and metabolism.

Content
The course is divided into two parts: Micronutrients and macronutrients. The micronutrient part includes fat-soluble vitamins, water-soluble vitamins, minerals, and trace elements. The macronutrient part introduces basic nutritional aspects of proteins, fats, carbohydrates, and energy metabolism. The nutrients are described in relation to digestion, absorption, and metabolism. Special aspects of homeostasis and homeorhesis are emphasized.

Lecture notes
There is no script. Powerpoint presentations will be made available.

Literature

Competencies
Subject-specific Competencies
Concepts and Theories fostered

Nutrition-Related Physiology
752-6301-00L
W 3 credits 2V F. von Meyenn, E. Gasser

Abstract
Gives the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctions, of major organ systems on the other hand.

Objective
Some basic knowledge in physiology is recommended for this course, which revisits important physiological topics, emphasizing their relation to nutrition. The aim is to give the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand. For students with a background in medicine, pharmacy or biology, the course is useful as a review of previously acquired knowledge. Major topics are basic neuroanatomy and neurophysiology; general endocrinology; the physiology of taste and smell; nutrient digestion and absorption; intermediary metabolism and energy homeostasis; and some aspects of cardiovascular physiology and water balance.

Lecture notes
Handouts for each lecture will be uploaded to Moodle every week.
Abstract
The course introduces basic concepts of the interaction between nutrition and exercise performance.

Objective
To understand the potential effects of nutrition on exercise performance, with a focus on concepts and principles of nutrition before, during and after exercise.

Content
The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise. Although this is a scientific course, it is a goal of the course to translate basic sports nutrition science into practical sports nutrition examples.

Lecture notes
Lecture slides and required handouts will be available on the ETH website (moodle).

Literature
Information on further reading will be announced during the lecture. There will be some mandatory as well as voluntary readings.

Prerequisites / notice
General knowledge about nutrition, human biology, physiology and biochemistry is a prerequisite for this course. The course builds on basic nutrition and biochemistry knowledge to address exercise and performance related aspects of nutrition.

The course is designed for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).
This course looks into scientific theories and also empirical studies on human learning and relates them to the school. Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way human process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

Thematic Schwerpunkte:
Lernen als Verhaltensänderung und als Informationsverarbeitung; Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzenerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen; Intelligenztheorien, Geschlechtsunterschiede beim Lernen

Lernformen:

Folien werden zur Verfügung gestellt.


This course is only apt for students who intend to enrol in the programs "Lehrdiplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.

Coping with Psychosocial Demands of Teaching (EW4 W DZ)

The successful participation in EW1 ("Human Learning") and EW2 ("Designing Learning Environments for School") is recommended, but not a mandatory prerequisite.

In this class, students will learn concepts and skills for coping with psychosocial demands of teaching. Students possess theoretical knowledge and practical competences to be able to cope with the psychosocial demands of teaching.

1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks).
2) They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. illegal or psychological services).

Human Intelligence

Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).

The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.

- Understanding of research methods used in the empirical human sciences
- Getting to know intelligence tests
- Understanding findings relevant for education

This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW1)".

This lecture is only apt for students who intend to enrol in the programs "Teaching Diploma" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.
Adaptability and Flexibility

In this course students learn the principles and techniques of teaching singular lessons, based on scientific knowledge about learning. The course promotes exchange between student teachers and elementary school teachers in STEM teaching with 3 parts: 1) block seminar (ca. 16 h), 2) collaboration with elementary school teacher in a class (ca. 34 h, with approx. 50% spent in the elementary or middle school class and ca. 50% for preparation), and 3) final report (ca. 10 h). Registration implies participation in all 3 parts.

Objective

Deepening the understanding of knowledge formation and learning processes of primary and secondary students from a cognitive and developmental psychology perspective for students. The assistant ship provides didactic experience and exposure to a different school level (more heterogeneous groups such as for example low-performing to very high-performing Children, language problems etc.).

Content

Students learn more about the potential and challenges of pupils. They get to know the early stages of knowledge as well as the development of pre-concepts of students in their subject area. The seminar with a phase of cooperation consists of three phases: In the block seminar, pre-concepts are discussed in their own subject as well as theoretical inputs from developmental and cognitive psychology. During the cooperation phase, a teaching task defined by the primary and secondary school teachers is actively undertaken in a class. Finally, a final report is written, which contains a description of the students’ level of knowledge. This seminar is only suitable for students who can adapt flexibly to the needs of pupils from lower class levels.

Prerequisites / notice

https://www.minterlink.ch/student

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Analytical Competencies</th>
<th>Communication</th>
<th>Cooperation and Teamwork</th>
<th>Leadership and Responsibility</th>
<th>Sensitivity to Diversity</th>
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<tbody>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>Creative Thinking</td>
<td>Critical Thinking</td>
<td>Self-awareness and Self-reflection</td>
<td>Fostered</td>
<td>Assessed</td>
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Subject Didactics and Professional Training

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>376-8001-00L</td>
<td>Didactics of Health Sciences and Technology I</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>S. Maurer, S. Sinistaj</td>
</tr>
<tr>
<td></td>
<td>Enrolment at the earliest possible with the lecture 851-0240-00L &quot;Human Learning&quot;</td>
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<tr>
<td>Abstract</td>
<td>In this course students learn the principles and techniques of teaching singular lessons, based on scientific knowledge about learning. The aim is to plan, realize, evaluate and reflect lessons effectively and efficiently. Students take the learning goals as a starting point considering previous knowledge as well as the professional environment and the ambitions of the learners. Students apply the basic teaching techniques of their subject area in a sensible way and know how to appropriately arrange the phases of learning. Students know how to simplify and present complex technical contents of their subject area.</td>
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<tr>
<td>Competencies</td>
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<tbody>
<tr>
<td>376-8008-00L</td>
<td>Teaching Internship Including Examination Lessons</td>
<td>O</td>
<td>6</td>
<td>13P</td>
<td>S. Maurer, S. Sinistaj, further</td>
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<tr>
<td></td>
<td>Health Sciences and Technology</td>
<td></td>
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<td></td>
<td>Lecturers</td>
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<tr>
<td></td>
<td>The teaching internship can just be visited if all other courses of TC are completed. Repetition of the teaching internship is excluded even if the examination lessons are to be repeated.</td>
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<tr>
<td>Abstract</td>
<td>Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching. They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils. They learn the skills of the teaching trade. They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution. They learn to assess pupils' work. Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.</td>
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</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-8011-00L</td>
<td>Mentored Work Subject Didactics Health Sciences and</td>
<td>O</td>
<td>2</td>
<td>4A</td>
<td>S. Maurer, S. Sinistaj, further</td>
</tr>
<tr>
<td></td>
<td>Technology</td>
<td></td>
<td></td>
<td></td>
<td>Lecturers</td>
</tr>
<tr>
<td></td>
<td>The teaching internship can just be visited if all other courses of TC are completed.</td>
<td></td>
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<tr>
<td>Abstract</td>
<td>Students study their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching. They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils. They learn the skills of the teaching trade. They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution. They learn to assess pupils' work. Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Students study their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching. They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils. They learn the skills of the teaching trade. They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution. They learn to assess pupils' work. Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.</td>
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</tbody>
</table>
Technology

Abstract
The mentored paper is designed to bring together the findings from the FD1 and the FD2. By using various teaching techniques and methods a semester plan, which is based on various curricula will be elaborated for a given topic.

Objective
1. The students have planned a curriculum for a semester course.
2. Students reflect on formative and summative ways such a teaching unit to examine and implement parts of it.
3. The students have implemented parts of the semester curriculum.
4. The students deal with the question to what extend teaching techniques, teaching methods but also sequences of self-study must be involved in the planning.

Prerequisites / notice
Didactics of Health Sciences and Technology II (376-8002-00L)

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**Health Sciences and Technology TC - Key for Type**

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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**Key for Hours**

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

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ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0300-00L</td>
<td>Essentials in Translational Science</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>J. Goldhahn</td>
</tr>
</tbody>
</table>

**Abstract**

Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people (e.g., Medicines). The course should help to clarify basics of translational science, illustrate successful applications and enable students to integrate key features into their future projects.

**Objective**

After completing this course, students will be able to understand:

- Key steps of drug development and their interdependencies. Project management, communication & funding options. Students should be able to apply this knowledge in drug development programs in Pharma, Biotech or their own spin-off.

**Content**

First lecture will guide you through drug development from bench to bedside and provide industry perspectives which support you in your first industry role or when building a startup. The course will integrate knowledge across the many disciplines which are required to develop new medicines which are transformational for patients.

- Key steps of the Drug development process
- Disease Biology and mechanism of action
- Translation of 'Mechanism of Action' into patient and payer benefit
- Drug design
- Drug formulation
- Toxicology
- Pharmacokinetics & pharmacodynamics
- Translational medicine
- Clinical trials
- Regulatory requirements
- Patenting
- Market access

- How are these steps connected and impacting each other?

Positive and negative examples will be illustrated by distinguished guest speakers.

**Competencies**

- Concepts and Theories assessed
- Techniques and Technologies fostered
- Analytical Competencies fostered
- Decision-making assessed
- Problem-solving assessed
- Project Management fostered
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Negotiation fostered
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered

### Electives

#### Electives Courses I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0221-00L</td>
<td>Methods and Concepts in Human Systems Neuroscience and Motor Control</td>
<td>W</td>
<td>4</td>
<td>3P</td>
<td>S. Gerritzen, L. Imbach, D. Ledergerber Wäller, W. Potok-Szybinska</td>
</tr>
</tbody>
</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1241 of 2653
This course provides hands-on experience with measurement and analysis methods relevant for Humans Systems Neuroscience and Motor control (nerve/brain stimulation, EMG, EEG, psycho-physical paradigms etc). Students read scientific material, set up experiments, perform measurements in the lab, analyse data, apply statistics and write short reports or essays.

Objectives

This course will prepare students for experimental work as it typically done during the master thesis. The goal is to gain hands-on experience with measurement and analysis methods relevant for Humans Systems Neuroscience and Motor control (for example peripheral nerve stimulation, electrical and magnetic brain stimulation, EMG, EEG, psycho-physical paradigms etc). Students will learn how to perform small scientific projects in this area. Students will work individually or in small groups and solve scientific problems which require them to perform measurements in human participants, extract relevant readouts from the data, apply appropriate statistics and interpret the results. They will also be required to write small essays and reports and they will get feedback on their writing throughout the course.

Prerequisites / notice

Students are required to have successfully completed the course "Neural control of movement and motor learning" and to have basic knowledge of applied statistics.

4 credits

376-0223-00L

Advanced Topics in Exercise Physiology

W

4 credits

2S

C. Spengler, G. D'Hulst, F. Gabe Beltrami

Abstract

In this course, students read, present and discuss seminal publications in the area of exercise physiology. The focus lies on critical analysis of scientific content, conceptual as well as ethical aspects of publications. Students are trained in the most common scientific presentation techniques such as oral and poster presentations.

Objective

Students gain further knowledge and a deeper understanding of concepts in exercise physiology. Emphasis is put on critical analysis and discussion of scientific publications as well as on improving scientific presentation skills.

Content

About two third of the semester will be spent discussing structure and content of 2-3 scientific papers per double-lecture. This includes a student presenting the paper orally first, followed by the group discussion. Each student will also prepare and present a poster on a self-selected, scientific publication, participate in a poster discussion session and lead another discussion session as a facilitator. Students groups will prepare a scientific study design to a given, applied exercise physiology question. Furthermore, students will compare an article published in the lay press to the scientific publication the article is based on.

Literature

Material will be provided in moodle.

Prerequisites / notice

Successful completion of the Exercise Physiology Course.

376-0225-00L

Critical Appraisal of Evidence for Exercise in Health

W

3 credits

2V

E. Giannouli, E. de Bruin, R. Knols

Abstract

This course will discuss the mechanisms and latest evidence-based recommendations of physical activity and exercise for a series of conditions and populations. In the second part of each lecture session, published randomized controlled trials of the respective lecture’s topic will be discussed and critically appraised based on established tools.

Objective

On completion of this course students will be able to:

1. understand the role of physical activity and sedentary behavior in the maintenance of health and the etiology, prevention and treatment of disease
2. synthesize effective physical activity and exercise interventions for the prevention and management of several diseases and populations
3. evaluate recent evidence regarding physical activity and exercise interventions

Content

New trends in physical activity for prevention and rehabilitation
Introduction to critical appraisal tools
Exercise for Cancer Rehabilitation
Exercise for Musculoskeletal Rehabilitation (Focus on Osteoarthritis and Low Back Pain)
Exercise for Parkinson’s disease
Exercise for Rehabilitation of Metabolic Disorders (Focus on Obesity and Diabetes type 2)
Exercise for age-related diseases and disorders, Part A (Focus on Frailty and Falls)
Exercise for Stroke Rehabilitation
Exercise for Dementia and Mild Cognitive Impairment
Exercise for Children’s Rehabilitation (focus on Cerebral Palsy)
Exercise for age-related diseases and disorders, Part B (Focus on Sarcopenia and Osteoporosis)
Exercise in Multiple Sclerosis
Exercise for Cardiovascular Rehabilitation (Focus on Heart Failure)

Literature


Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies fostered

Method-specific Competencies
- Analytical Competencies fostered
- Decision-making fostered
- Problem-solving fostered

Personal Competencies
- Critical Thinking assessed
- Integrity and Work Ethics fostered

376-1651-00L

Clinical and Movement Biomechanics

W

4 credits

3G

D. K. Ravi, S. H. Hosseini Nasab, R. List, further lecturers

Abstract

Measurement and modeling of the human movement during daily activities and in a clinical environment.

Objective

The students are able to analyse the human movement from a technical point of view, to process the data and perform modeling with a focus towards clinical application.

Content

This course includes study design, measurement techniques, clinical testing, accessing movement data and analysis as well as modeling with regards to human movement.

752-6101-00L

Nutrition and Chronic Disease

W

3 credits

2V

F. von Meyenn, M. Andersson

Abstract

To have the student gain an understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Objective

To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic diseases, as well as the progression of complications of the chronic diseases.

Content

The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Lecture notes

There is no script. Powerpoint presentations will be made available on-line to students.

Literature

To be provided by the individual lecturers, at their discretion.

No compulsory prerequisites, but prior completion of the courses “Introduction to Nutritional Science” and “Advanced Topics in Nutritional Science” is strongly advised.
Introduction to diagnostic medical imaging based on electromagnetic and acoustic fields including X-ray planar and tomographic imaging, radio-tracer based nuclear imaging techniques, magnetic resonance imaging and ultrasound-based procedures.

Upon completion of the course students are able to:

- Explain the physical and mathematical foundations of diagnostic medical imaging systems
- Characterize system performance based on signal-to-noise ratio, contrast-to-noise ratio and transfer function
- Design a basic diagnostic imaging system chain including data acquisition and data reconstruction
- Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications

Introduction (intro, overview, history)

- Signal theory and processing (foundations, transforms, filtering, signal-to-noise ratio)
- X-rays (production, tissue interaction, contrast, modular transfer function)
- X-rays (resolution, detection, digital subtraction angiography, Radon transform)
- X-rays (filtered back-projection, spiral computed tomography, image quality, dose)
- Nuclear imaging (radioactive tracer, collimation, point spread function, SPECT/PECT)
- Nuclear imaging (detection principles, image reconstruction, kinetic modelling)
- Magnetic Resonance (magnetic moment, spin transitions, excitation, relaxation, detection)
- Magnetic Resonance (plane wave encoding, Fourier reconstruction, pulse sequences)
- Magnetic Resonance (contrast mechanisms, gradient- and spin-echo, applications)
- Ultrasound (mechanical wave generation, propagation in tissue, reflection, transmission)
- Ultrasound (spatial and temporal resolution, phased arrays)
- Ultrasound (Doppler shift, implementations, applications)

Summary, example exam questions

Elective Courses II

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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</thead>
<tbody>
<tr>
<td>227-0385-10L</td>
<td>Biomedical Imaging</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>S. Kozerke, K. P. Prüssmann</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to diagnostic medical imaging based on electromagnetic and acoustic fields including X-ray planar and tomographic imaging, radio-tracer based nuclear imaging techniques, magnetic resonance imaging and ultrasound-based procedures.</td>
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<table>
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<th>Objective</th>
<th>Upon completion of the course students are able to:</th>
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</thead>
<tbody>
<tr>
<td>Content</td>
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<td></td>
<td>- Characterize system performance based on signal-to-noise ratio, contrast-to-noise ratio and transfer function</td>
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<tr>
<td></td>
<td>- Design a basic diagnostic imaging system chain including data acquisition and data reconstruction</td>
</tr>
<tr>
<td></td>
<td>- Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications</td>
</tr>
</tbody>
</table>

| Prerequisites / notice | Analysis, Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming |

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Media and Digital Technologies</th>
<th>Problem-solving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
<td>assessed</td>
<td>fostered</td>
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</table>

<table>
<thead>
<tr>
<th>Social Competencies</th>
<th>Communication</th>
<th>Cooperation and Teamwork</th>
<th>assessed</th>
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<table>
<thead>
<tr>
<th>Personal Competencies</th>
<th>Adaptability and Flexibility</th>
<th>Creative Thinking</th>
<th>Critical Thinking</th>
<th>Integrity and Work Ethics</th>
<th>Self-direction and Self-management</th>
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<tr>
<td></td>
<td>fostered</td>
<td>assessed</td>
<td>assessed</td>
<td>assessed</td>
<td>fostered</td>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0386-00L</td>
<td>Biomedical Engineering</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the basic vocabulary of biomedical engineering and getting familiar with concepts that govern common medical instruments and the most important organs from an engineering point of view.</td>
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</tbody>
</table>

| Objective   | In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined. |

| Content     | History of BME and the role of biomedical engineers. Ethical issues related to BME. Biomedical sensors both wearable and also biochemical sensors. Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices. Bioinformatics: genomic and proteomic tools, databases and basic calculations. Equations describing basic reactions and enzyme kinetics. Medical optics: Optical components and systems used in hospitals. Basic concepts of tissue engineering and organ printing. Biomaterials and their medical applications. Function of the heart and the circulatory system. Transport and exchange of substances in the human body, compartment modeling. The respiratory system. Bioimaging. Orthopedic biomechanics. Lectures (2h), discussion of practical exercises (1h) and homework exercises. |

<table>
<thead>
<tr>
<th>Lecture notes</th>
<th>Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino</th>
</tr>
</thead>
</table>

| Prerequisites / notice | No specific requirements, BUT ITET, MAVT, PHYS students will have to learn a lot of new words related to biochemistry, biology and medicine, while HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.). |

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1243 of 2653
### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

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**Image Analysis and Computer Vision**

**W 6 credits 3V+1U E. Konukoglu, E. Erdil, F. Yu**

<table>
<thead>
<tr>
<th>Abstract</th>
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<table>
<thead>
<tr>
<th>Objective</th>
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</thead>
<tbody>
<tr>
<td>Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.</td>
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</table>

<table>
<thead>
<tr>
<th>Content</th>
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<tbody>
<tr>
<td>This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Lecture notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course material Script, computer demonstrations, exercises and problem solutions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prerequisites: Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.</td>
</tr>
</tbody>
</table>

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**From Publication to the Doctor’s Office**

**W 3 credits 2S+1A O. Demler**

<table>
<thead>
<tr>
<th>Abstract</th>
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<tbody>
<tr>
<td>This seminar course is designed to provide students with an opportunity to review and critically evaluate recent publications in medical field focusing on examples when CS method or bioinformatics/statistical technique has lead to an instrumentation, technique or drug approved for clinical practice use.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective</th>
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<tbody>
<tr>
<td>Throughout the course, students will read and analyze recent publications that demonstrate successful applications and sometimes failures in medicine. Promising research applications will also be discussed. The publications will cover a wide range of topics, including drug discovery, image analysis, prognostic models, and learning healthcare.</td>
</tr>
</tbody>
</table>
The course will be structured as half lecture content and half seminar content. Lectures will review state of the medical practice prior to the discovery, obstacles in moving the field forward, and the need for improvement. Lecture will be followed by the seminar part where students will take turns presenting the assigned publications and leading the discussions. Students' presentations will focus on the main findings, and specific steps taken to translate the finding into clinical practice.

The course will be structured as half lecture content and half seminar content. Lectures will review state of the medical practice prior to the discovery, obstacles in moving the field forward, and the need for improvement. Lecture will be followed by the seminar part where students will take turns presenting the assigned publications and leading the discussions. Students' presentations will focus on the main findings, and specific steps taken to translate the finding into clinical practice.

Covered topics will include some of the following:
- Drug discovery: Computer-aided drug discovery has become an integral part of the drug development process, enabling researchers to design and screen large libraries of molecules in silico (i.e., using computer simulations) before synthesizing and testing them in the lab. This has led to the discovery of new drug candidates for a wide range of diseases, including cancer, Alzheimer's disease, and HIV/AIDS.
- Genomics: Advances in computational genomics have enabled researchers to analyze and interpret large-scale genomic data, including DNA sequencing data, to identify disease-causing mutations, genetic risk factors, and drug targets. Examples of the development of personalized medicine, where treatments are tailored to an individual's genetic makeup. Examples when drug target identified by genetics has led to approved treatment.
- Imaging: Computer vision and image processing techniques have revolutionized medical imaging, enabling researchers to extract quantitative information from medical images that were previously inaccessible. This has led to the development of new diagnostic and prognostic tools for a wide range of diseases, including cancer, cardiovascular disease, and neurological disorders.
- Real-world data applications: emulation of clinical trials using electronic health records data.
- Large language models: Generating clinical trial protocols using large language models. Natural Language Processing for information extraction and interpretation.
- Learning healthcare systems: Advances in data analytics and information technology have enabled the development of learning healthcare systems, which use real-time data from electronic health records, medical devices, and other sources to improve patient outcomes and reduce healthcare costs. This has the potential to transform the way healthcare is delivered, making it more personalized, efficient, and effective.

In addition to the presentations, students will also be required to write critical reviews of the assigned publications throughout the course. The reviews will be evaluated based on the students' ability to identify the strengths and weaknesses of the publications and to provide insightful and constructive feedback.


**Prerequisites / notice**

The course is intended for advanced undergraduate and graduate students with a background in computer science, bioinformatics, or a related field and interest in applying their skills to medical research.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>fostered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>fostered</td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>fostered</td>
</tr>
<tr>
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<td>Communication</td>
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<td>Social Competencies</td>
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<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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</tbody>
</table>

For PhD students, postdocs and others, a fee will be charged (https://scopem.ethz.ch/education/MITP.html).

All applicants must additionally register on this form:
https://docs.google.com/forms/d/1Xw8L_2yXE9qXxW9C06mj6MVqVhxSJEa9CwD/Xk0/edit

The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

**Abstract**

This introductory course on Scanning Electron Microscopy (SEM) emphasizes hands-on learning. Using ScopeM SEMs, students have the opportunity to study their own samples (or samples provided) and solve practical problems by applying knowledge acquired during the lectures. At the end of the course, students will be able to apply SEM for their (future) research projects.

**Objective**

- Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize microscope performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.
During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications.

This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

Lectures:
- Introduction on Electron Microscopy and instrumentation
- electron sources, electron lenses and probe formation
- beam/specimen interaction, image formation, image contrast and imaging modes.
- sample preparation techniques for EM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

Practicals:
- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast (and image processing)
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Practice on real-world samples and report results

Lecturer notes

Lecture notes will be distributed.

Lectures:
During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications.

Lecturer notes

Lecture notes will be distributed.

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Lecture notes will be distributed.

Prerequisites / notice
No mandatory prerequisites.

Objective
Understanding of
1. the set-up and individual components of a TEM
2. the basics of electron optics and image formation
3. the basics of electron beam – sample interactions
4. the contrast mechanism
5. various sample preparation techniques

Learning how to
1. align and operate a TEM
2. acquire data using different operation modes of a TEM instrument, i.e. Bright-field and Dark-field imaging
3. record electron diffraction patterns and index diffraction patterns
4. interpret TEM data

Content
Lectures:
- basics of electron optics and the TEM instrument set-up
- TEM imaging modes and image contrast
- STEM operation mode
- Sample preparation techniques for hard and soft materials

Practicals:
- Demo, practical demonstration of a TEM: instrument components, alignment, etc.
- Hands-on training for students: sample loading, instrument alignment and data acquisition.
- Sample preparation for different types of materials
- Practical work with TEMs
- Demonstration of advanced Transmission Electron Microscopy techniques

Lecture notes

Lecture notes will be distributed.

Literature

No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.

Abstract
The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

W 2 credits 3P  P. Zeng, E. J. Barthazy Meier, A. G. Bittermann, F. Gramm, A. Sologubenko

W 3 credits 2G  G. Grote
The course is organized in a highly interactive fashion, where discussion in class is as important as the input by the lecturer. Understanding the dynamics in organizations is helped enormously by concrete examples, which will be provided by the lecturer, by talks of guest lecturers, and also the students themselves based on their prior experience from working in various roles (as employees, volunteers, student assistants etc.). Through class discussion we aim to deepen the understanding of the themes covered in the course. The current changes in organizations brought about by Covid-19 will also be an important example which allows to illustrate and discuss many of the key concepts of the course.

Specifically, the course will cover the following topics:
- Work design: From Adam Smith to job crafting
- Effects of work design on performance and well-being
- Approaches to analyzing and designing work
- Modes of organizational change and change methods
- Balancing stability and flexibility in organizations as design criterion
- The organization-technology interaction and its impact on work design and organizational change
- Example Flexible working arrangements (e.g. home office)
- Strategic choices for work design

All through the course, students will be guided to work on their projects also, with about 25% of class time devoted to the projects. In the final session, students will present the main results of their projects and discuss main insights also across projects.

Literature
A list of required readings will be provided at the beginning of the course.

Prerequisites / notice
The course includes the completion of a course project to be conducted in groups of four students. The project entails applying a particular method for analyzing and designing work processes and is carried out by means of interviews and observations in companies chosen by the students.

Competencies

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**363-0790-00L Technology Entrepreneurship**

**Abstract**
Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding.

This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are success factors in the creation of new firms, including founding, financing and growing a venture.

**Objective**
This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures. A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases.

**Content**
Weekly sessions - recorded.
10+ sessions carried out by guest lecturers: experts in the broad field of technology entrepreneurship (e.g., serial entrepreneurs, venture capitalists, (E)MBA professors, company builders, patent experts, scale-up executives, …). Final session: multiple choice semester assignment (100% of grade).

Typical lecture format (2h):
15': Introduction
60': Guest testimonial
15': Discussion related to topic (in groups)
10': Plenary discussion
20': Q&A with (guest) lecturer

**Lecture notes**
Lecture slides and case material

**Competencies**

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**363-1163-00L Developing Digital Biomarkers**

**Abstract**
Particularly suitable for students with a technical background who are interested in healthcare.

The course gives an introduction to digital biomarkers and provides students with the foundations to develop their own digital biomarkers. More specifically, the course will cover fundamental topics such as designing observational studies, collecting, and exploring data generated by consumer-centric devices, and applying analytical methods to predict health-related outcomes.
Objective

The widespread use of mobile technologies (e.g., wearable sensors, mobile applications, social media, and location-tracking technologies) has the potential to meet the health monitoring needs of the world’s aging population and the ever-growing number of chronic patients. However, this premise is based on the application of Machine Learning algorithms that allow us to use this data in many different ways. In this course we will analyze systematic ways to collect data, review the most relevant methods and applications in healthcare, discuss the main challenges they present and apply the newly gained knowledge in practical assignments.

The course has four core learning objectives. Students should:
- understand the anatomy of digital biomarkers
- understand the potential and applications of digital biomarkers
- be able to critically reflect and assess existing digital biomarkers
- be able to design and implement a digital biomarker

Content

The course will consist of four topic clusters that will allow the discussion of the most relevant digital biomarker applications in healthcare:

1) Digital Biomarkers: From biological to digital biomarkers. How are they motivated, defined and how can they be leveraged for monitoring? Prognostic vs. diagnostic vs. predictive biomarkers. Passive sensing vs. active sensing. Digital biomarker vs. Digital therapeutics.

2) Consumer-centric device data: Today, vast amount of physiological, environmental, and behavioral observations can be collected with consumer centric devices. To derive clinical meaningful information from this data is, however, difficult. We will analyze strategies for extracting knowledge from those measurements.

3) Methodology: In the last decade, neural networks (also known as “deep learning”) have helped push the boundaries of the state-of-the-art in a myriad of domains. They have also uncovered a number of different problems. We will discuss advantages and disadvantage as well as alternative methods for their application to digital biomarker data.

4) Applications: Digital biomarkers are still an emerging subfield, but given that longitudinal in digital biomarker data are arguably easy to acquire in large quantities, it is expected that many relevant Machine Learning applications will emerge in the near future. We will review and discuss current applications and challenges.

Literature


Prerequisites / notice

Some programming experience in Python is required, and some experience in Machine Learning is highly recommended.

Competencies

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376-0121-00L Multiscale Bone Biomechanics  ■ W 6 credits 3S R. Müller, X.-H. Qin

Abstract

The seminar provides state-of-the-art insight into the biomechanical function of bone from molecules, to cells, tissue and up to the organ. Multiscale imaging and simulation allows linking different levels of hierarchy, where systems biology helps understanding the mechanobiological response of bone to loading and injury in scenarios relevant for personalized health and translational medicine.

Objective

The learning objectives include:
1. advanced knowledge of the state-of-the-art in multiscale bone biomechanics;
2. basic understanding of the biological principles governing bone in health, disease and treatment from molecules, to cells, tissue and up to the organ;
3. good understanding of the prevalent biomechanical testing and imaging techniques on the various levels of bone hierarchy;
4. practical implementation of state-of-the-art multiscale simulation techniques;
5. improved programming skills through the use of python;
6. hands on experience in designing solutions for clinical and industrial problems;
7. encouragement of critical thinking and creating an environment for independent and self-directed studying.
Bone is one of the most investigated biological materials due to its primary function of providing skeletal stability. Bone is susceptible to injury, discomfort, prevention and rehabilitation. They analyse and describe human movement according to the laws of mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.

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**376-0130-00L Laboratory Course in Exercise Physiology**

W 4 credits 4P C. Spengler

**Abstract**
Conduct physical performance tests and measurements that are typically used to assess performance of athletes and/or patients and that deepen the understanding of physiological processes in response to physical exertion.

**Objective**
Gain hands-on experience in exercise physiology and consolidate knowledge on physiological adaptations to different types and degrees of physical activity and climatic influences. Learn fundamental assessment techniques of the muscular system, the cardio-respiratory system and of whole-body performance, learn scientifically correct data analysis and interpretation of results. Insight into today's Sports Medicine.

**Content**
Laboratory course:
Various exercise tests assessing human performance and assessments of physiological responses to activity (examples are VO2max-test, Conconi-Tests, Determination of anaerobic threshold, Cooper-Test, 1-repetition maximum test, lactate minimum test), dynamometry, mechanography, body composition etc.). Insight into measurements in Sports Medicine.

**Lecture notes**
Tutorial on Laboratory Experiments in Exercise Physiology (Editor: Exercise Physiology Lab)

**Literature**
Schmidt/Lang/Heckmann: Physiologie des Menschen, Springer-Verlag, Heidelberg

**Prerequisites / notice**
Anatomy and physiology classes and lab course in physiology successfully completed (BWS students please contact C. M. Spengler)

**Desirable:**
Exercise Physiology Lecture (concomitantly or passed; is selection criterion in case of more applications than lab spaces)

**376-0203-00L Movement and Sport Biomechanics**

W 4 credits 3G W. R. Taylor, R. List

**Abstract**
Learning to view the human body as a (bio-) mechanical system. Making the connections between everyday movements and sports activity with injury, discomfort, prevention and rehabilitation.

**Objective**
Students are able to describe the human body as a mechanical system. They analyse and describe human movement according to the laws of mechanics.

**Content**
Movement- and sports biomechanics deals with the attributes of the human body and their link to mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.

**Lecture notes**
Is available within the Moodle

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Exercise Physiology

This course provides an overview over molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interactions of the different systems influencing factors, e.g. genetics, gender, age, altitude/depth, heat/cold, with respect to performance and health.

The aim of this course is to understand molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interaction of the different systems regarding health-relevant aspects and performance in healthy people and persons with selected diseases. Furthermore, students will understand the influence of genetics, gender, age, altitude/depth, heat and cold on the named factors.

History of Exercise Physiology, research methods, fibertype heterogeneity and its functional significance, neural control of muscle force, molecular nad cellular mechanisms of muscle adaptation to resistance, endurance and stretching exercise, interindividual variability in the response to training, cardiorespiratory and metabolic responses to acute and chronic exercise, sexi differences relevant to exercise performance, exercise in hot and cold environment, children and adolescents in sport and exercise, exercise at altitude and depth, aging and exercise performance, exercise for health, exercise in the context of disease.

Online material is provided during the course.

Wird in der Vorlesung bekannt gegeben.

Molecular and Cellular Biology of Exercise and Muscle Regeneration - Practical Aspects

The overall goal of this course is to integrate transferrable principles of human research project management into preparation, conduction, and dissemination of own/future research projects and beyond. The following objectives are part of this course:

- Create/select well-founded research hypotheses and study designs for a specific research topic
- Apply universal good clinical practice guidelines in future research projects
- Integrate well-documted data management and open science principles into future research projects
- Integrate principles of effective communication in speaking, writing and graphical illustrations of future research idea/output
- Integrate effective summarizing of research output/topic in an abstract and pitch presentation

This course equips the students with several key principles such as good clinical practice, ethical study requirements, reproducible data management and effective oral, graphical, and written communication to design and manage good quality, ethically sound human research studies and represents a 101-toolkit of transferable research management skills/digital tools.

The course will consist of 4 main research themes and the anticipated 16 students will be divided into 4 subgroups of 4 students- each one will focus on one of the following research topics:

- Topic 1: Molecular pathways that control muscle stem cell self-renewal and differentiation
- Topic 2: Genome engineering to correct genetic mutations that cause muscle diseases
- Topic 3: Muscle fiber composition, force production and insulin sensitivity
- Topic 4: Amino acid sensitivity in skeletal muscle following exercise

The course will be organized into 7 sessions, each approx. 4 hours: the first 2 sessions will be theoretical and include an introductory lectures by the professors in addition to a journal club presentation by the students. This journal club aims to provide theoretical and scientific background that will be used to identify outstanding research questions. This will be followed by 4 practical sessions (hands-on experience) and 1 final evaluation session.

For the journal club, each group of students will receive a peer-review article that is highly relevant to the respective group’s research topic. Each of the 4 groups will present and discuss the article in a journal club format to the rest of the participants the following week. During the four practical sessions, students will gain hands-on experiences and learn different lab techniques related to molecular biology of exercise and muscle regeneration. Each group will be presented with a research objective that is related to their topic, and perform in collaboration with teaching assistants a set of experiments that aim to address the research objective. At the final evaluation session, each group of students will present their results and identify follow-up research questions and hypothesis based on their experimental achievements.

Select practical methods that the proposed course will teach include:

- Group 1: tissue culture, isolation of muscle stem cells via FACS, differentiation of muscle stem cell into muscle fibers, small molecules screens, quantitative analysis of muscle cell proliferation and fusion, Immunofluorescence.
- Group 2: tissue culture, differentiation of muscle stem cells into muscle fibers, guide RNA design and Crisp-Cas9 gene editing of genetic mutations that cause muscle diseases in muscle stem cells and fibers. Immunofluorescence and PCR.
- Group 3: ex vivo assessment of muscle force characteristics, cryosectioning of muscle tissue, immunofluorescence and western blot.
- Group 4: culture of muscle stem cells, isolation of muscle stem cells and differentiation into muscle fibers, amino acid stimulation of muscle fibers, Western blot.

The course will cover the following topics:

- Introduction to different study designs and ethical requirements thereof in Switzerland
- Introduction to literature search and searching platforms
- How to collect and sort publications/ keep up to date on research topic
- Inputs on critically evaluating papers
- How to pre-define study requirements to "future-proof" the research (hypothesis, sample size definition, pre-registration)
- Correct conduction of fundamental human research procedures (e.g., screening, consent process, CRF) and identification/prevention of deviations and emergencies (e.g., SAE/EA; protocol violations, research misconduct)
- Principles of reproducible and integral study documentation and data management (e.g., definition of source files, SOP/WI, Master Trial File, metatiles)
- FAIR principles and open science
- Design principles and free digital tools for graphical illustrations
- Effective summarizing of research output/topic in an abstract and pitch presentation

This course provides an overview over molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interactions of the different systems influencing factors, e.g. genetics, gender, age, altitude/depth, heat/cold, with respect to performance and health.

The objective of this course is to introduce students into current research topics and outstanding questions in skeletal muscle biology. Also, the course will give students hands-on experience in respect to the tools needed to perform basic molecular biology research in the field of exercise and skeletal muscle biology. Students will learn how to translate a scientific question in muscle biology into a small scientific project. They will learn how to design an experiment and to analyze and critically interpret experimental data.
Ein Skript für die aktuelle Veranstaltung wird abgegeben.

Sport Pedagogy

C. Herrmann


Instructional materials for each course will be made available to students. All lecture materials will be available to students on Moodle.


Sport Psychology

H. Gubelmann

This lecture is intended as an introduction to sport psychology and imparts knowledge on selected areas of the subject. Students are given insight into different work areas of sport psychology. In order to understand what «sport psychology» is, it is necessary to explain the essence and tasks of sport psychology and what it relates to, and to work out an underlying basis for key topics, such as cognition and emotions. Students’ expertise is furthered by presenting and providing more in-depth treatment of additional topics of sport psychology. Selected intervention forms are intended to provide insight into applied sport psychology and ensure that mental processes and their impact in sport can be recognised. Case studies and practical exercises (e.g. objective training) are intended to prompt students to reflect to a greater extent on the forms in which sport psychology can be applied in their practice of sports and to integrate these in their teaching.

Sociology of Sport

R. Bürgi

These lectures deal with the current changes in society and sport and provide an overview of the many different problems and perspectives of sport sociology.

Wearable and Mobile Technologies of the Future - Focus on Sports and Health

C. Menon

This course focuses on the progress in the field of wearable and unobtrusive technologies for sports and health. Topics as monitoring heart health and blood pressure, biofeedback and improvement of motor skills and performance are covered. The focus lies on learning about the principles and design of the new generation of non-invasive technologies in fitness-, athletic and medical applications.
Objective 1:
Acquire knowledge about the latest technological advancements in wearable and unobtrusive technologies for sport and health.

Objective 2:
Acquire skills to design novel non-invasive technologies for sport and health.

Content
The course consists of two modules.

Module 1: Movement
This module provides the scientific background needed to understand the principles that current technologies investigating movement rely on. The latest technological advancements to track parameters of gait and running, improve posture as well as to monitor overall body movement and provide feedback on motion during sport, rehabilitation or at work will be investigated. The focus will be on wearable-related (e.g., textile-based) technologies.

Module 2: Cardiac
This module focuses on the latest technologies for monitoring the cardiac cycle and blood pressure. The module starts by succinctly providing background information on cardiac physiology and then briefly introduces conventional technologies used in daily practice. This module subsequently focuses on the latest technologies and the latest data analysis techniques to monitor the cardiac cycle for assisting individuals in sport activities or monitoring their health conditions.

Prerequisites / notice
- Students should be proficient in programming (any language).
- Note: assignments will be in MATLAB. Students are expected to learn MATLAB on their own if not experienced with this programming language.
- Course prerequisites:
  - For Biomedical Engineering Master’s: none
  - For ITET Master’s: none
  - For D-MAVT Master’s: none
  - For D-HEST Master’s and PhD students:
    - If BSc in electrical/mechanical engineering or computer science: none
    - If any other BSc program: 376-0022-00L (Imaging and Computing in Medicine) or 376-1983-00L (Foundations of Data Science)

376-1177-00L Human Factors I

Abstract
Strategies of human-system-interaction, individual needs, physical & mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people’s health, well-being, and satisfaction as well as the overall system performance.

Objective
Students are expected to learn about how to enable an efficient and qualitatively high standing interaction between human and the environment, considering costs, benefits, health, and safety as well. Thus, an ergonomic design and evaluation process of products, tasks, and environments may be promoted in different disciplines. The goal is achieved in addressing a broad variety of topics and embedding the discussion in macroscopic factors such as the behavior of consumers and objectives of economy.

Content
- Physiological, physical, and cognitive factors in sensation, perception, and action
- Body spaces and functional anthropometry, Digital Human Models
- Experimental techniques in assessing human performance, well-being, and comfort
- Usability engineering in system designs, product development, and innovation
- Human information processing and biological cybernetics
- Interaction among consumers, environments, behavior, and tasks

Literature
- Gavriel Salvendy, Handbook of Human Factors and Ergonomics, 4th edition (2012), is available on NEBIS as electronic version and for free to ETH students
- Further textbooks are introduced in the lecture
- Broduches, checklists, key articles etc. are uploaded in ILIAS

Y. Hedinger Huang, R. Huang

376-1179-00L Applications of Cybernetics in Ergonomics

Abstract
Cybernetics systems have been studied and applied in various research fields, such as for applications in ergonomics. Topics discussed in this lecture (man-machine-interaction, performance in multi-modal interactions, quantification in gestalt principles for the use in product development, information processing) are deepened with exercises conducted at our labs.

Objective
The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications.

Content
- If Fitt's law applied in manipulation tasks
- Hick-Hyman law applied in design of the driver assistance systems - Vigilance applied in quality inspection
- Accommodationvergence crosslink function
- Cross-link models in neurobiology- the ocular motor control system
- Human performance in optimization of production lines

Literature

Y. Hedinger Huang, R. Huang

376-1219-00L Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions

Abstract
Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

Objective
Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.
Introduction, problem definition, overview
Rehabilitation of visual function
- Anatomy and physiology of the visual sense
- Technical aids (glasses, sensor substitution)
- Retina and cortex implants
Rehabilitation of hearing function
- Anatomy and physiology of the auditory sense
- Hearing aids
Cochlea Implants
Rehabilitation and use of kinesthetic and tactile function
- Anatomy and physiology of the kinesthetic and tactile sense
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
Rehabilitation of vestibular function
- Anatomy and physiology of the vestibular sense
- Rehabilitation strategies and devices (e.g. BrainPort)
Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter
Brain stimulation and recording
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces

Literature

Introductionary Books:


Selected Journal Articles and Web Links:


VideoTact, ForeThought Development, LLC. http://my.execpc.com/?dwysocki/videotac.html

Prerequisites / notice
Target Group:
Students of higher semesters and PhD students of
- D-MAVT, D-ITET, D-INFK, D-HEST
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich
Students of other departments, faculties, courses are also welcome
This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

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### 376-1220-00L  Rehabilitation and Inclusion

**W** 3 credits  2G  R. Riener

**Abstract**
This course presents origins and prevention of different physical, sensory, mental impairments, their treatments, and methods of assistance in public and home environments. Rehabilitation is put into a larger context providing insights into healthcare systems, health economy, accessibility, barrier-free architecture, para-sports, legal & regulatory aspects, disability policy, and inclusion.

**Objective**
With this lecture, we want to not only transfer a broad knowledge about rehabilitation and inclusion, but also raise awareness about the challenges and needs of people with impairments, the economy and the overall society. Students should learn about the complex and multi-faceted interaction of care, treatment, assistance, reimbursement, accessibility, legal regulation, and social inclusion. This knowledge and awareness should be presented in a multi-modal way using interactive tools and organizing group/plenar discussions.

**Content**
The course will cover the following topics:
- Introduction: definition of terms, historical and legal background, role of the UNO, WHO, ICRC
- Origins: reasons and origins of physical, sensory and mental impairments; surgical and pharmaceutical treatments
- Therapy: physical therapy, occupational therapy, speech therapy, psychotherapy
- Technological support: Robot-aided therapy, Virtual Reality, muscle stimulation, Brain-Computer Interfaces (BCIs)
- Home therapy: personal assistance, mobile health systems, tele-monitoring, tele-therapy
- Assistive technologies: gait assistance, prosthesis, orthoses, seeing/hearing aids, etc.
- Social inclusion: definition of normality and belongingness, social behaviours, UN-BRK, etc.
- Accessibility: national and international aspects of accessibility
- Health economy in rehabilitation: public and private cost models, health insurance, SUVA, IV
- Barrier-free building and living: environmental obstacles, norms in architecture, inclusive design
- Paraports: history of Olympics and Paralympics, Special Olympics, Deaflympics, Cybathlon
- Policy: health, social, equal opportunity, disability
- Regulatory affairs: ethics committees, Swissmedic, Bundesamt für Gesundheit (BA), law and disability
- Prevention: primary and secondary prevention, social prevention

### Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Conceptual and Theoretical</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
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<tr>
<td>Personal Competencies</td>
<td>Leadership and Responsibility</td>
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### 376-1533-00L  Nanostructured Materials Safety

**W** 2 credits  1V  P. Wick, T. Bürki-Thurnherr

**Abstract**
Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection.

**Objective**
Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials.

**Content**
Building upon new technologies to engineer and functionalize well-defined nanostructured materials, a plethora of exciting discoveries were made and found their way in our daily live. These customized nanomaterials provide extraordinary properties and make them attractive for many innovative applications. Exactly these new properties may have the potential to be responsible for unforeseen side effects, which hamper a straightforward translation into new products. Therefore, the safety research provide the evidence for a responsible and sustainable use of nanomaterials.

The lecture will focus on basic principles of nanotoxicology, provide the understanding of the potential side effects of nanomaterial in a context-specific way addressing the main exposure routes such as inhalation, ingestion, topical applications and intravenous injections as well as it will provide impulses for safer material designs.

1. Introduction: the principles of nanotoxicology
2. Lung- particles interactions: two disease scenarios and their molecular mechanism
3. GI – particles interactions: intendent and unintendent particle exposure via food
4. Skin – particles interactions: body care products and their influence on skin physiology
5. Intravenous injection: colloidal stability, protein corona and cellular effects
6. Micro- / Nanoplastics and development of a safety research plan
7. End of semester exam

**Lecture notes**
Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website.

**Prerequisites / notice**
Course "Introduction to Toxicology"
This semester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their technological application. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences.

The course starts off with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain Ethics of Life Sciences and Biotechnology.

- A. Identify ethical issues in in life sciences and biotechnology.
- B. Analyze and critically discuss ethical issues in life sciences and biotechnology.
- C. Become aware of relevant legal and public policy frameworks.
- D. Distinguish different ethical approaches and argumentative strategies in applied ethics.
- E. Recognize how ethical issues relate to different accounts of technology and innovation.
- F. Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
- G. Autonomously anticipate ethical issues.
- H. Propose and communicate solutions to ethical challenges and dilemmas.

The course starts off with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain of applied ethics. The students will also be introduced to current theoretical accounts of technology and will start to appreciate the relevance of ethics especially with respect to new and emerging technologies. Usable analytic tools will also be provided, thus enabling the students to engage with the discipline in a practical way from the very onset of the semester.

The course will continue with thematic sessions covering a broad variety of topics all of which are relevant to the different study tracks offered by the department. In particular, the course will cover the following domains: digital health technologies and medical AI; food, nutrition and healthy longevity; biomedical engineering; genetics; neuroscience and Neurotechnologies; medical robotics; disability and rehabilitation; environmental ethics. The course will also include sessions on cross-cutting ethically relevant aspects of health sciences and technologies, namely: access to innovation, translational research, and the relation between science and public policy.

All the topics of the course will be illustrated and interactively discussed through many case studies, offering the students the opportunity to prepare and present them, and to use them in individual as well as group exercises. Throughout the course, the students will have multiple opportunities to experiment with ethical argumentation and to practice their evolving skills.

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: fostered
  - Decision-making: fostered
  - Problem-solving: fostered
  - Project Management: fostered
  - Communication: fostered
  - Cooperation and Teamwork: fostered

- **Social Competencies**
  - Communication: fostered
  - Cooperation and Teamwork: fostered
  - Leadership and Responsibility: fostered
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered
  - Adaptability and Flexibility: fostered
  - Creative Thinking: fostered
  - Critical Thinking: fostered
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: assessed

### Abstract

This semester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their technological application. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences.

This course is tailored to D-HEST students who want to become familiar with pharmaceutical development and its ethical implications. By the end of this course, students will have developed a comprehensive understanding of the ethical complexities and challenges in drug development. They will be equipped with the knowledge and analytical skills to navigate ethical reasoning and contribute to the specific learning objectives of the course are:

- Discuss relevant legal and public policy frameworks in drug development, ensuring an understanding of the broader regulatory context within which policy and regulatory decisions are made.
- Recognize and identify ethical dilemmas inherent to drug development, fostering a heightened awareness of ethical considerations across various stages of the process.
- Identify and discuss ethical issues in drug development in light of recent advances in the field of artificial intelligence.
- Critically analyze ethical challenges within drug development, enabling them to discuss complex issues, evaluate competing ethical perspectives, and form reasoned judgments.
- Understand the ethical theories and principles that underpin drug regulation.
- Evaluate the ethical implications of alternative pathways, such as Accelerated Approval and Compassionate Use, equipping students to assess potential benefits, risks, and societal consequences.
- Assess the ethical dimensions of drug pricing decisions and their impact on equity and accessibility, encouraging thoughtful reflection on the broader societal implications of pricing strategies.

### Objective

- A. Identify ethical issues in in life sciences and biotechnology.
- B. Analyze and critically discuss ethical issues in life sciences and biotechnology.
- C. Become aware of relevant legal and public policy frameworks.
- D. Distinguish different ethical approaches and argumentative strategies in applied ethics.
- E. Recognize how ethical issues relate to different accounts of technology and innovation.
- F. Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
- G. Autonomously anticipate ethical issues.
- H. Propose and communicate solutions to ethical challenges and dilemmas.

The course is tailored to students who want to become familiar with the analysis of ethical issues in all the different domains of life sciences and biotechnology. The course aims at equipping students with the necessary knowledge and analytic skills to understand, discuss and address the ethical aspects of science and technology in the domain of human health. The specific learning objectives of this course are:

- Identify ethical issues in in life sciences and biotechnology.
- Analyze and critically discuss ethical issues in life sciences and biotechnology.
- Become aware of relevant legal and public policy frameworks.
- Distinguish different ethical approaches and argumentative strategies in applied ethics.
- Recognize how ethical issues relate to different accounts of technology and innovation.
- Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
- Autonomously anticipate ethical issues.
- Propose and communicate solutions to ethical challenges and dilemmas.

### Content

The course starts off with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain of applied ethics. The students will also be introduced to current theoretical accounts of technology and will start to appreciate the relevance of ethics especially with respect to new and emerging technologies. Usable analytic tools will also be provided, thus enabling the students to engage with the discipline in a practical way from the very onset of the semester.

The course will continue with thematic sessions covering a broad variety of topics all of which are relevant to the different study tracks offered by the department. In particular, the course will cover the following domains: digital health technologies and medical AI; food, nutrition and healthy longevity; biomedical engineering; genetics; neuroscience and Neurotechnologies; medical robotics; disability and rehabilitation; environmental ethics. The course will also include sessions on cross-cutting ethically relevant aspects of health sciences and technologies, namely: access to innovation, translational research, and the relation between science and public policy.

All the topics of the course will be illustrated and interactively discussed through many case studies, offering the students the opportunity to prepare and present them, and to use them in individual as well as group exercises. Throughout the course, the students will have multiple opportunities to experiment with ethical argumentation and to practice their evolving skills.

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: fostered
  - Decision-making: fostered
  - Problem-solving: fostered
  - Project Management: fostered
  - Communication: fostered
  - Cooperation and Teamwork: fostered

- **Social Competencies**
  - Communication: fostered
  - Cooperation and Teamwork: fostered
  - Leadership and Responsibility: fostered
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered
  - Adaptability and Flexibility: fostered
  - Creative Thinking: fostered
  - Critical Thinking: fostered
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: assessed

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**Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1255 of 2653**
Communication Application of MATLAB in the Human Movement

Students will learn to import, process and graphically present experimental data using the MATLAB computing environment. Both the data fostered and the methods of analysis will be typical for experiments in Human Movement Science (i.e. kinematics, kinetics and electromyography).

376-1714-00L Biocompatible Materials

**Abstract**
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

**Objective**
The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

**Content**
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Literature**

(available online via ETH library)

**Prerequisites / notice**
A Laptop with MATLAB installed (v2009 or higher) and wireless internet access is mandatory. Two students can share a laptop if necessary. A MATLAB student version can be obtained at Stud-IDES for free.

376-1720-00L Application of MATLAB in the Human Movement

**Abstract**
Students will learn to import, process and graphically present experimental data using the MATLAB computing environment. Both the data and the methods of analysis will be typical for experiments in Human Movement Science (i.e. kinematics, kinetics and electromyography).

**Objective**
Students will acquire the ability to independently load, plot, and process kinematic, kinetic and electromyographical data using the MATLAB computing environment.

**Content**
Drawbacks of Excel; Possibilities in MATLAB; Import of several data formats; Plot of one and more signals; Removing of an offset and filtering of data based on self-written functions; Normalisation and parametrisation of data; Reliability; Interpolation, Differentiation and Integration in MATLAB.

**Prerequisites / notice**
A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Literature**
Handouts and references therein.

**Prerequisites / notice**
A Laptop with MATLAB installed (v2009 or higher) and wireless internet access is mandatory. Two students can share a laptop if necessary. A MATLAB student version can be obtained at Stud-IDES for free.

376-1721-00L Bone Biology: Basics, Research and Clinics

**Abstract**
The course gives an introduction into bone biology and provides an overview on current research methods and clinical approaches. Emphasis is put on skeletal development and metabolism, osteoporosis as well as fracture healing. Each topic is structured into three parts: basics, research and clinics.

**Objective**
After completing the Bone Biology course, students will be able to:
1. Remember and apply basics in bone biology and disease
2. Remember clinical features and surgical approaches
3. Select adequate research methods and approaches
4. Evaluate publications on topics presented in the lecture

**Competencies**

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<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
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<tbody>
<tr>
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<td>Techniques and Technologies</td>
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<td>Media and Digital Technologies</td>
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**Social Competencies**

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<tr>
<th>Communication</th>
<th>Cooperation and Teamwork</th>
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**Personal Competencies**

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<tr>
<th>Adaptable and Flexibility</th>
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<th>Integrity and Work Ethics</th>
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<th>Self-direction and Self-management</th>
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Spinal Cord Injury and Exercise

Prerequisite: Anatomy and Physiology.

Abstract
Intensive discussion concerning complications of a spinal cord injury and their consequences on trainability and exercise performance of persons sitting in a wheelchair. Overview on the clinical application of exercise testing as well as on the implementation of sport scientific findings to optimise performance of individuals with spinal cord injury in rehabilitation and elite sports.

Objective
Knowledge of the pathophysiology and the concomitant complications of a spinal cord injury and the consequences for physical exercise and trainability during rehabilitation as well as in recreational and elite sport.

Content
The following issues will be discussed: Epidemiology and etiology of spinal cord injury; complications and consequences of spinal cord injury; trainability/exercise physiology and spinal cord injury; history and organisation of wheelchair sports; elite sport and spinal cord injury

Literature
General literature:
H.G. Koch, V. Geng
Querschnittlähmung verständlich erklärt (Band 1 und Band 2)
Selbstverlag Manfred-Sauer-Stiftung und Schweizer Paraplegiker-Vereinigung
ISBN 978-3-00-069888-0 (Band 1) und 978-3-00-069889-7 (Band 2)

G.A. Zäch, H. G. Koch
Paraplegie - ganzheitliche Rehabilitation
Karger-Verlag, 2006
ISBN 3-8055-7890-2

V. Goosse-Tolfrey
Wheelchair sport: A complete guide for athletes, coaches and teachers
Human Kinetics, 2010

Y.C. Vanlandewijck, W.R. Thompson
The Paralympic Athlete
Wiley-Blackwell, 2011
ISBN 978-1-4443-3404-3

Liz Broad
Sports Nutrition for Paralympic Athletes, Second Edition
CRC Press 2019
ISBN 978-1-38-58900-1

Y.C. Vanlandewijck, W.R. Thompson
Training and Coaching the Paralympic Athlete
ISBN 978-1-119-04433-8

Prerequisites / notice
Voraussetzung: Vorlesung Anatomie/Physiologie besucht!

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity assessed
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Colloquium in Biomechanics

Abstract
Current topics in biomechanics presented by speakers from academia and industry.

Objective
Getting insight into actual areas and problems of biomechanics.

Trauma Biomechanics

Abstract
Trauma biomechanics in an interdisciplinary research field investigating the biomechanics of injuries and related subjects such as prevention. The lecture provides an introduction to the basic principles of trauma biomechanics.

Objective
Introduction to the basic principles of trauma biomechanics.

Content
This lecture serves as an introduction to the field of trauma biomechanics. Emphasis is placed on the interdisciplinary nature of impact biomechanics, which uses the combination of fundamental engineering principles and advanced medical technologies to develop injury prevention measures. Topics include: accident statistics and accident reconstruction, biomechanical response of the human to impact loading, injury mechanisms and injury criteria, test methods (including crash tests), computer simulations, aspects of vehicle safety. Real world examples mainly from automobile safety are used to augment lecture material.

Lecture notes
Handouts will be made available.

Literature
A sound understanding of physiological implications of food design will allow to shape new products, which feature health as well as safety. The course links the physiological driven requirements with food structure design and subsequent engineering steps.

Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.

The course will be given as a mixture of lectures, studies of original research and guided discussions that focus on current research topics. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation networks in populations and single cells. Key methods to be covered are various modeling approaches, metabolic flux analyses, metabolomics and other omics.

The statistical software R will be used in the exercises. If you are unfamiliar with R, it is highly recommend to view the online R course "etutoR".

A course work is required. The mark of this course work contributes to the final credits for this lecture. Details will be given during the first lecture.

Student orientation and team work.

The objective of this course is to highlight the link between human physiology, product sensory, nutritional functions, and engineering approaches to facilitate the design of food matrices reflecting the requirements for the beforementioned properties. To identify and manipulate these properties, the pathways that control the interaction of food structures and their physiological action will be introduced. Students are introduced to a skill set that will encompass basic digestion, sensory physiology knowledge, and food structures. Students will be exposed to the interplay along the gastrointestinal tract including taste, aroma, and texture perception, swallowing mechanics, and gastrointestinal digestion with an engineering or physical sciences angle.
The course introduces basic concepts of the interaction between nutrition and exercise performance.

13A

Analytical Competencies

Concepts and Theories

To understand the potential effects of nutrition on exercise performance, with a focus on concepts and principles of nutrition before, during and after exercise. Exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise. Metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how nutritional aspects during exercise can influence exercise performance, and post-exercise recovery.

The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how nutritional aspects during exercise can influence exercise performance, and post-exercise recovery.

Method-specific Competencies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Project Management

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Project Management

Communication

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Lecture notes

Lecture notes are available at Moodle

ECTS

701-1701-00L

Human Health, Nutrition and Performance: Term Paper

Only for students of the Major Human Health, Nutrition

Number

Title

Type

ECTS

Hours

Lecturers

701-1701-00L

Human Health, Nutrition and Environment: Term Paper

O

6 credits

13A


Major in Human Health, Nutrition and Environment

Compulsory Courses

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Autumn Semester 2024

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Abstract Writing of a review paper of scientific quality on a topic in the domain of Human Health, Nutrition and Environment based on critical evaluation of scientific literature.

Objective - Acquisition of knowledge in the field of the review paper
- Assessment of original literature as well as synthesis and analysis of the findings
- Practising of academic writing in English
- Giving an oral presentation with discussion on the topic of the review paper

Content Topics are offered in the domains of the major ‘Human Health, Nutrition and Environment’ covering ‘Public Health’, ‘Infectious Diseases’, ‘Nutrition and Health’ and ‘Environment and Health’.

Lecture notes Guidelines will be handed out in the beginning.

Literature Literature will be identified based on the topic chosen.

Competencies

376-0300-00L Essentials in Translational Science O 3 credits 2G J. Goldhahn

Abstract Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people (e.g. Medicines). The course should help to clarify basics of translational science, illustrate successful applications and enable students to integrate key features into their future projects.

Objective After completing this course, students will be able to understand:

- Key steps of drug development and their interdependencies. Project management, communication & funding options. Students should be able to apply this knowledge in drug development programs in Pharma, Biotech or their own spin-off.

Content This lecture will guide you through drug development from bench to bedside and provide industry perspectives which support you in your first industry role or when building a startup. The course will integrate knowledge across the many disciplines which are required to develop new medicines which are transformational for patients.

- Disease Biology and mechanism of action
- Translation of ‘Mechanism of Action’ into patient and payer benefit
- Drug design
- Drug formulation
- Toxicology
- Pharmacokinetics & pharmacodynamics
- Translational medicine
- Clinical trials
- Regulatory requirements
- Patenting
- Market access
- How are these steps connected and impacting each other?

Positive and negative examples will be illustrated by distinguished guest speakers.

Competencies

376-0302-01L GCP Basic Course (Modules 1 and 2) O 1 credit 1G G. Senti, C. Fila, R. Grossmann

Abstract The basic course in “Good Clinical Practice” (GCP) contains of two full-time training days (Module 1 and Module 2) and addresses elementary aspects for the appropriate conduct of clinical trials and non-clinical research projects involving human beings. Successful participation will be confirmed by a certificate that is recognized by the Swiss authorities.

Objective Students will get familiar with:

- Key Ethics documents
- (Inter)national Guidelines and Laws (e.g. ICH-GCP, DIN EN ISO 14155, TPA, HRA)
- Sequence of research projects and project-involved parties
- Planning of research projects (statistics, resources, study design, set-up of the study protocol)
- Approval of research projects by Authorities (SwissEthics, Swissmedic, FOPH)
- Roles and responsibilities of project-involved parties

Students will learn how to:

- Classify research projects according the risk-based approach of the HRA
- Write a study protocol
- Inform participating patients/study subjects
- Obtain consent by participating patients/study subjects
- Classify, document and report Adverse Events
- Handle projects with biological material from humans and/or health-related personal data
Public Health Concepts

This course is structured into three parts. The first part focuses on Linear and Generalised Linear Models. The second part introduces more advanced methodologies such as Linear Mixed-Effects Models and Generalised Additive Models. The course strongly focuses on applied aspects of data analysis.

After this course students:
- revised Linear Models
- revised or got introduced to Generalised Linear Models
- got introduced to Linear Mixed-Effects Models
- got introduced to Generalised Additive Models
- are able to select among these methods to solve an applied problem in Biostatistics
- can perform the data analysis using the statistical software R
- can interpret the results of such an analysis and draw valid "biological" conclusions

This course is structured into three parts. The first part focuses on Linear and Generalised Linear Models. The second part introduces more advanced methodologies such as Linear Mixed-Effects Models and Generalised Additive Models. Both, part one and two will include the following topics: exploratory data analysis, model fitting, model "selection", residual diagnostics, model validation and results interpretation. Analyses will be carried out using the statistical software R. Finally, in the third part of the course students will be analysing real-world datasets to put into practice the knowledge and skills acquired during the first two parts.

The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware of how epidemiological facts are used in prevention, practice and politics.

Module: Infectious Diseases

Students majoring in Human Health, Nutrition and Environment: At least one of the courses listed in this module must be selected.

Elective Courses I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-0629-00L</td>
<td>Applied Biostatistics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>M. Tanadini</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course covers the main methods used in Biostatistics. It starts by revising Linear Models (Regression, Anova), then moves to Generalised Linear Models (logistic regression and methods for count data) and finally introduces more advanced topics (Linear Mixed-Effects Models and Generalised Additive Models). The course strongly focuses on applied aspects of data analysis.</td>
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<tr>
<td>Objective</td>
<td>After this course students:</td>
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<tr>
<td></td>
<td>- revised Linear Models</td>
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<td>- revised or got introduced to Generalised Linear Models</td>
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<td>- got introduced to Linear Mixed-Effects Models</td>
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<td>- got introduced to Generalised Additive Models</td>
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<td>- are able to select among these methods to solve an applied problem in Biostatistics</td>
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<td>- can perform the data analysis using the statistical software R</td>
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<td>- can interpret the results of such an analysis and draw valid &quot;biological&quot; conclusions</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The statistical software R will be used in the exercises. If you are unfamiliar with R, it is highly recommend to view the online R course &quot;etutoR&quot;.</td>
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<tbody>
<tr>
<td>752-6105-00L</td>
<td>Epidemiology and Prevention</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>M. Puh, R. Heusser</td>
</tr>
<tr>
<td>Abstract</td>
<td>The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.</td>
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<td>Objective</td>
<td>The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware of how epidemiological facts are used in prevention, practice and politics.</td>
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<tr>
<td>Content</td>
<td>The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.</td>
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<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<td>Concepts and Theories</td>
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<td>Problem-solving</td>
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<td>Project Management</td>
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<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>752-6151-00L</td>
<td>Public Health Concepts</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>R. Heusser</td>
</tr>
<tr>
<td>Abstract</td>
<td>The module &quot;public health concepts&quot; offers an introduction to key principles of public health. Students get acquainted with the concepts and methods of epidemiology. Students also learn to use epidemiological data for prevention and health promotion purposes. Public health concepts and intervention strategies are presented, using examples from infectious and chronic diseases.</td>
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<tr>
<td>Objective</td>
<td>At the end of this module students are able:</td>
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<td>- to interpret the results of epidemiological studies</td>
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<td>- to critically assess scientific literature</td>
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<td>- to know the definition, dimensions and determinants of health</td>
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<td>- to plan public health interventions and health promotion projects</td>
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<td>- to draw a bridge from evidence to policies and politics</td>
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<tr>
<td>Content</td>
<td>Concepts of descriptive and analytical epidemiology, study designs, measures of effect, confounding and bias, screening, surveillance, definition of health and health promotion, health dimensions and health determinants, prevention strategies, public health interventions, public health action cycle, epidemiology and prevention of infectious and chronic diseases (HIV, COVID-19, Obesity, Iodine/PH nutrition).</td>
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<tr>
<td>Lecture notes</td>
<td>Handouts are provided to students in the classroom.</td>
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<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<td>Method-specific Competencies</td>
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<td>Analytical Competencies</td>
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<td>Decision-making</td>
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Elective Courses II

Module: Infectious Diseases

Students majoring in Human Health, Nutrition and Environment: At least one of the courses listed in this module must be selected.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0223-00L</td>
<td>Immunology III</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>M. Kopf, S. B. Freigang, S. R. Leibundgut, F. Mair, A. Oxenius, C. Schneider, E. Slack, R. Spöri, further lecturers</td>
</tr>
</tbody>
</table>
Abstract
This course provides a detailed understanding of:
- development of T and B cells
- the dynamics of an immune response during acute and chronic infection
- mechanisms of immunopathology
- modern vaccination strategies
Key experimental results will be shown to help understanding how immunological textbook knowledge has evolved.

Objective
Obtain a detailed understanding of:
- the development, activation, and differentiation of different types of T cells and their effectormechanisms during immune responses.
- Recognition of pathogenic microorganisms by the host cells and molecular events thereafter.
- events and signals for maturation of naive B cells to antibody producing plasma cells and memory B cells.
- Optimization of B cell responses by intelligent design of new vaccines

Content
- Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg)
- NK T cells and responses to lipid antigens
- Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17
- Overview of cytokines and their effector function
- Co-stimulation (signals 1-3)
- Dendritic cells
- Evolution of the "Danger" concept
- Cells expressing Pattern Recognition Receptors and their downstream signals
- T cell function and dysfunction in acute and chronic viral infections

Content
- Immunology I and II recommended but not compulsory
- Immunology I and II recommended but not compulsory
- Immunology I and II recommended but not compulsory
- Immunology I and II recommended but not compulsory
- Immunology I and II recommended but not compulsory
- Immunology I and II recommended but not compulsory

Literature
Documents of the lectures are available for download at: https://moodle-app2.let.ethz.ch/course/view.php?id=2581

Prerequisites / notice

<table>
<thead>
<tr>
<th>701-0263-01L</th>
<th>Seminar in Evolutionary Ecology of Infectious Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Students of this course will discuss current topics from the field of infectious disease biology. From a list of publications, each student chooses some themes that he/she is going to explain and discuss with all other participants and under supervision. The actual topics will change from year to year corresponding to the progress and new results occurring in the field.</td>
</tr>
<tr>
<td>Objective</td>
<td>This is an advanced course that will require significant student participation. Students will learn how to evaluate and present scientific literature and trace the development of ideas related to understanding the ecology and evolutionary biology of infectious diseases.</td>
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<tr>
<td>Content</td>
<td>A core set of ~10 classic publications encompassing unifying themes in infectious disease ecology and evolution, such as virulence, resistance, metapopulations, networks, and competition will be presented and discussed. Pathogens will include bacteria, viruses and fungi. Hosts will include animals, plants and humans.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Papers will be assigned and downloaded from a web page announced during the lecture.</td>
</tr>
<tr>
<td>Literature</td>
<td>Publications and class notes can be downloaded from a web page announced during the lecture.</td>
</tr>
<tr>
<td>Competencies</td>
<td>Subject-specific Competencies: Concepts and Theories, Analytical Competencies, Decision-making</td>
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<tr>
<td></td>
<td>Method-specific Competencies: Communication, Cooperation and Teamwork, Leadership and Responsibility, Self-presentation and Social Influence, Sensitivity to Diversity, Negotiation</td>
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<tr>
<td></td>
<td>Social Competencies: Adaptability and Flexibility, Critical Thinking, Self-awareness and Self-reflection</td>
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<table>
<thead>
<tr>
<th>701-1471-00L</th>
<th>Ecological Parasitology</th>
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<tbody>
<tr>
<td>Abstract</td>
<td>The course will not take place this semester.</td>
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<tr>
<td>Objective</td>
<td>Does not take place this semester.</td>
</tr>
<tr>
<td>Content</td>
<td>Course focuses on the ecology and evolution of macroparasites and their hosts. Through lectures and practical work, students learn about diversity and natural history of parasites, adaptations of parasites, ecology of host-parasite interactions, applied parasitology, and human macroparasites in the modern world.</td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>The three practicals will take place at the 03.10.2023, the 17.10.2023 and the 07.11.2023 at Eawag Dübendorf from 08:15 - 12:00. Note that each practical takes 2 hours longer than the weekly lecture.</td>
</tr>
</tbody>
</table>
This course explores infectious disease from both the host and pathogen perspective. Through short lectures, reading and active discussion, students will identify areas where evolutionary thinking can improve our understanding of infectious diseases and, ultimately, our ability to treat them effectively.

Content
We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (< 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

Literature
The focus is on primary literature, but for some parts the following text books provide good background information:
- Schmid Hempel 2011 Evolutionary Parasitology
- Stearns & Medzhitov 2016 Evolutionary Medicine

Prerequisites / notice
A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

### 701-1703-00L
**Evolutionary Medicine for Infectious Diseases**

| Objective | Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses. |
| Content | We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (< 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class. |
| Literature | The focus is on primary literature, but for some parts the following text books provide good background information: |
| Prerequisites / notice | A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential. |

### 752-4009-00L
**Molecular Biology of Foodborne Pathogens**

| Objective | Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents. |
| Content | Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention. |

### Module: Nutrition and Health

**Students majoring in Human Health, Nutrition and Environment:** At least one of the courses listed in this module must be selected.

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<tr>
<th>Number</th>
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</tbody>
</table>
### Food and Consumer Behaviour

**Number:** 752-2122-00L  
**Title:** Food and Consumer Behaviour  
**ECTS:** 2  
**Lecturers:** M. Siegrist, F. Michel  

**Abstract:**  
This course focuses on food consumer behavior, consumer’s decision-making processes and consumer’s attitudes towards food products. 

**Objective:**  
Students will be able…

- to describe heuristics that influence consumer behavior in the food domain
- to explain the consumer led food product development
- to summarise how consumers perceive the environmental impact and the healthiness of foods
- to assess the cultural, the environmental and and the food policy impact on consumer behavior
- to explain psychological factors influencing eating behavior

**Competencies:**

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<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Critical Thinking</td>
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<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Customer Orientation</td>
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<td>Problem-solving</td>
<td>Sensitivity to Diversity</td>
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### Nutrition and Chronic Disease

**Number:** 752-6101-00L  
**Title:** Nutrition and Chronic Disease  
**ECTS:** 3  
**Lecturers:** F. von Meyenn, M. Andersson

**Abstract:**  
To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Objective:**  
To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic disease, as well as the progression of complications of the chronic diseases.

**Content:**  
The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Lecture notes:**  
There is no script. Powerpoint presentations will be made available on-line to students.

**Prerequisites / notice**

- No compulsory prerequisites, but prior completion of the courses “Introduction to Nutritional Science” and “Advanced Topics in Nutritional Science” is strongly advised.

### Module: Environment and Health

**Students majoring in Human Health, Nutrition and Environment:** At least one of the courses listed in this module must be selected.

#### Nanostructured Materials Safety

**Number:** 376-1353-00L  
**Title:** Nanostructured Materials Safety  
**ECTS:** 2  
**Lecturers:** P. Wick, T. Bürki-Thurnherr  

**Abstract:**  
Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection

**Objective:**  
Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials

**Content:**  
Building upon new technologies to engineer and functionalize well-defined nanostructured materials, a plethora of exciting discoveries were made and found their way in our daily live. These customized nanomaterials provides extraordinary properties and make them attractive for many innovative applications. Exactly these new properties may have the potential to be responsible for unforeseen side effects, which can hamper a straightforward translation into new products. Therefore, the safety research provide the evidence for a responsible and sustainable use of nanomaterials.

The lecture will focus on basic principles of nanotoxicology, provide the understanding of the potential side effects of nanomaterial in a context-specific way addressing the main exposure routes such as inhalation, ingestion, topical applications and intravenous injections as well as it will provide impulses for safer material designs.

Structure of the planned lecture (2 x 45 min)

1. Introduction: the principles of nanotoxicology
2. Lung - particles interactions: two disease scenarios and their molecular mechanism
3. GI – particles interactions: intendent and unintendent particle exposure via food
4. Skin – particles interactions: body care products and their influence on skin physiology
5. Intravenous injection: colloidal stability, protein corona and cellular effects
6. Micro- / Nanoplastics and development of a safety research plan
7. End of semester exam

**Lecture notes**

Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website

**Prerequisites / notice**

- course “Introduction to Toxicology”

### Compulsory Courses

#### Essentials in Translational Science

**Number:** 376-0300-00L  
**Title:** Essentials in Translational Science  
**ECTS:** 3  
**Lecturers:** J. Goldhahn

**Abstract:**  
Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people (e.g. medicines). The course should help to clarify basics of translational science, illustrate successful applications and enable students to integrate key features into their future projects.

**Objective:**  
After completing this course, students will be able to understand:

- Key steps of drug development and their interdependencies. Project management, communication & funding options. Students should be able to apply this knowledge in drug development programs in Pharma, Biotech or their own spin-off.
This lecture will guide you through drug development from bench to bedside and provide industry perspectives which support you in your first industry role or when building a startup. The course will integrate knowledge across the many disciplines which are required to develop new medicines which are transformational for patients.

Key steps of the Drug development process
- Disease Biology and mechanism of action
- Translation of 'Mechanism of Action' into patient and payer benefit
- Drug design
- Drug formulation
- Toxicology
- Pharmacokinetics & pharmacodynamics
- Translational medicine
- Clinical trials
- Regulatory requirements
- Patenting
- Market access

- How are these steps connected and impacting each other?

Positive and negative examples will be illustrated by distinguished guest speakers.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: assessed
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered

376-0302-01L GCP Basic Course (Modules 1 and 2) O 1 credit 1G G. Senti, C. Fila, R. Grossmann

Abstract
The basic course in “Good Clinical Practice” (GCP) contains of two full-time training days (Module 1 and Module 2) and addresses elementary aspects for the appropriate conduct of clinical trials and non-clinical research projects involving human beings. Successful participation will be confirmed by a certificate that is recognized by the Swiss authorities.

Objective
Students will get familiar with:
- Key Ethics documents
- (Inter)national Guidelines and Laws (e.g. ICH-GCP, DIN EN ISO 14155, TPA, HRA)
- Sequence of research projects and project-involved parties
- Planning of research projects (statistics, resources, study design, set-up of the study protocol)
- Approval of research projects by Authorities (SwissEthics, Swissmedic, FOPH)
- Roles and responsibilities of project-involved parties

Students will learn how to:
- Classify research projects according the risk-based approach of the HRA
- Write a study protocol
- Inform participating patients/study subjects
- Obtain consent by participating patients/study subjects
- Classify, document and report Adverse Events
- Handle projects with biological material from humans and/or health-related personal data

Content
Module 1:
- Research and Research Ethics, Guidelines, (inter)national Legislation, Development of therapeutic products, Methodology (Study Design), Study documents (Study protocol, Investigator's Brochure, Patient Information Leaflet, Informed Consent Form)

Module 2:
- Roles and Responsibilities, Approval procedures, Notification and Reporting, Study documentation, Research with biological material and health-related data, data protection, data retention

Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>151-0604-00L</td>
<td>Microrobotics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>B. Nelson</td>
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</tbody>
</table>

Abstract
Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Objective
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

Content
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microrobots

Lecture notes
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

Prerequisites / notice
The lecture will be taught in English.
Introduction to selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

**Abstract**
- Learning the basic vocabulary of biomedical engineering and getting familiar with concepts that govern common medical instruments and the most important organs from an engineering point of view.

**Objective**
- Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs.

**Content**
- Biomedical Engineering: Concepts and Theories.
- Techniques and Technologies.
- Analytical Competencies.
- Decision-making.
- Media and Digital Technologies.
- Problem-solving.
- Communication.
- Cooperation and Teamwork.
- Adaptability and Flexibility.
- Creative Thinking.
- Critical Thinking.
- Integrity and Work Ethics.
- Self-direction and Self-management.

**Method-specific Competencies**
- Signal theory and processing.
- X-rays (production, tissue interaction, contrast, modular transfer function).
- Nuclear imaging (detection principles, image reconstruction, kinetic modelling).
- Magnetic Resonance imaging (magnetic moment, spin transitions, excitation, relaxation, detection).
- Magnetic Resonance imaging (plane wave encoding, Fourier reconstruction, pulse sequences).
- Ultrasound (mechanical wave generation, propagation in tissue, reflection, transmission).
- Ultrasound (spatial and temporal resolution, phased arrays).
- Ultrasound (Doppler shift, implementations, applications).
- Summary, exam questions.

**Prerequisites / notice**
- No specific requirements, BUT students will have to learn a lot of new words related to biochemistry, biology and medicine, while HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.).

**Lecture notes**
- Lecture notes and handouts.

**Literature**
- Analysis, Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming.
- Biomedical sensors both wearable and also biochemical sensors.
- Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices.
- Bioinformatics: genomic and proteomic tools, databases and basic calculations.
- Equations describing basic reactions and enzyme kinetics.
- Medical optics: Optical components and systems used in hospitals.
- Basic concepts of tissue engineering and organ printing.
- Biomaterials and their medical applications.
- Function of the heart and the circulatory system.
- Transport and exchange of substances in the human body, compartment modeling.
- The respiratory system.
- Bioimaging.
- Orthopedic biomechanics.
- Lectures (2h), discussion of practical exercises (1h) and homework exercises.
- Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino.

**Competencies**
- **Subject-specific Competencies**
  - Concepts and Theories.
  - Techniques and Technologies.
  - Analytical Competencies.
  - Decision-making.
  - Media and Digital Technologies.
  - Problem-solving.
  - Communication.
  - Cooperation and Teamwork.
  - Adaptability and Flexibility.
  - Creative Thinking.
  - Critical Thinking.
  - Integrity and Work Ethics.
  - Self-direction and Self-management.

**Summary**
- Design a basic diagnostic imaging system chain including data acquisition and data reconstruction.
- Characterize system performance based on signal-to-noise ratio, contrast-to-noise ratio and transfer function.
- Explain the physical and mathematical foundations of diagnostic medical imaging systems.
- Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications.

**Personal Competencies**
- Self-direction and Self-management.
- Integrity and Work Ethics.
- Creativity and Credibility.
- Communication and Teamwork.
- Problem-solving.
- Decision-making.
- Conflict resolution.

**Social Competencies**
- Creativity and Credibility.
- Communication and Teamwork.
- Professionalism.
- Leadership.
- Negotiation.
- Conflict resolution.

**Method-specific Competencies**
- Signal theory and processing.
- X-rays (production, tissue interaction, contrast, modular transfer function).
- Nuclear imaging (detection principles, image reconstruction, kinetic modelling).
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- Bioimaging.
- Orthopedic biomechanics.
- Lectures (2h), discussion of practical exercises (1h) and homework exercises.
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**Competencies**
- **Subject-specific Competencies**
  - Concepts and Theories.
  - Techniques and Technologies.
  - Analytical Competencies.
  - Decision-making.
  - Media and Digital Technologies.
  - Problem-solving.
  - Communication.
  - Cooperation and Teamwork.
  - Adaptability and Flexibility.
  - Creative Thinking.
  - Critical Thinking.
  - Integrity and Work Ethics.
  - Self-direction and Self-management.
Bioelectronics and Biosensors

W 6 credits 2V+2U J. Vörös, M. F. Yanik

Abstract
The course introduces bioelectricity and the sensing concepts that enable obtaining information about neurons and their networks. The sources of electrical fields and currents in the context of biological systems are discussed. The fundamental concepts and challenges of measuring bioelectronic signals and the basic concepts to record optogenetically modified organisms are introduced.

Objective
During this course the students will:
- learn the basic concepts in bioelectronics including the sources of bioelectronic signals and the methods to measure them
- be able to solve typical problems in bioelectronics
- learn about the remaining challenges in this field

Content
Lecture topics:

1. Introduction

Sources of bioelectronic signals
2. Membrane and Transport
3-4. Action potential and Hodgkin-Huxley

Measuring bioelectronic signals
5. Detection and Noise
6. Measuring currents in solutions, nanopore sensing and patch clamp pipettes
7. Measuring potentials in solution and core conductance model
8. Measuring electronic signals with wearable electronics, ECG, EEG
9. Measuring mechanical signals with bioelectronics

In vivo stimulation and recording
10. Functional electric stimulation
11. In vivo electrophysiology

Optical recording and control of neurons (optogenetics)
12. Measuring neurons optically, fundamentals of optical microscopy
13. Fluorescent probes and scanning microscopy, optogenetics, in vivo microscopy
14. Measuring biochemical signals

Lecture notes
A detailed script is provided to each lecture including the exercises and their solutions.

Literature
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites / notice
The course requires an open attitude to the interdisciplinary approach of bioelectronics.
In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).
### Subject-specific Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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### Method-specific Competencies

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### Social Competencies

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### Personal Competencies

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</table>

### Competencies Overview

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<th>Credits</th>
<th>Type</th>
<th>Lecturer</th>
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<td>227-0447-00L</td>
<td>Image Analysis and Computer Vision</td>
<td>W</td>
<td>6</td>
<td>E. Konukoglu, E. Erdil, F. Yu</td>
</tr>
<tr>
<td>227-0939-00L</td>
<td>Cell Biophysics</td>
<td>W</td>
<td>6</td>
<td>T. Zambelli</td>
</tr>
</tbody>
</table>

### Abstracts

**Image Analysis and Computer Vision**


**Cell Biophysics**

- Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.

### Objective

**Image Analysis and Computer Vision**

- This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

**Cell Biophysics**

- Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

### Content

**Image Analysis and Computer Vision**

- The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

**Cell Biophysics**

- By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

### Lecture Notes

**Image Analysis and Computer Vision**

- No lecture notes because the two proposed textbooks are more than exhaustive!

**Cell Biophysics**

- I am willingly available Mondays 17.00 o’clock - 18.00 in my office GLC F12.2 for whatever discussion about the lessons and the exercises.

- !!! I am using OneNote. All lectures will be broadcast via ZOOM, while corresponding videos of the previous years (lectures and exercises) are available in Moodle !!!

Data: 15.06.2024 12:39

Autumn Semester 2024

Page 1268 of 2653
This course teaches state-of-the-art methods and models for fMRI data analysis in lectures and exercises. It covers all aspects of statistical parametric mapping (SPM), including preprocessing, the general linear model, statistical inference, multiple comparison corrections, event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data.

Participants need a good command of:

- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.

**Competencies**

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Social Competencies**

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Personal Competencies**

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

**Prerequisites / notice**

- **Literature**

  As further deepening:
  - Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

**227-0965-00L Micro and Nano-Tomography of Biological Tissues**

**Abstract**

The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry, and statistics.

**Objective**

Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

**Content**

Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

**Lecture notes**

Will be indicated during the lecture.

**Literature**

Available online

**227-0969-00L Methods & Models for fMRI Data Analysis**

**Abstract**

This course teaches methods and models for fMRI data analysis, covering all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, statistical inference, multiple comparison corrections, event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data.

Does not take place this semester.

**Objective**

To obtain in-depth knowledge of the theoretical foundations of SPM and DCM and of their practical application to empirical fMRI data.

**Content**

This course teaches state-of-the-art methods and models for fMRI data analysis in lectures and exercises. It covers all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, frequentist and Bayesian inference, multiple comparison corrections, and event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. A particular emphasis of the course will be on methodological questions arising in the context of clinical studies in psychiatry and neurology. Practical exercises serve to consolidate the skills taught in lectures.

**263-5057-00L From Publication to the Doctor’s Office**

**Abstract**

This seminar course is designed to provide students with an opportunity to review and critically evaluate recent publications in medical field focusing on examples when CS method or bioinformatics/statistical technique has lead to an instrumentation, technique or drug approved for clinical practice use.

**Objective**

Throughout the course, students will read and analyze recent publications that demonstrate successful applications and sometimes failures in medicine. Promising research applications will also be discussed. The publications will cover a wide range of topics, including drug discovery, image analysis, prognostic models, and learning healthcare.
The course will be structured as half lecture content and half seminar content. Lectures will review state of the medical practice prior to the discovery, obstacles in moving the field forward, and the need for improvement. Lecture will be followed by the seminar part where students will take turns presenting the assigned publications and leading the discussions. Students' presentations will focus on the main findings, and specific steps taken to translate the finding into clinical practice.

Publications will include examples of:
- specific CS/bioinformatics/statistics applications that has been brought to "bedside" – has been approved by European Medicines Agency / Food and Drug Administration (USA) for clinical use or are widely used in medical research;
- examples of failures of how a discovery did not translate into an endproduct and why;
- current active research areas.

Covered topics will include some of the following:
- Drug discovery: Computer-aided drug discovery has become an integral part of the drug development process, enabling researchers to design and screen large libraries of molecules in silico (i.e., using computer simulations) before synthesizing and testing them in the lab. This has led to the discovery of new drug candidates for a wide range of diseases, including cancer, Alzheimer's disease, and HIV/AIDS.
- Genomics: Advances in computational genomics have enabled researchers to analyze and interpret large-scale genomic data, including DNA sequencing data, to identify disease-causing mutations, genetic risk factors, and drug targets. Examples of the development of personalized medicine, where treatments are tailored to an individual's genetic makeup. Examples when drug target identified by genetics has led to approved treatment.
- Imaging: Computer vision and image processing techniques have revolutionized medical imaging, enabling researchers to extract quantitative information from medical images that were previously inaccessible. This has led to the development of new diagnostic and prognostic tools for a wide range of diseases, including cancer, cardiovascular disease, and neurological disorders.
- Real-world data applications: emulation of clinical trials using electronic health records data.
- Large language models: Generating clinical trial protocols using large language models. Natural Language Processing for information extraction and interpretation.
- Learning healthcare systems: Advances in data analytics and information technology have enabled the development of learning healthcare systems, which use real-time data from electronic health records, medical devices, and other sources to improve patient outcomes and reduce healthcare costs. This has the potential to transform the way healthcare is delivered, making it more personalized, efficient, and effective.

In addition to the presentations, students will also be required to write critical reviews of the assigned publications throughout the course. The reviews will be evaluated based on the students' ability to identify the strengths and weaknesses of the publications and to provide insightful and constructive feedback.

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<th>Method-specific Competencies</th>
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<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
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| Personal Competencies                  |                          |                                |
|----------------------------------------|--------------------------|
| Integrity and Work Ethics              | fostered                 |
| Creative Thinking                      | fostered                 |

327-0505-00L Surfaces and Interfaces I: Fundamentals, Analytics and Applications

Extended course starting HS23. Old title: Surfaces, Interfaces and their Applications I. Students who obtained credit points for the old course cannot retake it.

Abstract

This course teaches the basics of surface and interface science and technology, including surface modifications and forces. It covers various analytical techniques to study surface and interface properties, and explores phenomena of applied relevance like friction, lubrication, phoresis, and wetting where surfaces play a crucial role.

Objective

Students are able to
- describe the physical and chemical properties of surfaces and interfaces.
- analyze and compare analytical tools for surfaces.
- choose and combine appropriate surface-analytical approaches for solving problems connected to applications.
- understand and explain the importance of surfaces and interfaces in a broad range of phenomena and applications.

Content

- Introduction to surfaces and interfaces
- Structure of surfaces over different length scales: from macroscopic roughness to atomic structure
- Surface modifications
- Adsorption and adsorption models
- Surface forces
- Basic physical concepts
- Thermodynamics of surfaces and interfaces
- Measurement of intermolecular and surface forces
- Dynamics and history effects
- Surface analytics: X-ray Photoelectron Spectroscopy (XPS) – principles and modern developments
- Surface analytic: Secondary Ion Mass Spectroscopy (SIMS) and IR Spectroscopy – Principles and examples
- Atomic Force Microscopy (AFM): Principles and modes of operation
- Tribology: Adhesion, Friction and Lubrication
- Contact mechanics
- Micro and macroscale friction
- Boundary lubrication
- Wetting
- Contact angles
- Phoretic phenomena
- Electric double layer and electrophoresis
- Electro-osmosis
- Other types of phoresis
- Case studies

Publications will include examples of:
- specific CS/bioinformatics/statistics applications that has been brought to "bedside" – has been approved by European Medicines Agency / Food and Drug Administration (USA) for clinical use or are widely used in medical research;
- examples of failures of how a discovery did not translate into an endproduct and why;
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Covered topics will include some of the following:
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- Real-world data applications: emulation of clinical trials using electronic health records data.
- Large language models: Generating clinical trial protocols using large language models. Natural Language Processing for information extraction and interpretation.
- Learning healthcare systems: Advances in data analytics and information technology have enabled the development of learning healthcare systems, which use real-time data from electronic health records, medical devices, and other sources to improve patient outcomes and reduce healthcare costs. This has the potential to transform the way healthcare is delivered, making it more personalized, efficient, and effective.

In addition to the presentations, students will also be required to write critical reviews of the assigned publications throughout the course. The reviews will be evaluated based on the students' ability to identify the strengths and weaknesses of the publications and to provide insightful and constructive feedback.

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This introductory course on Scanning Electron Microscopy (SEM) emphasizes hands-on learning. Using ScopeM SEMs, students have the opportunity to study their own samples (or samples provided) and solve practical problems by applying knowledge acquired during the lectures. At the end of the course, students will be able to apply SEM for their (future) research projects.

### Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Critical Thinking</td>
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### 327-2125-00L Microscopy Training SEM I - Introduction to SEM


For PhD students, postdocs and others, a fee will be charged (https://scopem.ethz.ch/education/MTP.html).

All applicants must additionally register on this form: https://docs.google.com/forms/d/1Xw8L_z2yXTE9qXxW9C66nK MVq9VxSUJaEa-9c3WX4xk/edit

**The selected applicants will be contacted and asked for confirmation a few weeks before the course date.**

### Abstract

This introductory course on Scanning Electron Microscopy (SEM) emphasizes hands-on learning. Using ScopeM SEMs, students have the opportunity to study their own samples (or samples provided) and solve practical problems by applying knowledge acquired during the lectures. At the end of the course, students will be able to apply SEM for their (future) research projects.

### Objective

- Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize microscope performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.

### Content

During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications. This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

### Lectures:

- Introduction on Electron Microscopy and instrumentation
- electron sources, electron lenses and probe formation
- beam/specimen interaction, image formation, image contrast and imaging modes.
- sample preparation techniques for EM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

### Practicals:

- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast (and image processing)
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Practice on real-world samples and report results

### Literature


### Prerequisites / notice

No mandatory prerequisites.

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### 327-2126-00L Microscopy Training TEM I - Introduction to TEM

| W | 2 credits | 3P | P. Zeng, E. J. Barthazy Meier, A. G. Bittermann, F. Gramm, A. Sologubenko |

For PhD students, postdocs and others, a fee will be charged (https://scopem.ethz.ch/education/MTP.html).

All applicants must additionally register on this form: https://docs.google.com/forms/d/1rv0D7HjPySCB7XkZ1NxWfrFW7Wf+s6EMJ9carEAO28/edit

**The selected applicants will be contacted and asked for confirmation a few weeks before the course date.**

### Abstract

The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

### Notice

Salt: 15.06.2024 12:39

Autumn Semester 2024
Objective
Understanding of
1. the set-up and individual components of a TEM
2. the basics of electron optics and image formation
3. the basics of electron beam – sample interactions
4. the contrast mechanism
5. various sample preparation techniques
Learning how to
1. align and operate a TEM
2. acquire data using different operation modes of a TEM instrument, i.e. Bright-field and Dark-field imaging
3. record electron diffraction patterns and index diffraction patterns
4. interpret TEM data

Content
Lectures:
- basics of electron optics and the TEM instrument set-up
- TEM imaging modes and image contrast
- STEM operation mode
- Sample preparation techniques for hard and soft materials

Practicals:
- Demo, practical demonstration of a TEM: instrument components, alignment, etc.
- Hands-on training for students: sample loading, instrument alignment and data acquisition.
- Sample preparation for different types of materials
- Practical work with TEMs
- Demonstration of advanced Transmission Electron Microscopy techniques

Literature

Prerequisites / notice
No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.

363-0790-00L Technology Entrepreneurship W 2 credits 2V F. Hacklin

Abstract
Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding.

This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are success factors in the creation of new firms, including founding, financing and growing a venture.

Content
Weekly sessions - recorded.
10+ sessions carried out by guest lecturers: experts in the broad field of technology entrepreneurship (e.g., serial entrepreneurs, venture capitalists, (E)MBA professors, company builders, patent experts, scale-up executives, …). Final session: multiple choice semester assignment (100% of grade).

Typical lecture format (2h):
15': Introduction
60': Guest testimonial
15': Discussion related to topic (in groups)
10': Plenary discussion
20': Q&A with (guest) lecturer

Lecture notes
Lecture slides and case material

Competencies

Subject-specific Competencies
Method-specific Competencies

Social Competencies

Personal Competencies

363-1163-00L Developing Digital Biomarkers W 3 credits 2V F. Da Conceição Barata

Particularly suitable for students with a technical background who are interested in healthcare.

Abstract
The course gives an introduction to digital biomarkers and provides students with the foundations to develop their own digital biomarkers. More specifically, the course will cover fundamental topics such as designing observational studies, collecting, and exploring data generated by consumer-centric devices, and applying analytical methods to predict health-related outcomes.

Objective
The widespread use of mobile technologies (e.g., wearable sensors, mobile applications, social media, and location-tracking technologies) has the potential to meet the health monitoring needs of the world’s aging population and the ever-growing number of chronic patients. However, this premise is based on the application of Machine Learning algorithms that allow us to use this data in many different ways. In this course we will analyze systematic ways to collect data, review the most relevant methods and applications in healthcare, discuss the main challenges they present and apply the newly gained knowledge in practical assignments.

The course has four core learning objectives. Students should:
• understand the anatomy of digital biomarkers
• understand the potential and applications of digital biomarkers
• be able to critically reflect and assess existing digital biomarkers
• be able to design and implement a digital biomarker
The course will consist of four topic clusters that will allow the discussion of the most relevant digital biomarker applications in healthcare:

1) Digital Biomarkers: From biological to digital biomarkers. How are they motivated, defined and how can they be leveraged for monitoring? Prognostic vs. diagnostic vs. predictive biomarkers. Passive sensing vs. active sensing. Digital biomarker vs. Digital therapeutics.

2) Consumer-centric device data: Today, vast amount of physiological, environmental, and behavioral observations can be collected with consumer centric devices. To derive clinical meaningful information from this data is, however, difficult. We will analyze strategies for extracting knowledge from those measurements.

3) Methodology: In the last decade, neural networks (also known as "deep learning") have helped push the boundaries of the state-of-the-art in a myriad of domains. They have also uncovered a number of different problems. We will discuss advantages and disadvantage as well as alternative methods for their application to digital biomarker data.

4) Applications: Digital biomarkers are still an emerging subfield, but given that longitudinal in digital biomarker data are arguably easy to acquire in large quantities, it is expected that many relevant Machine Learning applications will emerge in the near future. We will review and discuss current applications and challenges.

Literature


Prerequisites / notice

Some programming experience in Python is required, and some experience in Machine Learning is highly recommended.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Social Competencies

Communication assessed
Cooperation and Teamwork assessed

Personal Competencies

Creative Thinking assessed
Critical Thinking assessed
Self-direction and Self-management assessed

Abstract

Materials and Mechanics in Medicine W 4 credits 3G M. Zenobi-Wong, J. G. Snedeker

Objective

Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Content

Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

Lecture notes

course website on Moodle

Literature


Abstract

Multiscale Bone Biomechanics W 6 credits 3S R. Müller, X.-H. Qin

Objective

The learning objectives include
1. advanced knowledge of the state-of-the-are in multiscale bone biomechanics;
2. basic understanding of the biological principles governing bone in health, disease and treatment from molecules, to cells, tissue and up to the organ;
3. good understanding of the prevalent biomechanical testing and imaging techniques on the various levels of bone hierarchy;
4. practical implementation of state-of-the-art multiscale simulation techniques;
5. improved programing skills through the use of python;
6. hands on experience in designing solutions for clinical and industrial problems;
7. encouragement of critical thinking and creating an environment for independent and self-directed studying.

Academic Press
Bone is one of the most investigated biological materials due to its primary function of providing skeletal stability. Bone is susceptible to different local stimuli including mechanical forces and has great capabilities in adapting its mechanical properties to the changes in its environment. Nevertheless, aging or hormonal changes can make bone lose its ability to remodel appropriately, with loss of strength and increased fracture risk as a result, leading to devastating diseases such as osteoporosis.

To better understand the biomechanical function of bone, one has to understand the hierarchical organization of this fascinating material down from the molecules, to the cells, tissue and up to the organ. Multiscale imaging and simulation allow to link these different levels of hierarchy. Incorporating systems biology approaches, not only biomechanical strength of the material can be assessed but also the mechanobiological response of the bone triggered by loading and injury in scenarios relevant for personalized health. Watching cells working together to build and repair bone in a coordinated fashion is a spectacle, which will need dynamic image content and deep discussions in the lecture room to probe the imagination of the individual student interested in the topic. Lastly, state-of-the-art developments in tissue engineering and regeneration, 3D bioprinting and bio-manufacturing and organoid technology will be highlighted towards personalized health.

For the seminar, concepts of video lectures will be used in a flipped classroom setup, where students can study the basic biology, engineering, and mathematical concepts in video tutorials online (TORQUES). All videos and animations will be incorporated in Moodle and PolyBook allowing studying and interactive course participation online. It is anticipated that the students need to prepare 2x45 minutes for the study of the actual lecture material. The course is structured as a seminar in three parts of 45 minutes with video lectures and a flipped classroom setup. In the first part (TORQUES: Tiny, Open-with-Restrictions courses focused on Qulality and Effectiveness), students study the basic concepts in short, interactive video lectures on the online learning platform Moodle. Students are able to pose questions at the end of each video lecture or the Moodle forum that will be addressed in the second part of the lectures using a flipped classroom concept. For the flipped classroom, the lecturers may prepare additional teaching material to answer the posted questions (Q&A).

Following the Q&A, the students will have to form small groups to try to solve such problems and to present their solutions for advanced multiscale investigation of bone ranging from basic science to clinical application. Towards the end of the semester, students will have to present self-selected publications associated with the different topics of the lecture identified through PubMed or the Web of Science.

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<td>Communication</td>
<td>assessed</td>
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<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
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<td></td>
<td>Cooperation and Teamwork</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<th>Prerequisites</th>
<th>Laboratory Course in Molecular Biology (376-0006-02L)</th>
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<tr>
<th>Content</th>
<th>Molecular and Cellular Biology of Exercise and Muscle Regeneration - Practical Aspects W 3 credits 2G O. Bar-Nur, K. De Bock</th>
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</table>

Abstract: The skeletal muscle biology field purposes to understand how muscles coordinate movement, regenerate following injury and adapt to exercise stimuli. In this course, the students will acquire insights into the molecular aspects of muscle biology and exercise, in addition to gaining hands-on experience in experimental techniques that are commonly used to research muscle regeneration and exercise.

Objective: The objective of this course is to introduce students into current research topics and outstanding questions in skeletal muscle biology. Also, the course will give students hands-on experience in respect to the tools needed to perform basic molecular biology research in the field of exercise and skeletal muscle biology. Students will learn how to translate a scientific question in muscle biology into a small scientific project. They will learn how to design an experiment and to analyze and critically interpret experimental data.

Content: The course will consist of 4 main research themes and the anticipated 16 students will be divided into 4 subgroups of 4 students each focusing on one of the following research topics:

- **Topic 1**: Molecular pathways that control muscle stem cell self-renewal and differentiation
- **Topic 2**: Genome engineering to correct genetic mutations that cause muscle diseases
- **Topic 3**: Muscle fiber composition, force production and insulin sensitivity
- **Topic 4**: Amino acid sensitivity in skeletal muscle following exercise

The course will be organized into 7 sessions, each approx. 4 hours: the first 2 sessions will be theoretical and include an introductory lectures by the professors in addition to a journal club presentation by the students. This journal club aims to provide theoretical and scientific background that will be used to identify outstanding research questions. This will be followed by 4 practical sessions (hands-on experience) and 1 final evaluation session.

For the journal club, each group of students will receive a peer-review article that is highly relevant to the respective group’s research topic. Each of the 4 groups will present and discuss the article in a journal club format to the rest of the participants following the week. During the four practical sessions, students will gain hands-on experiences and learn different lab techniques related to molecular biology of exercise and muscle regeneration. Each group will present with a research objective that is related to their topic, and perform in collaboration with teaching assistants a set of experiments that aim to address the research objective. At the final evaluation session, each group of students will present their results and identify follow-up research questions and hypothesis based on their experimental achievements.

Select practical methods that the proposed course will teach include:

- **i. Group 1**: tissue culture, isolation of muscle stem cells via FACSC, differentiation of muscle stem cell into muscle fibers, small molecules screens, quantitative analysis of muscle cell proliferation and fusion, Immunofluorescence.
- **ii. Group 2**: tissue culture, differentiation of muscle stem cells into muscle fibers, guide RNA design and Crispr-Cas9 gene editing of genetic mutations that cause muscle diseases in muscle stem cells and fibers. Immunofluorescence and PCR.
- **iii. Group 3**: ex vivo assessment of muscle force characteristics, cryosectioning of muscle tissue, immunofluorescence and western blot.
- **iv. Group 4**: tissue culture of muscle stem cells, isolation of muscle stem cells and differentiation into muscle fibers, amino acid stimulation of muscle fibers, Western blot.

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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1274 of 2653
Abstract

This course equips the students with several key principles such as good clinical practice, ethical study requirements, reproducible data management and effective oral, graphical, and written communication to design and execute good quality, ethically sound human research studies and represents a 101-toolkit of transferable research management skills/digital tools.

Objective

The overall goal of this course is to integrate transferable principles of human research project management into preparation, conduction, and dissemination of own/future research projects and beyond. The following objectives are part of this course:

- Creating well-defined research hypothesis for a specific research topic
- Apply universal good clinical practice guidelines in future research projects
- Integrate well-documented data management and open science principles into future research projects
- Integrate principles of effective communication in speaking, writing and graphical illustrations of future research idea/output

Content

The course will cover the following topics:

- Introduction to different study designs and ethical requirements thereof in Switzerland
- Introduction to literature search and searching platforms
- How to collect and sort publications/keep up to date on research topic
- Inputs on critically evaluating papers
- How to pre-define study requirements to "future-proof" the research (hypothesis, sample size definition, pre-registration)
- Correct conduction of fundamental human research procedures (e.g., screening, consent process, CRF) and identification/prevention of deviations and emergencies (e.g., SAE/AE, protocol violation, research misconduct)
- Principles of reproducible and integral study documentation and data management (e.g., definition of source files, SOP/WI, Master Trial File, metadata)
- FAIR principles and open science
- Design principles and free digital tools for graphical illustrations
- Effective summarizing of research output/topic in an abstract and pitch presentation

Prerequisites / notice

- Students should be proficient in programming (any language).
- Course prerequisites:
  - For Biomedical Engineering Master’s: none
  - For ITET Master’s: none
  - For D-MAVT Master’s: none
  - For D-HEST Master’s and PhD students:
    - If BSc in electrical/mechanical engineering or computer science: none
    - If any other BSc program: 376-0022-00L (Imaging and Computing in Medicine) or 376-1983-00L (Foundations of Data Science)

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1275 of 2653
Abstract
Strategies of human-system-interaction, individual needs, physical & mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people’s health, well-being, and satisfaction as well as the overall system performance.

Objective
The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications. Students are expected to learn about how to enable an efficient and qualitatively high standing interaction between human and the environment, considering costs, benefits, health, and safety as well. Thus, an ergonomic design and evaluation process of products, tasks, and environments may be promoted in different disciplines. The goal is achieved in addressing a broad variety of topics and embedding the discussion in macroscopic factors such as the behavior of consumers and objectives of economy.

Content
- Physiological, physical, and cognitive factors in sensation, perception, and action
- Body spaces and functional anthropometry, Digital Human Models
- Experimental techniques in assessing human performance, well-being, and comfort
- Usability engineering in system designs, product development, and innovation
- Human information processing and biological cybernetics
- Interaction among consumers, environments, behavior, and tasks

Literature
- Gavriel Salvendy, Handbook of Human Factors and Ergonomics, 4th edition (2012), is available on NEBIS as electronic version and for free to ETH students
- Further textbooks are introduced in the lecture
- Brouchures, checklists, key articles etc. are uploaded in ILIAS

376-1179-00L Applications of Cybernetics in Ergonomics W 1 credit 1U M. Menozzi Jäckli, Y.-Y. Hedinger Huang, R. Huang
Abstract
Cybernetics systems have been studied and applied in various research fields, such as for applications in ergonomics. Topics discussed in this lecture (man-machine-interaction, performance in multi-modal interactions, quantification in gestalt principles for the use in product development, information processing) are deepened with exercises conducted at our labs.

Objective
To learn and practice cybernetics principles in interface designs and product development.

Content
- Fitt's law applied in manipulation tasks
- Hick-Hyman law applied in design of the driver assistance systems - Vigilance applied in quality inspection
- Accommodation/vergence crosslink function
- Cross-link models in neurobiology- the ocular motor control system
- Human performance in optimization of production lines

Literature

376-1219-00L Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions W 3 credits 2V R. Rien, O. Lambercy
Abstract
Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

Objective
Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

Content
Introduction, problem definition, overview
Rehabilitation of visual function
- Anatomy and physiology of the visual sense
- Technical aids (glasses, sensor substitution)
- Retina and cortex implants
Rehabilitation of hearing function
- Anatomy and physiology of the auditory sense
- Hearing aids
- Cochlea Implants
Rehabilitation and use of kinesthetic and tactile function
- Anatomy and physiology of the kinesthetic and tactile sense
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
Rehabilitation of vestibular function
- Anatomy and physiology of the vestibular sense
- Rehabilitation strategies and devices (e.g. BrainPort)
Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter
- Brain stimulation and recording
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces
Literature

Introductory Books:


Selected Journal Articles and Web Links:


Prerequisites / notice

Target Group:
- Students of higher semesters and PhD students of - D-MAVT, D-ITET, D-INFK, D-HEST
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich

Students of other departments, faculties, courses are also welcome

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Leadership and Responsibility

Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

376-1351-00L Micro/Nanotechnology and Microfluidics for Biomedical Applications W 2 credits 2V E. Delamarche

Abstract
This course is an introduction to techniques in micro/nanotechnology and to microfluidics. It reviews how many familiar devices are built and can be used for research and biomedical applications. Transistors for DNA sequencing, beamers for patterning proteins, hard-disk technology for biosensing and microfluidics for point-of-care diagnostics are just a few examples of the covered topics.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1277 of 2653
Objective
The main objective of the course is to introduce micro/nanotechnology and microfluidics to students having any technical background. The course is multi-disciplinary and covers a broad range of techniques. For each lecture, a brief historical perspective is given to illustrate by whom and how the techniques were invented.

The course should familiarize the students with the techniques used in micro/nanotechnology, cleanroom microfabrication, and show them how micro/nanotechnology pervades throughout life sciences. Microfluidics will be emphasized due to their increasing importance in research and for medical applications.

The second objective is to have life sciences students less intimidated by micro/nanotechnology and make them able to link instruments and techniques to specific problems that they might have in their projects/studies. This will also help students getting access to the ETHZ/IBM Nanotech Center infrastructure if needed.

Content
Mostly formal lectures (2 x 45 min), with few specific guest lectures on topics of particular relevance. For example, an introduction to cleanroom and micro/nanotechnology instruments and 3D printing will be provided. Last 3 weeks would be dedicated to the presentation and evaluation of projects by students (2 to 3 students per team). For this, about 12 recent technologies are listed and each team picks a technology and makes a short report and presentation describing how it works, its strengths and weaknesses, and describes what problem it solves.

In terms of technical content, the lectures will cover:
- an overview of the microelectronic industry, Moore’s law, field-effect transistors, next-generation DNA sequencing
- liquid crystal displays, organic light emitting diodes, electrophoretic displays, micromirrors and beamers, photopatterning of proteins and cells, optogenetics, and flexible displays and electronics
- hard disk drives and the giant magnetoresistance effect, magnetic nanoparticles, photonicss, magnetic sensing and optical biosensing
- cleanroom techniques and instruments, from design to microfabrication of simple devices and microfluidics, examples of DNA microarrays
- the principles of microfluidics, microfluidic functions and fabrication, from microfluidics for research to point-of-care diagnostics, and the (infamous) history of Theranos, as well as some discussions on diagnostics for COVID, R0, and (im)precision of diagnostic devices and why it matters

- 2 x 45 min will be covered by Yuksel Temiz, a master of Arduino programming and do-it-yourself electronics, who will present how to make 20$ electronic components that are synergistic to microfluidic devices and that can be controlled using a smartphone

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Social Competencies
- Communication: fostered

Personal Competencies
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered

376-1353-00L
Nanostructured Materials Safety
W 2 credits 1V P. Wick, T. Bürki-Thurnherr

Abstract
Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection.

Objective
Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials.

Content
Building upon new technologies to engineer and functionalize well-defined nanostructured materials, a plethora of exciting discoveries were made and found their way in our daily live. These customized nanomaterials provides extraordinary properties and make them attractive for many innovative applications. Exactly these new properties may have the potential to be responsible for unforeseen side effects, which hamper a straightforward translation into new products. Therefore, the safety research provide the evidence for a responsible and sustainable use of nanomaterials.

The lecture will focus on basic principles of nanotoxicology, provide the understanding of the potential side effects of nanomaterial in a context-specific way addressing the main exposure routes such as inhalation, ingestion, topical applications and intravenous injections as well as it will provide impulses for safer material designs.

Structure of the planed lecture (2 x 45 min)
1. Introduction: the principles of nanotoxicology
2. Lung- particles interactions: two disease scenarios and their molecular mechanism
3. GI – particles interactions: intendent and unintendent particle exposure via food
4. Skin – particles interactions: body care products and their influence on skin physiology
5. Intravenous injection: colloidal stability, protein corona and cellular effects
6. Micro- / Nanoplastics and development of a safety research plan
7. End of semester exam

Lecture notes
Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website.

Prerequisites /
notice
course “Introduction to Toxicology”

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: fostered
- Problem-solving: fostered
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

376-1504-00L
Physical Human Robot Interaction (pHRI)
W 4 credits 2V+2U O. Lambercy, P. Wolf

Abstract
This course focuses on the emerging, interdisciplinary field of physical human-robot interaction, bringing together themes from robotics, real-time control, human factors, haptics, virtual environments, interaction design and other fields to enable the development of human-oriented robotic systems.
The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and design safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1) identify critical human factors in physical human-robot interaction and use these to derive design requirements;
2) compare and select mechatronic components that optimally fulfill the defined design requirements;
3) derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;
4) design control hardware and software and implement and test human-interactive control strategies on the physical setup;
5) characterize and optimize such systems using both engineering and psychophysical evaluation metrics;
6) investigate and optimize one aspect of the physical setup and convey and defend the gained insights in a technical presentation.

This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in device design for humans such as transparency and stability analysis, safety hardware and procedures. The course is organized into lectures that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical-human-robot interaction, laboratory sessions and lab visits.

Students will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. Here the salient features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic paddle (https://relab.ethz.ch/downloads/open-hardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

Will be distributed on Moodle before the lectures.

The students are expected to have basic control knowledge from previous classes.

The lecture will be held in English.

There are 4 credit points for this lecture.

The registration is limited to 26 students

Notice:

- Devices and Scenarios, pages 157-162.

Notice:

The registration is limited to 26 students.

There are 4 credit points for this lecture.

The lecture will be held in English.

The students are expected to have basic control knowledge from previous classes.

http://www.relab.ethz.ch/education/courses/phri.html
## Practical Methods in Tissue Engineering

**Objective**

Practical exercises on topics including sterile cell culture, light microscopy and histology, and biomaterials are covered. Practical work on manufacturing and evaluating hydrogels and scaffolds for tissue engineering will be performed in small groups. In addition to practical lab work, the course will teach skills in data acquisition/analysis.

**Prerequisites / notice**

A laptop is needed with the below Systems Requirements:
- Memory: 16 GB
- Processor: 3rd gen i7
- DirectX® 11.0 compliant AMD Radeon/NVIDIA® GeForce® card with 2 GB RAM
- Storage: 15 GB

Mac computer can be used by pre-installing Windows through bootcamp (older Macs) or Parallels Desktop (14d trial license, 35 CHF license purchasable in the IT shop of ETH).

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories: ass
d  
  - Techniques and Technologies: ass
d  
- **Method-specific Competencies**
  - Analytical Competencies: fos
  - Decision-making: ass
d
  - Problem-solving: ass
d
  - Project Management: ass
d
- **Social Competencies**
  - Communication: ass
d
- **Personal Competencies**
  - Cooperation and Teamwork: ass
d
  - Adaptability and Flexibility: fos
  - Critical Thinking: ass
  - Self-direction and Self-management: fos

### Abstract

The goal of this course is to teach MSc students the necessary skills for doing research in the fields of tissue engineering and regenerative medicine.

### Content

- Measurement and modeling of the human movement during daily activities and in a clinical environment.

### Prerequisites / notice

- A laptop is needed with the below Systems Requirements:
  - Memory: 16 GB
  - Processor: 3rd gen i7
  - DirectX® 11.0 compliant AMD Radeon/NVIDIA® GeForce® card with 2 GB RAM
  - Storage: 15 GB

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories: ass
d  
  - Techniques and Technologies: fos
  - Analytical Competencies: ass
d  
  - Media and Digital Technologies: fos
  - Problem-solving: fos
  - Cooperation and Teamwork: fos
  - Leadership and Responsibility: fos
  - Self-presentation and Social Influence: fos
  - Sensitivity to Diversity: fos
  - Adaptable and Flexibility: fos
  - Creative Thinking: fos
  - Critical Thinking: ass
  - Integrity and Work Ethics: ass
  - Self-awareness and Self-reflection: ass
376-1664-00L Ethics in Drug Development W 3 credits 2V A. Blasimme, E. Vayena, to be announced

Abstract
This course provides a thorough exploration of drug development and involves ethical issues as well as critical analysis of ethical challenges and practical skills to resolve them. It includes elements of drug discovery, preclinical and clinical research ethics, alternative regulatory pathways and ethics of drug pricing and develops a solid grasp of ethical complexity as well as practical skills.

Objective
This course is tailored to D-HEST students who want to become familiar with pharmaceutical development and its ethical implications. By the end of this course, students will have developed a comprehensive understanding of the ethical complexities and challenges in drug development. They will be equipped with the knowledge and analytical skills to navigate ethical reasoning and contribute to the responsible advancement of pharmaceutical research. The specific learning objectives of the course are:

- Discuss relevant legal and public policy frameworks in drug development, ensuring an understanding of the broader regulatory context within which policy and regulatory decisions are made.
- Recognize and identify ethical dilemmas inherent to drug development, fostering a heightened awareness of ethical considerations across various stages of the process.
- Identify and discuss ethical issues in drug development in light of recent advances in the field of artificial intelligence.
- Critically analyze ethical challenges within drug development, enabling them to discuss complex issues, evaluate competing ethical perspectives, and form reasoned judgments.
- Understand the ethical theories and principles that underpin drug regulation.
- Evaluate the ethical implications of alternative pathways, such as Accelerated Approval and Compassionate Use, equipping students to assess potential benefits, risks, and societal consequences.
- Assess the ethical dimensions of drug pricing decisions and their impact on equity and accessibility, encouraging thoughtful reflection on the broader societal implications of pricing strategies.

Content
- Principles of biomedical ethics and how they relate pharmaceutical innovation
- Introduction to drug development, with a focus on the Swiss regulatory ecosystem
- Current trends and impediments to effective drug development, including the use of AI in drug discovery
- Translational medicine and its ethical implications
- Ethical Aspects of pre-clinical research, including animal replacement technologies like organoids and organ chips
- Ethical aspects of clinical research
- Special regulatory pathways: expanded access / compassionate use
- Special regulatory pathways: accelerated approval
- Drug development and public health, emergency use of new drugs
- Drug pricing: introduction to its regulatory and ethical aspects

376-1714-00L Biocompatible Materials W 4 credits 3V K. Maniura, M. Rottmar, M. Zenobi-Wong

Abstract
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

Objective
The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Content
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Lecture notes
Handouts are deposited online (moodle).

Literature
- Handouts and references therein.
- Literature:

  (available online via ETH library)

376-1721-00L Bone Biology: Basics, Research and Clinics W 2 credits 2V E. Wehrle, G. A. Kuhn, to be announced

Abstract
The course gives an introduction into bone biology and provides an overview on current research methods and clinical approaches. Emphasis is put on skeletal development and metabolism, osteoporosis as well as fracture healing. Each topic is structured into three parts: basics, research and clinics.

Objective
After completing the Bone Biology course, students will be able to:
1. Remember and apply basics in bone biology and disease
2. Remember clinical features and surgical approaches
3. Select adequate research methods and approaches
4. Evaluate publications on topics presented in the lecture
### Trauma Biomechanics

**Abstract**

Trauma biomechanics in an interdisciplinary research field investigating the biomechanics of injuries and related subjects such as prevention. The lecture provides an introduction to the basic principles of trauma biomechanics.

**Objective**

Introduction to the basic principles of trauma biomechanics.

**Content**

This lecture serves as an introduction to the field of trauma biomechanics. Emphasis is placed on the interdisciplinary nature of impact biomechanics, which uses the combination of fundamental engineering principles and advanced medical technologies to develop injury prevention measures. Topics include: accident statistics and accident reconstruction, biomechanical response of the human to impact loading, injury mechanisms and injury criteria, test methods (including crash tests), computer simulations, aspects of vehicle safety. Real world examples mainly from automobile safety are used to augment lecture material.

**Lecture notes**

Handouts will be made available.

**Literature**


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<th>Competencies</th>
<th>Subject-specific Competencies</th>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Creative Thinking</td>
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<td>Self-direction and Self-management</td>
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### Colloquium in Biomechanics

**Abstract**

Current topics in biomechanics presented by speakers from academia and industry.

**Objective**

Getting insight into actual areas and problems of biomechanics.

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<td>Techniques and Technologies</td>
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### Applied Biostatistics

**Abstract**

This course covers the main methods used in Biostatistics. It starts by revising Linear Models (Regression, Anova), then moves to Generalised Linear Models (logistic regression and methods for count data) and finally introduces more advanced topics (Linear Mixed-Effects Models and Generalised Additive Models). The course strongly focuses on applied aspects of data analysis.

**Objective**

After this course students:  
- revised Linear Models  
- revised or got introduced to Generalised Linear Models  
- got introduced to Linear Mixed-Effects Models  
- got introduced to Generalised Additive Models  
- are able to select among these methods to solve an applied problem in Biostatistics  
- can perform the data analysis using the statistical software R  
- can interpret the results of such an analysis and draw valid "biological" conclusions

**Content**

This course is structured into three parts. The first part focuses on Linear and Generalised Linear Models. The second part introduces more advanced methodologies such as Linear Mixed-Effects Models and Generalised Additive Models. Both, part one and two will include the following topics: exploratory data analysis, model fitting, model "selection", residual diagnostics, model validation and results interpretation. Analyses will be carried out using the statistical software R. Finally, in the third part of the course students will be analysing real-world datasets to put into practice the knowledge and skills acquired during the first two parts.

**Prerequisites / notice**

The statistical software R will be used in the exercises. If you are unfamiliar with R, it is highly recommend to view the online R course "etutoR".

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</table>

### Physics in Medical Research: From Atoms to Cells

**Abstract**

This course covers the main methods used in Biostatistics. It starts by revising Linear Models (Regression, Anova), then moves to Generalised Linear Models (logistic regression and methods for count data) and finally introduces more advanced topics (Linear Mixed-Effects Models and Generalised Additive Models). The course strongly focuses on applied aspects of data analysis.

**Objective**

After this course students:  
- revised Linear Models  
- revised or got introduced to Generalised Linear Models  
- got introduced to Linear Mixed-Effects Models  
- got introduced to Generalised Additive Models  
- are able to select among these methods to solve an applied problem in Biostatistics  
- can perform the data analysis using the statistical software R  
- can interpret the results of such an analysis and draw valid "biological" conclusions

**Content**

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<td>Techniques and Technologies</td>
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</table>
Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

<table>
<thead>
<tr>
<th>529-0041-00L</th>
<th>Modern Mass Spectrometry, Hyphenated Methods, and Chemometrics</th>
</tr>
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<tbody>
<tr>
<td>Abstract</td>
<td>Comprehensive knowledge about the analytical methods introduced in this course and their practical applications.</td>
</tr>
<tr>
<td>Objective</td>
<td>Modern mass spectrometry, hyphenated analytical methods, speciation, chemometrics.</td>
</tr>
<tr>
<td>Content</td>
<td>Hyphenation of separation with identification methods such as GC-MS, LC-MS, GC-IR, LC-IR, LC-NMR etc.; importance of speciation. Modern mass spectrometry: time-of-flight, orbitrap and ion cyclotron resonance mass spectrometry, ICP-MS. Soft ionization methods, desorption methods, spray methods. Mass spectrometry imaging. Use of statistical and computer-assisted methods for processing analytical data (chemometrics).</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes will be made available online.</td>
</tr>
<tr>
<td>Literature</td>
<td>Information about relevant literature will be available in the lecture &amp; in the lecture notes.</td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Exercises are an integral part of the lecture. Prerequisites: 529-0051-00 &quot;Analytische Chemie I (3. Semester)&quot; 529-0058-00 &quot;Analytische Chemie II (4. Semester)&quot; (or equivalent)</td>
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<td>Competencies</td>
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<td>Subject-specific Competencies</td>
<td>Concepts and Theories assessed</td>
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<td>Method-specific Competencies</td>
<td>Analytical Competencies assessed</td>
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<tr>
<td>Social Competencies</td>
<td>Communication fostered</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility fostered</td>
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<tr>
<th>529-0042-00L</th>
<th>Drug Delivery and Drug Targeting</th>
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<tbody>
<tr>
<td>Abstract</td>
<td>The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.</td>
</tr>
<tr>
<td>Objective</td>
<td>The students dispose of an overview on current principles and systems for the controlled delivery and targeting of drugs. The focus of the course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines.</td>
</tr>
<tr>
<td>Content</td>
<td>The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Selected lecture notes, documents and supporting material will be directly provided or may be downloaded from the course website.</td>
</tr>
</tbody>
</table>
Further references will be provided in the course.

### Competencies

#### Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

#### Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

#### Social Competencies

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

#### Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

### Literature

- W. U. Kutay

### 551-0317-00L Immunology I

<table>
<thead>
<tr>
<th>W</th>
<th>3 credits</th>
<th>2V</th>
<th>M. Kopf, A. O xenius</th>
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#### Abstract

Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

#### Objective

Introduction into structural and functional aspects of the immune system.

#### Content

- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

#### Lecture notes

Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien".

#### Literature

- Kuby, Immunology, 9th edition, Freemen + Co., New York, 2020

#### Prerequisites / notice

For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

### Competencies

#### Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

#### Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

#### Social Competencies

- Communication
- Cooperation and Teamwork

#### Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-direction and Self-management

### Literature


### 551-0319-00L Cellular Biochemistry (Part I)

<table>
<thead>
<tr>
<th>W</th>
<th>3 credits</th>
<th>2V</th>
<th>U. Kutay, F. Allain, T. Kleele, I. Zemp</th>
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</thead>
</table>

#### Abstract

Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

#### Objective

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

#### Content

- Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.
- Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

#### Lecture notes

Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)
After completing this course, students will be able to understand:

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<td>Techniques and Technologies</td>
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### 636-0108-00L Biological Engineering and Biotechnology

**Abstract**

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

**Objective**

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

**Content**


**Lecture notes**

Handout during the course.

### 752-3105-00L Physiology Guided Food Structure and Process Design

**Abstract**

A sound understanding of physiological implications of food design will allow to shape new products, which feature health as well as environmental benefits and on the other side do not compromise on organoleptic qualities, formulation and manufacturing, and quality and safety. The course links the physiological driven requirements with food structure design and subsequent engineering steps.

**Objective**

The objective of this course is to highlight the link between human physiology, product sensory, nutritional functions, and engineering approaches to facilitate the design of food matrices reflecting the requirements for the beforementioned properties. To identify and manipulate these properties, the pathways that control the interaction of food structures and their physiological action will be introduced. Students are introduced to a skill set that will encompass basic digestion, sensory physiology knowledge, and food structures. Students will be exposed to the interplay along the gastrointestinal tract including taste, aroma, and texture perception, swallowing mechanics, and gastrointestinal digestion with an engineering or physical sciences angle.

**Content**

Chapter 1: Introduction - The need for physiology guided structure and process design in the context of personalized nutrition (Peter Fischer)  
Chapter 2: Food Oral Processing: the impact of food oral breakdown on sensory perception (Marine Devezeaux de Lavergne)  
Chapter 3: Chewing and swallowing across the lifespan, from infants to elderly (Marine Devezeaux de Lavergne)  
Chapter 4: Perception physiology in humans and other species (Benoit von der Weid)  
Chapter 5: Biophysics of food digestion & how it can be exploited in the development of strategies for delivery (Timothy J. Wooster)  
Chapter 6: Numerical and experimental modelling of the intestinal system (Peter Fischer)

**Lecture notes**

Lecture notes are available at Moodle

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<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
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<td>Techniques and Technologies</td>
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### Major in Molecular Health Sciences

#### Compulsory Courses

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<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
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<tbody>
<tr>
<td>376-0300-00L</td>
<td>Essentials in Translational Science</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>J. Goldhahn</td>
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</table>

**Abstract**

Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people (e.g. Medicines). The course should help to clarify basics of translational science, illustrate successful applications and enable students to integrate key features into their future projects.

**Objective**

After completing this course, students will be able to understand:

Key steps of drug development and their interdependencies. Project management, communication & funding options. Students should be able to apply this knowledge in drug development programs in Pharma, Biotech or their own spin-off.

Data: 15.06.2024 12:39  
Autumn Semester 2024  
Page 1285 of 2653
This lecture will guide you through drug development from bench to bedside and provide industry perspectives which support you in your first industry role or when building a startup. The course will integrate knowledge across the many disciplines which are required to develop new medicines which are transformational for patients.

Key steps of the Drug development process
- Disease Biology and mechanism of action
- Translation of ‘Mechanism of Action’ into patient and payer benefit
- Drug design
- Drug formulation
- Toxicology
- Pharmacokinetics & pharmacodynamics
- Translational medicine
- Clinical trials
- Regulatory requirements
- Patenting
- Market access
- How are these steps connected and impacting each other?

Positive and negative examples will be illustrated by distinguished guest speakers.

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies fostered

Method-specific Competencies
- Analytical Competencies fostered
- Decision-making assessed
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered

376-0302-01L GCP Basic Course (Modules 1 and 2)
O 1 credit 1G
G. Senti, C. Fila, R. Grossmann

Abstract
The basic course in “Good Clinical Practice” (GCP) contains of two full-time training days (Module 1 and Module 2) and addresses elementary aspects for the appropriate conduct of clinical trials and non-clinical research projects involving human beings. Successful participation will be confirmed by a certificate that is recognized by the Swiss authorities.

Objective
Students will get familiar with:
- Key Ethics documents
- (Inter)national Guidelines and Laws (e.g. ICH-GCP, DIN EN ISO 14155, TPA, HRA)
- Sequence of research projects and project-involved parties
- Planning of research projects (statistics, resources, study design, set-up of the study protocol)
- Approval of research projects by Authorities (SwissEthics, Swissmedic, FOPH)
- Roles and responsibilities of project-involved parties

Students will learn how to:
- Classify research projects according to the risk-based approach of the HRA
- Write a study protocol
- Inform participating patients/study subjects
- Obtain consent by participating patients/study subjects
- Classify, document and report Adverse Events
- Handle projects with biological material from humans and/or health-related personal data

Content
Module 1:
- Research and Research Ethics, Guidelines, (inter)national Legislation, Development of therapeutic products, Methodology (Study Design), Study documents (Study protocol, Investigator's Brochure, Patient Information Leaflet, Informed Consent Form)

Module 2:
- Roles and Responsibilities, Approval procedures, Notification and Reporting, Study documentation, Research with biological material and health-related data, data protection, data retention

Elective Courses

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<tr>
<th>Number</th>
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<td>227-0939-00L</td>
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Abstract
Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.

Objective
Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars of thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding experimental results from the literature.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.
Content

- Basics of theory of probability
- Boltzmann's law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns

Theory and corresponding exercises are merged together during the classes.

Lecture notes

No lecture notes because the two proposed textbooks are more than exhaustive!

I am willingly available Mondays 17.00 o'clock - 18.00 in my office GLC F12.2 for whatever discussion about the lessons and the exercises.

!!! I am using OneNote. All lectures will be broadcast via ZOOM, while corresponding videos of the previous years (lectures and exercises) are available in Moodle !!!

Literature


As further deepening:


Prerequisites / notice

Participants need a good command of
- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Analytical Competencies
- Decision-making

Media and Digital Technologies
- Problem-solving

Project Management

Method-specific Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Project Management

Social Competencies

Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Personal Competencies

Assessed

Fostered

W 3 credits 2S+1A O. Demler

263-5057-00L From Publication to the Doctor's Office

The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract

This seminar course is designed to provide students with an opportunity to review and critically evaluate recent publications in medical field focusing on examples when CS method or bioinformatics/statistical technique has lead to an instrumentation, technique or drug approved for clinical practice use.

Objective

Throughout the course, students will read and analyze recent publications that demonstrate successful applications and sometimes failures in medicine. Promising research applications will also be discussed. The publications will cover a wide range of topics, including drug discovery, image analysis, prognostic models, and learning healthcare.
The course will be structured as half lecture content and half seminar content. Lectures will review state of the medical practice prior to the discovery, obstacles in moving the field forward, and the need for improvement. Lecture will be followed by the seminar part where students will take turns presenting the assigned publications and leading the discussions. Students’ presentations will focus on the main findings, and specific steps taken to translate the finding into clinical practice.

Covered topics will include some of the following:
- Drug discovery: Computer-aided drug discovery has become an integral part of the drug development process, enabling researchers to design and screen large libraries of molecules in silico (i.e., using computer simulations) before synthesizing and testing them in the lab. This has led to the discovery of new drug candidates for a wide range of diseases, including cancer, Alzheimer’s disease, and HIV/AIDS.
- Genomics: Advances in computational genomics have enabled researchers to analyze and interpret large-scale genomic data, including DNA sequencing data, to identify disease-causing mutations, genetic risk factors, and drug targets. Examples of the development of personalized medicine, where treatments are tailored to an individual’s genetic makeup. Examples when drug target identified by genetics has led to approved treatment.
- Imaging: Computer vision and image processing techniques have revolutionized medical imaging, enabling researchers to extract quantitative information from medical images that were previously inaccessible. This has led to the development of new diagnostic and prognostic tools for a wide range of diseases, including cancer, cardiovascular disease, and neurological disorders.
- Real-world data applications: emulation of clinical trials using electronic health records data.
- Large language models: Generating clinical trial protocols using large language models. Natural Language Processing for information extraction and interpretation.
- Learning healthcare systems: Advances in data analytics and information technology have enabled the development of learning healthcare systems, which use real-time data from electronic health records, medical devices, and other sources to improve patient outcomes and reduce healthcare costs. This has the potential to transform the way healthcare is delivered, making it more personalized, efficient, and effective.

In addition to the presentations, students will also be required to write critical reviews of the assigned publications throughout the course. The reviews will be evaluated based on the students’ ability to identify the strengths and weaknesses of the publications and to provide insightful and constructive feedback.

The course is intended for advanced undergraduate and graduate students with a background in computer science, bioinformatics, or a related field and interest in applying their skills to medical research.

This course assumes a working knowledge of R/Python and intermediate statistical analysis, including linear, logistic, survival regressions or ability and interest to learn them outside of the class.

### Competencies

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### Prerequisites / notice

The course is intended for advanced undergraduate and graduate students with a background in computer science, bioinformatics, or a related field and interest in applying their skills to medical research.

This course assumes a working knowledge of R/Python and intermediate statistical analysis, including linear, logistic, survival regressions or ability and interest to learn them outside of the class.

For PhD students, postdocs and others, a fee will be charged (https://scopem.ethz.ch/education/MTCP.html).

All applicants must additionally register on this form:
https://docs.google.com/forms/d/1Xw8L_2yXTE99xXy6C6fmjKVMVd9vxxSjUEa--9CwDk0/d/edit

The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

### Abstract

This introductory course on Scanning Electron Microscopy (SEM) emphasizes hands-on learning. Using ScopeM SEMs, students have the opportunity to study their own samples (or samples provided) and solve practical problems by applying knowledge acquired during the lectures. At the end of the course, students will be able to apply SEM for their (future) research projects.

### Objective

- Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize microscope performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.
During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications. This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

Lectures:
- Introduction on Electron Microscopy and instrumentation
- electron sources, electron lenses and probe formation
- beam/specimen interaction, image formation, image contrast and imaging modes.
- sample preparation techniques for EM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

Practicals:
- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast (and image processing)
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Practice on real-world samples and report results

Lecture notes
Lecture notes will be distributed.

Literature

Prerequisites / notice
No mandatory prerequisites.

327-2126-00L Microscopy Training TEM I - Introduction to TEM
W 2 credits 3P P. Zeng, E. J. Barthazy Meier, A. G. Bittermann, F. Gramm, A. Sologubenko

For PhD students, postdocs and others, a fee will be charged (https://scopem.ethz.ch/education/MTP.html).

All applicants must additionally register on this form: https://docs.google.com/forms/d/1nrDTHjPySCB7yK2qZiXFrFwF7wFv6EMJ9carEAO28/edit
The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

Abstract
The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

Objective
Understanding of
1. the set-up and individual components of a TEM
2. the basics of electron optics and image formation
3. the basics of electron beam – sample interactions
4. the contrast mechanism
5. various sample preparation techniques

Learning how to
1. align and operate a TEM
2. acquire data using different operation modes of a TEM instrument, i.e. Bright-field and Dark-field imaging
3. record electron diffraction patterns and index diffraction patterns
4. interpret TEM data

Content
Lectures:
- basics of electron optics and the TEM instrument set-up
- TEM imaging modes and image contrast
- STEM operation mode
- Sample preparation techniques for hard and soft materials

Practicals:
- Demo, practical demonstration of a TEM: instrument components, alignment, etc.
- Hands-on training for students: sample loading, instrument alignment and data acquisition.
- Sample preparation for different types of materials
- Practical work with TEMs
- Demonstration of advanced Transmission Electron Microscopy techniques

363-1163-00L Developing Digital Biomarkers
W 3 credits 2V F. Da Conceição Barata

Particularly suitable for students with a technical background who are interested in healthcare.

Abstract
The course gives an introduction to digital biomarkers and provides students with the foundations to develop their own digital biomarkers. More specifically, the course will cover fundamental topics such as designing observational studies, collecting, and exploring data generated by consumer-centric devices, and applying analytical methods to predict health-related outcomes.
The widespread use of mobile technologies (e.g., wearable sensors, mobile applications, social media, and location-tracking technologies) has the potential to meet the health monitoring needs of the world’s aging population and the ever-growing number of chronic patients. However, this premise is based on the application of Machine Learning algorithms that allow us to use this data in many different ways. In this course we will analyze systematic ways to collect data, review the most relevant methods and applications in healthcare, discuss the main challenges they present and apply the newly gained knowledge in practical assignments.

The course has four core learning objectives. Students should:

- understand the anatomy of digital biomarkers
- understand the potential and applications of digital biomarkers
- be able to critically reflect and assess existing digital biomarkers
- be able to design and implement a digital biomarker

1) Digital Biomarkers: From biological to digital biomarkers. How are they motivated, defined and how can they be leveraged for monitoring? Prognostic vs. diagnostic vs. predictive biomarkers. Passive sensing vs. active sensing. Digital biomarker vs. Digital therapeutics.

2) Consumer-centric device data: Today, vast amount of physiological, environmental, and behavioral observations can be collected with consumer centric devices. To derive clinical meaningful information from this data is, however, difficult. We will analyze strategies for extracting knowledge from those measurements.

3) Methodology: In the last decade, neural networks (also known as “deep learning”) have helped push the boundaries of the state-of-the-art in a myriad of domains. They have also uncovered a number of different problems. We will discuss advantages and disadvantage as well as alternative methods for their application to digital biomarker data.

4) Applications: Digital biomarkers are still an emerging subfield, but given that longitudinal in digital biomarker data are arguably easy to acquire in large quantities, it is expected that many relevant Machine Learning applications will emerge in the near future. We will review and discuss current applications and challenges.

Literature


Prerequisites / notice

Some programming experience in Python is required, and some experience in Machine Learning is highly recommended.

Competencies

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Abstract

The seminar provides state-of-the-art insight to the biomechanical function of bone from molecules, to cells, tissue and up to the organ. Multiscale imaging and simulation allows linking different levels of hierarchy, where systems biology helps understanding the mechanobiological response of bone to loading and injury in scenarios relevant for personalized health and translational medicine.

The learning objectives include:

1. advanced knowledge of the state-of-the-are in multiscale bone biomechanics;
2. basic understanding of the biological principles governing bone in health, disease and treatment from molecules, to cells, tissue and up to the organ;
3. good understanding of the prevalent biomechanical testing and imaging techniques on the various levels of bone hierarchy;
4. practical implementation of state-of-the-art multiscale simulation techniques;
5. improved programming skills through the use of python;
6. hands on experience in designing solutions for clinical and industrial problems;
7. encouragement of critical thinking and creating an environment for independent and self-directed studying.
Content

Bone is one of the most investigated biological materials due to its primary function of providing skeletal stability. Bone is susceptible to different local stimuli including mechanical forces and has great capabilities in adapting its mechanical properties to the changes in its environment. Nevertheless, aging or hormonal changes can make bone lose its ability to remodel appropriately, with loss of strength and increased fracture risk as a result, leading to devastating diseases such as osteoporosis.

To better understand the biomechanical function of bone, one has to understand the hierarchical organization of this fascinating material down from the molecules, to the cells, tissue and up to the organ. Multiscale imaging and simulation allow to link these different levels of hierarchy. Incorporating systems biology approaches, not only biomechanical strength of the material can be assessed but also the mechanobiological response of the bone triggered by loading and injury in scenarios relevant for personalized health. Watching cells working together to build and repair bone in a coordinated fashion is a spectacle, which will need dynamic image content and deep discussions in the lecture room to probe the imagination of the individual student interested in the topic. Lastly, state-of-the-art developments in tissue engineering and regeneration, 3D bioprinting and bio-manufacturing and organoid technology will be highlighted towards personalized health.

For the seminar, concepts of video lectures will be used in a flipped classroom setup, where students can study the basic biology, engineering, and mathematical concepts in video tutorials online (TORQUES). All videos and animations will be incorporated in Moodle and PolyBook allowing studying and interactive course participation online. It is anticipated that the students need to prepare 2x45 minutes for the study of the actual lecture material. The course is structured as a seminar in three parts of 45 minutes with video lectures and a flipped classroom setup. In the first part (TORQUES: Tiny, Open-with-Restrictions courses focused on Qality and Effectiveness), students study the basic concepts in short, interactive video lectures on the online learning platform Moodle. Students are able to post questions at the end of each video lecture or the Moodle forum that will be addressed in the second part of the lectures using a flipped classroom concept. For the flipped classroom, the lecturers may prepare additional teaching material to answer the posted questions (Q&A).

Following the Q&A, the students will have to form small groups to try to solve such problems and to present their solutions for advanced multiscale investigation of bone ranging from basic science to clinical application. Towards the end of the semester, students will have to present self-selected publications associated with the different topics of the lecture identified through PubMed or the Web of Science.

Lecture notes

Material will be provided on Moodle and eColab.

Prerequisites / notice

Prior experience with the programming language python is beneficial but not mandatory. ETH offers courses for practical programming with python.

Competencies

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<tr>
<td>376-0208-00L</td>
<td>Molecular and Cellular Biology of Exercise and Muscle Regeneration - Practical Aspects</td>
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Prerequisites:

Laboratory Course in Molecular Biology (376-0006-02L)

Abstract

The skeletal muscle biology field purposes to understand how muscles coordinate movement, regenerate following injury and adapt to exercise stimuli. In this course, the students will acquire insights into the molecular aspects of muscle biology and exercise, in addition to gaining hands-on experience in experimental techniques that are commonly used to research muscle regeneration and exercise.

Objective

The objective of this course is to introduce students into current research topics and outstanding questions in skeletal muscle biology. Also, the course will give students hands-on experience in respect to the tools needed to perform basic molecular biology research in the field of exercise and skeletal muscle biology. Students will learn how to translate a scientific question in muscle biology into a small scientific project. They will learn how to design an experiment and to analyze and critically interpret experimental data.

Content

The course will consist of 4 main research themes and the anticipated 16 students will be divided into 4 subgroups of 4 students- each one will focus on one of the following research topics:

Topic 1: Molecular pathways that control muscle stem cell self-renewal and differentiation

Topic 2: Genome engineering to correct genetic mutations that cause muscle diseases

Topic 3: Muscle fiber composition, force production and insulin sensitivity

Topic 4: Amino acid sensitivity in skeletal muscle following exercise

The course will be organized into 7 sessions, each approx. 4 hours: the first 2 sessions will be theoretical and include an introductory lectures by the professors in addition to a journal club presentation by the students. This journal club aims to provide theoretical and scientific background that will be used to identify outstanding research questions. This will be followed by 4 practical sessions (hands-on experience) and 1 final evaluation session.

For the journal club, each group of students will receive a peer-review article that is highly relevant to the respective group’s research topic. Each of the 4 groups will present and discuss the article in a journal club format to the rest of the participants the following week. During the four practical sessions, students will gain hands-on experiences and learn different lab techniques related to molecular biology of exercise and muscle regeneration. Each group will be presented with a research objective that is related to their topic, and perform in collaboration with teaching assistants a set of experiments that aim to address the research objective. At the final evaluation session, each group of students will present their results and identify follow-up research questions and hypothesis based on their experimental achievements.

Select practical methods that the proposed course will teach include:

i. Group 1: tissue culture, isolation of muscle stem cells via FACS, differentiation of muscle stem cell into muscle fibers, small molecules screens, quantitative analysis of muscle cell proliferation and fusion, Immunofluorescence.

ii. Group 2: tissue culture, differentiation of muscle stem cells into muscle fibers, guide RNA design and Crispr-Cas9 gene editing of genetic mutations that cause muscle diseases in muscle stem cells and fibers. Immunofluorescence and PCR.

iii. Group 3: ex vivo assessment of muscle force characteristics, cryosectioning of muscle tissue, Immunofluorescence and western blot.

iv. Group 4: tissue culture of muscle stem cells, isolation of muscle stem cells and differentiation into muscle fibers, amino acid stimulation of muscle fibers. Western blot.

Prerequisites:

376-0006-02L Laboratory Course in Molecular biology
Colloquium in Translational Science (Autumn Semester)

Abstract
Current topics in translational medicine presented by speakers from academia and industry.

Objective
Getting insight into actual areas and problems of translational medicine.

Content
Timely and concise presentations of postgraduate students, post-docs, senior scientists, professors, as well as external guests from both academics and industry will present topics of their interest related to translational medicine.

Prerequisites / notice
No compulsory prerequisites, but student should have basic knowledge about biomedical research.

376-1353-00L Nanostructured Materials Safety

Abstract
Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection.

Objective
Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials

Content
Building upon new technologies to engineer and functionalize well-defined nanostructured materials, a plethora of exciting discoveries were made and found their way in our daily live. These customized nanomaterials provides extraordinary properties and make them attractive for many innovative applications. Exactly these new properties may have the potential to be responsible for unforeseen side effects, which hamper a straightforward translation into new products. Therefore, the safety research provide the evidence for a responsible and sustainable use of nanomaterials.

The lecture will focus on basic principles of nanotoxicology, provide the understanding of the potential side effects of nanomaterial in a context-specific way addressing the main exposure routes such as inhalation, ingestion, topical applications and intravenous injections as well as it will provide impulses for safer material designs.

Structure of the planed lecture (2 x 45 min)
1. Introduction: the principles of nanotoxicology
2. Lung- particles interactions: two disease scenarios and their molecular mechanism
3. GI – particles interactions: intendent and unintendent particle exposure via food
4. Skin – particles interactions: body care products and their influence on skin physiology
5. intravenous injection: colloidal stability, protein corona and cellular effects
6. Micro- / Nanoplastics and development of a safety research plan
7. End of semester exam

Prerequisites / notice
course "Introduction to Toxicology"

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork

376-1622-00L Practical Methods in Tissue Engineering

Abstract
The goal of this course is to teach MSc students the necessary skills for doing research in the fields of tissue engineering and regenerative medicine.

Objective
Practical exercises on topics including sterile cell culture, light microscopy and histology, and biomaterials are covered. Practical work on manufacturing and evaluating hydrogels and scaffolds for tissue engineering will be performed in small groups. In addition to practical lab work, the course will teach skills in data acquisition/analysis.

Prerequisites / notice
A laptop is needed with the below Systems Requirements:
- Memory: 16 GB
- Processor: 3rd gen i7
- DirectX® 11.0 compliant AMD Radeon/NVIDIA® GeForce® card with 2 GB RAM
- Storage: 15 GB

Mac computer can be used by pre-installing Windows through bootcamp (older Macs) or Parallels Desktop (14d trial license, 35 CHF license purchasable in the IT shop of ETH+).

376-1661-00L Ethics of Life Sciences and Biotechnology

Abstract
This semester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their technological application. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences

Objective
This course is tailored to students who want to become familiar with the analysis of ethical issues in all the different domains of life sciences and biotechnology. The course aims at equipping students with the necessary knowledge and analytic skills to understand, discuss and address the ethical aspects of science and technology in the domain of human health. The specific learning objectives of this course are:

A. Identify ethical issues in in life sciences and biotechnology.
B. Analyze and critically discuss ethical issues in life sciences and biotechnology.
C. Become aware of relevant legal and public policy frameworks.
D. Distinguish different ethical approaches and argumentative strategies in applied ethics.
E. Recognize how ethical issues relate to different accounts of technology and innovation.
F. Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
G. Autonomous anticipate ethical issues.
H. Propose and communicate solutions to ethical challenges and dilemmas.

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Content

The course starts off with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain of applied ethics. The students will also be introduced to current theoretical accounts of technology and will start to appreciate the relevance of ethics especially with respect to new and emerging technologies. Usable analytic tools will also be provided, thus enabling the students to engage with the discipline in a practical way from the very onset of the semester.

The course will continue through broad and diverse topics which are relevant to the different study tracks offered by the department. In particular, the course will cover the following domains: digital health technologies and medical AI; food, nutrition and healthy longevity; biomedical engineering; genetics; neuroscience and Neurotechnologies; medical robotics; disability and rehabilitation; environmental ethics. The course will also include sessions on cross-cutting ethically relevant aspects of health sciences and technologies, namely: access to innovation, translational research, and the relation between science and public policy.

All the topics of the course will be illustrated and interactively discussed through many case studies, offering the students the opportunity to prepare and present them, and to use them in individual as well as group exercises. Throughout the course, the students will have multiple opportunities to experiment with ethical argumentation and to practice their evolving skills.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
Method-specific Competencies
- Analytical Competencies: fostered
- Media and Digital Technologies: fostered
- Problem-solving: fostered
Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed

376-1664-00L Ethics in Drug Development

W 3 credits 2V A. Blasimme, E. Vayena, to be announced

Abstract

This course provides a thorough exploration of drug development and involved ethical issues as well as critical analysis of ethical challenges and practical skills to resolve them. It includes elements of drug discovery, preclinical and clinical research ethics, alternative regulatory pathways and ethics of drug pricing and develops a solid grasp of ethical complexity as well as practical skills.

Objective

This course is tailored to D-HEST students who want to become familiar with pharmaceutical development and its ethical implications. By the end of this course, students will have developed a comprehensive understanding of the ethical complexities and challenges in drug development. They will be equipped with the knowledge and analytical skills to navigate ethical reasoning and contribute to the responsible advancement of pharmaceutical research. The specific learning objectives of the course are:

- Discuss relevant legal and public policy frameworks in drug development, ensuring an understanding of the broader regulatory context within which policy and regulatory decisions are made.
- Recognize and identify ethical dilemmas inherent to drug development, fostering a heightened awareness of ethical considerations across various stages of the process.
- Identify and discuss ethical issues in drug development in light of recent advances in the field of artificial intelligence.
- Critically analyze ethical challenges within drug development, enabling them to discuss complex issues, evaluate competing ethical perspectives, and form reasoned judgments.
- Understand the ethical theories and principles that underpin drug regulation.
- Evaluate the ethical implications of alternative pathways, such as Accelerated Approval and Compassionate Use, equipping students to assess potential benefits, risks, and societal consequences.
- Assess the ethical dimensions of drug pricing decisions and their impact on equity and accessibility, encouraging thoughtful reflection on the broader societal implications of pricing strategies.

Content

- Principles of biomedical ethics and how they relate pharmaceutical innovation
- Introduction to drug development, with a focus on the Swiss regulatory ecosystem
- Current trends and impediments to effective drug development, including the use of AI in drug discovery
- Translational medicine and its ethical implications
- Ethical Aspects of pre-clinical research, including animal replacement technologies like organoids and organ chips
- Ethical aspects of clinical research
- Special regulatory pathways: expanded access / compassionate use
- Special regulatory pathways: accelerated approval
- Drug development and public health. emergency use of new drugs
- Drug pricing: introduction to its regulatory and ethical aspects
- Modern mass spectrometry, hyphenated methods, and chemometrics

529-0041-00L Modern Mass Spectrometry, Hyphenated Methods, and Chemometrics

W 6 credits 3G R. Zenobi, B. Hattendorf, P. Sinués Martinez-Lozano

Abstract

Modern mass spectrometry, hyphenated analytical methods, speciation, chemometrics.

Objective

Comprehensive knowledge about the analytical methods introduced in this course and their practical applications.

Content

Hyphenation of separation with identification methods such as GC-MS, LC-MS, GC-IR, LC-IR, LC-NMR etc.; importance of speciation.

Modern mass spectrometry: time-of-flight, orbitrap and ion cyclotron resonance mass spectrometry, ICP-MS. Soft ionization methods, desorption methods, spray methods. Mass spectrometry imaging.

Use of statistical and computer-assisted methods for processing analytical data (chemometrics).

Lecture notes

Lecture notes will be made available online.

Literature

Information about relevant literature will be available in the lecture & in the lecture notes.

Prerequisites / notice

Exercises are an integral part of the lecture.

Prerequisites:

529-0051-00 "Analytische Chemie I (3. Semester)"
529-0056-00 "Analytische Chemie II (4. Semester)"
(or equivalent)
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-presentation and Social Influence: fostered
- Self-awareness and Social-reflection: fostered
- Self-direction and Self-management: fostered

Immunology III


Abstract
This course provides a detailed understanding of:
- development of T and B cells
- the dynamics of an immune response during acute and chronic infection
- modern vaccination strategies

Key experimental results will be shown to help understanding how immunological textbook knowledge has evolved.

Objective
Obtain a detailed understanding of:
- the development, activation, and differentiation of different types of T cells and their effector mechanisms during immune responses,
- recognition of pathogenic microorganisms by the host cells and molecular events thereafter,
- events and signals for maturation of naive B cells to antibody producing plasma cells and memory B cells.
- Optimization of B cell responses by intelligent design of new vaccines

Content
- Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg)
- NK T cells and responses to lipid antigens
- Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17
- Overview of cytokines and their effector function
- Co-stimulation (signals 1-3)
- Dendritic cells
- Evolution of the "Danger" concept
- Cells expressing Pattern Recognition Receptors and their downstream signals
- T cell function and dysfunction in acute and chronic viral infections

Literature
Documents of the lectures are available for download at:
https://moodle-app2.let.ethz.ch/course/view.php?id=2581&notifyeditingon=1

Prerequisites / notice
Immunology I and II recommended but not compulsory

Concepts in Modern Genetics

W 6 credits 4V  Y. Barral, A. Hajnal, O. Voinnet, University lecturers

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module BIC348 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree/courses/special-students-university-of-zurich.html

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Immunology I

W 3 credits 2V  M. Kopf, A. Oxenius

551-0223-00L
Immunology III

551-0309-00L
Concepts in Modern Genetics

551-0317-00L
Immunology I

Immunology I

Autumn Semester 2024
Abstract
Introduction into structural and functional aspects of the immune system.

Objective
Introduction into structural and functional aspects of the immune system.

Content
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Lecture notes
Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien" fostered

Literature
- Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020

Prerequisites
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Techniques and Technologies</td>
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<td>assessed</td>
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Method-specific Competencies

| Analytical Competencies | Decision-making | fostered |
| Problem-solving         |                  | fostered |
| Project Management      |                  | fostered |

Social Competencies

| Communication           | fostered |

Personal Competencies

| Adaptability and Flexibility | fostered |
| Creative Thinking          | fostered |
| Critical Thinking          | assessed |
| Self-direction and Self-management | fostered |

551-0512-00L Current Topics in Molecular and Cellular Neurobiology W 2 credits 1S U. Suter fostered

Abstract
The course is a literature seminar or "journal club". Each Friday a student, or a member of the Suter Lab in the Institute of Molecular Health Sciences, will present a paper from the recent literature.

Objective
The course introduces you to recent developments in the fields of cellular and molecular neurobiology. It also supports you to develop your skills in critically reading the scientific literature. You should be able to grasp what the authors wanted to learn i.e. their goals, why the authors chose the experimental approach they used, the strengths and weaknesses of the experiments and the data presented, and how the work fits into the wider literature in the field. You will present one paper yourself, which provides you with practice in public speaking.

Content
You will present one paper yourself. Give an introduction to the field of the paper, then show and comment on the main results (all the papers we present are available online, so you can show original figures with a beamer). Finish with a summary of the main points and a discussion of their significance.

Lecture notes
Presentations will be made available after the seminars.

Prequisites
You must attend at least 80% of the journal clubs, and give a presentation of your own. At the end of the semester there will be a 30 minute oral exam on the material presented during the semester. The grade will be based on the exam (45%), your presentation (45%), and a contribution based on your active participation in discussion of other presentations (10%).

551-0571-00L From DNA to Diversity: the Evolution of Multicellular Organisms (University of Zurich) W 2 credits 2V A. Hajnal, D. Bopp fostered

Abstract
The evolution of the various body-plans is investigated by means of comparison of developmentally essential control genes of molecularly analysed model organisms.

Objective
By the end of this module, each student should be able to
- recognize the universal principles underlying the development of different animal body plans.
- explain how the genes encoding the molecular toolkit have evolved to create animal diversity.
- relate changes in gene structure or function to evolutionary changes in animal development.

Key skills:
By the end of this module, each student should be able to
- present and discuss a relevant evolutionary topic in an oral presentation
- select and integrate key concepts in animal evolution from primary literature
- participate in discussions on topics presented by others

551-1153-00L Systems Biology of Metabolism W 4 credits 2V U. Sauer, N. Zamboni fostered

Abstract
Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.
The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments. Critical Thinking

Analytical Competencies

Guided by an expert in the field, students will engage in classical round-table style discussions of current literature with frontal 

B. Ludewig, T. Vaughan

Original and review articles will be distributed by the respective lecturer.

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using Computational Biology

6 credits

3G+2A

T. Vaughan, C. Magnus, T. Stadler

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand

Objective

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

* stochastic models in molecular evolution
* phylogenetic & phylodynamic inference
* maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

* epidemiology
* pathogen evolution
* macroevolution of species

Content

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylogeography, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes

Lecture slides will be available on moodle.
A sound understanding of physiological implications of food design will allow to shape new products, which feature health as well as environmental benefits and on the other side do not compromise on organoleptic qualities, formulation and manufacturing, and quality and safety. The course links the physiological driven requirements with food structure design and subsequent engineering steps.

Prerequisites / notice

Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSEE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place in Basel before the start of the semester.

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed

Decision-making assessed

Problem-solving assessed

Personal Competencies

Creative Thinking assessed

Critical Thinking assessed

636-0108-00L Biological Engineering and Biotechnology

Abstract

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content


Lecture notes

Handout during the course.

701-1703-00L Evolutionary Medicine for Infectious Diseases

Abstract

This course explores infectious disease from both the host and pathogen perspective. Through short lectures, reading and active discussion, students will identify areas where evolutionary thinking can improve our understanding of infectious diseases and, ultimately, our ability to treat these effectively.

Objective

Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses.

Content

We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (< 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

Literature

The focus is on primary literature, but for some parts the following text books provide good background information:

- Schmid Hempel 2011 Evolutionary Parasitology
- Stearns & Medzhitov 2016 Evolutionary Medicine

Prerequisites / notice

A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies assessed

Method-specific Competencies

Problem-solving assessed

Project Management assessed

Social Competencies

Communication assessed

Cooperation and Teamwork assessed

Personal Competencies

Creative Thinking assessed

Critical Thinking assessed

752-3105-00L Physiology Guided Food Structure and Process Design

Abstract

A sound understanding of physiological implications of food design will allow to shape new products, which feature health as well as environmental benefits and on the other side do not compromise on organoleptic qualities, formulation and manufacturing, and quality and safety. The course links the physiological driven requirements with food structure design and subsequent engineering steps.

Objective

The objective of this course is to highlight the link between human physiology, product sensory, nutritional functions, and engineering approaches to facilitate the design of food matrices reflecting the requirements for the beforementioned properties. To identify and manipulate these properties, the pathways that control the interaction of food structures and their physiological action will be introduced.

Students are introduced to a skill set that will encompass basic digestion, sensory physiology knowledge, and food structures. Students will be exposed to the interplay along the gastrointestinal tract including taste, aroma, and texture perception, swallowing mechanics, and gastrointestinal digestion with an engineering or physical sciences angle.

Content

Chapter 1: Introduction - The need for physiology guided structure and process design in the context of personalized nutrition (Peter Fischer)

Chapter 2: Food Oral Processing: the impact of food oral breakdown on sensory perception (Marine Devezzeaux de Lavergne)

Chapter 3: Chewing and swallowing across the lifespan, from infants to elderly (Marine Devezzeaux de Lavergne)

Chapter 4: Perception physiology in humans and other species (Benoit von der Weid)

Chapter 5: Biophysics of food digestion & how it can be exploited in the development of strategies for delivery (Timothy J. Wooster)

Chapter 6: Numerical and experimental modelling of the intestinal system (Peter Fischer)

Lecture notes

Lecture notes are available at Moodle
Nutrition and Chronic Disease

The course offers detailed information on selected foodborne pathogens and toxin-producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Objective
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with a focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content
Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc.) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Literature
Recommendations will be given in the first lecture.

Prerequisites / notice
Lectures (2 hours) will be held as a single session of approximately 60 minutes (10:15 until approx. 11:15 h), without a break!

Competencies
- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management
- Social Competencies
  - Communication
- Personal Competencies
  - Creative Thinking
  - Critical Thinking

M. Loesener, A. Harms, M. Schuppler, E. Slack

752-4099-00L Molecular Biology of Foodborne Pathogens

Objective
To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis, and food allergies.

Content
The course offers detailed information on selected foodborne pathogens and toxin-producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Lecture notes
There is no script. Powerpoint presentations will be made available on line to students.

Literature
To be provided by the individual lecturers, at their discretion.

Prerequisites / notice
No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

Competencies
- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Problem-solving
  - Project Management
- Social Competencies
  - Communication
- Personal Competencies
  - Creative Thinking
  - Critical Thinking

F. von Meyenn, M. Andersson

752-6101-00L Nutrition and Chronic Disease

Objective
To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis, and food allergies.

Content
The course offers detailed information on selected foodborne pathogens and toxin-producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Lecture notes
There is no script. Powerpoint presentations will be made available on-line to students.

Literature
To be provided by the individual lecturers, at their discretion.

Prerequisites / notice
No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

Competencies
- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Problem-solving
  - Project Management
- Social Competencies
  - Communication
- Personal Competencies
  - Creative Thinking
  - Critical Thinking

F. von Meyenn, M. Andersson

752-6105-00L Epidemiology and Prevention

Objective
To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis, and food allergies.

Content
The course offers detailed information on selected foodborne pathogens and toxin-producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Lecture notes
There is no script. Powerpoint presentations will be made available on-line to students.

Literature
To be provided by the individual lecturers, at their discretion.

Prerequisites / notice
No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

Competencies
- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Problem-solving
  - Project Management
- Social Competencies
  - Communication
- Personal Competencies
  - Creative Thinking
  - Critical Thinking

M. Puhan, R. Heusser

752-0300-00L Essentials in Translational Science

Objective
Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people (e.g. Medicines). The course should help to clarify basics of translational science, illustrate successful applications and enable students to integrate key features into their future projects.
Objective
After completing this course, students will be able to understand:
Key steps of drug development and their interdependencies. Project management, communication & funding options. Students should be able to apply this knowledge in drug development programs in Pharma, Biotech or their own spin-off.

Content
This lecture will guide you through drug development from bench to bedside and provide industry perspectives which support you in your first industry role or when building a startup. The course will integrate knowledge across the many disciplines which are required to develop new medicines which are transformational for patients.

Key steps of the Drug development process
- Disease Biology and mechanism of action
- Translation of 'Mechanism of Action' into patient and payer benefit
- Drug design
- Drug formulation
- Toxicology
- Pharmacokinetics & pharmacodynamics
- Translational medicine
- Clinical trials
- Regulatory requirements
- Patenting
- Market access
- How are these steps connected and impacting each other?

Positive and negative examples will be illustrated by distinguished guest speakers.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies fostered

Method-specific Competencies
- Analytical Competencies fostered
- Decision-making assessed
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered

376-0302-01L GCP Basic Course (Modules 1 and 2) O 1 credit 1G G. Senti, C. Fila, R. Grossmann

Abstract
The basic course in "Good Clinical Practice" (GCP) contains of two full-time training days (Module 1 and Module 2) and addresses elementary aspects for the appropriate conduct of clinical trials and non-clinical research projects involving human beings. Successful participation will be confirmed by a certificate that is recognized by the Swiss authorities.

Objective
Students will get familiar with:
- Key Ethics documents
- (Inter)national Guidelines and Laws (e.g. ICH-GCP, DIN EN ISO 14155, TPA, HRA)
- Sequence of research projects and project-involved parties
- Planning of research projects (statistics, resources, study design, set-up of the study protocol)
- Approval of research projects by Authorities (SwissEthics, Swissmedic, FOPH)
- Roles and responsibilities of project-involved parties

Students will learn how to:
- Classify research projects according the risk-based approach of the HRA
- Write a study protocol
- Inform participating patients/study subjects
- Obtain consent by participating patients/study subjects
- Classify, document and report Adverse Events
- Handle projects with biological material from humans and/or health-related personal data

Content
Module 1:
Research and Research Ethics, Guidelines, (inter)national Legislation, Development of therapeutic products, Methodology (Study Design), Study documents (Study protocol, Investigator's Brochure, Patient Information Leaflet, Informed Consent Form)

Module 2:
Roles and Responsibilities, Approval procedures, Notification and Reporting, Study documentation, Research with biological material and health-related data, data protection, data retention

Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0447-00L</td>
<td>Image Analysis and Computer Vision</td>
<td>W</td>
<td>6 credits</td>
<td>3V+1U</td>
<td>E. Konukoglu, E. Erdil, F. Yu</td>
</tr>
</tbody>
</table>

Abstract

Objective
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.
Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.

This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Course material Script, computer demonstrations, exercises and problem solutions

Abstract
Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

Content
This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

This seminar reviews the philosophical and phenomenological as well as the neurobiological aspects of consciousness. The subjective features of consciousness are explored, and modern research into its neural substrate, particularly in the visual domain, is explained. Emphasis is placed on students developing their own thinking through a discussion-centered course structure.

The course's goal is to give an overview of the contemporary state of consciousness research, with emphasis on the contributions brought by modern cognitive neuroscience. We aim to clarify concepts, explain their philosophical and scientific backgrounds, and to present experimental protocols that shed light on a variety of consciousness related issues.

From Publication to the Doctor's Office
The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

This seminar course is designed to provide students with an opportunity to review and critically evaluate recent publications in medical field focusing on examples when CS method or bioinformatics/statistical technique has lead to an instrumentation, technique or drug approved for clinical practice use.

Throughout the course, students will read and analyze recent publications that demonstrate successful applications and sometimes failures in medicine. Promissing research applications will also be duscussed. The publications will cover a wide range of topics, including drug discovery, image analysis, prognostic models, and learning healthcare.

Objective
The course includes discussions of scientific as well as philosophical articles. We review current schools of thought, models of consciousness: From Philosophy to Neuroscience (University of Zurich) No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI410

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

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The course's goal is to give an overview of the contemporary state of consciousness research, with emphasis on the contributions brought by modern cognitive neuroscience. We aim to clarify concepts, explain their philosophical and scientific backgrounds, and to present experimental protocols that shed light on a variety of consciousness related issues.

Content
The course includes discussions of scientific as well as philosophical articles. We review current schools of thought, models of consciousness, and proposals for the neural correlate of consciousness (NCC).

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Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.
Content

The course will be structured as half lecture content and half seminar content. Lectures will review state of the medical practice prior to the discovery, obstacles in moving the field forward, and the need for improvement. Lecture will be followed by the seminar part where students will take turns presenting the assigned publications and leading the discussions. Students’ presentations will focus on the main findings, and specific steps taken to translate the finding into clinical practice.

Publications will include examples of:
- specific CS/bioinformatics/statistics applications that has been brought to „bedside“ – has been approved by European Medicines Agency / Food and Drug Administration (USA) for clinical use or are widely used in medical research;
- examples of failures of how a discovery did not translate into an endproduct and why;
- current active research areas.

Covered topics will include some of the following:
- Drug discovery: Computer-aided drug discovery has become an integral part of the drug development process, enabling researchers to design and screen large libraries of molecules in silico (i.e., using computer simulations) before synthesizing and testing them in the lab. This has led to the discovery of new drug candidates for a wide range of diseases, including cancer, Alzheimer’s disease, and HIV/AIDS.
- Genomics: Advances in computational genomics have enabled researchers to analyze and interpret large-scale genomic data, including DNA sequencing data, to identify disease-causing mutations, genetic risk factors, and drug targets. Examples of the development of personalized medicine, where treatments are tailored to an individual’s genetic makeup. Examples when drug target identified by genetics has led to approved treatment.
- Imaging: Computer vision and image processing techniques have revolutionized medical imaging, enabling researchers to extract quantitative information from medical images that were previously inaccessible. This has led to the development of new diagnostic and prognostic tools for a wide range of diseases, including cancer, cardiovascular disease, and neurological disorders.
- Real-world data applications: emulation of clinical trials using electronic health records data.
- Large language models: Generating clinical trial protocols using large language models. Natural Language Processing for information extraction and interpretation.
- Learning healthcare systems: Advances in data analytics and information technology have enabled the development of learning healthcare systems, which use real-time data from electronic health records, medical devices, and other sources to improve patient outcomes and reduce healthcare costs. This has the potential to transform the way healthcare is delivered, making it more personalized, efficient, and effective.

In addition to the presentations, students will also be required to write critical reviews of the assigned publications throughout the course. The reviews will be evaluated based on the students’ ability to identify the strengths and weaknesses of the publications and to provide insightful and constructive feedback.

Prerequisites / notice
The course is intended for advanced undergraduate and graduate students with a background in computer science, bioinformatics, or a related field and interest in applying their skills to medical research.

This course assumes a working knowledge of R/Python and intermediate statistical analysis, including linear, logistic, survival regressions or ability and interest to learn them outside of the class.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
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<td>Communication</td>
<td>Creative Thinking</td>
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<td>Analytical Competencies</td>
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<td>Leadership and Responsibility</td>
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Objective
- Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize microscope performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.

For PhD students, postdocs and others, a fee will be charged (https://scopem.ethz.ch/education/MTP.html).

All applicants must additionally register on this form: https://docs.google.com/forms/d/1Xw8L_2yXTE9qXxWbCc6mjKMVqdVxsSJe-9cwiDXkd0/edit

The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1301 of 2653
During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications.

This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

**Lectures:**
- Introduction on Electron Microscopy and instrumentation
- Beam/specimen interaction, image formation, image contrast and imaging modes.
- Sample preparation techniques for TEM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, line-scan and spectral mapping

**Practicals:**
- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast (and image processing)
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Practice on real-world samples and report results

**Content**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Description</th>
<th>Credits</th>
<th>Module</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>327-2126-00L</td>
<td>Microscopy Training TEM I - Introduction to TEM</td>
<td>W 2 credits</td>
<td>3P</td>
<td>P. Zeng, E. J. Barthazy Meier, A. G. Bittermann, F. Gramm, A. Sologubenko</td>
</tr>
</tbody>
</table>

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All applicants must additionally register on this form: https://docs.google.com/forms/d/1nrDTHjPySCB7iXkZiNwFwF7wFv6EMJ9carEAQ28/edit

The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

**Abstract**

The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation and analysis are discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

**Objective**

Understanding of:
1. the set-up and individual components of a TEM
2. the basics of electron optics and image formation
3. the basics of electron beam – sample interactions
4. the contrast mechanism
5. various sample preparation techniques

Learning how to:
1. align and operate a TEM
2. acquire data using different operation modes of a TEM instrument, i.e. Bright-field and Dark-field imaging
3. record electron diffraction patterns and index diffraction patterns
4. interpret TEM data

**Content**

Lectures:
- Basics of electron optics and the TEM instrument set-up
- TEM imaging modes and image contrast
- STEM operation mode
- Sample preparation techniques for hard and soft materials

Practicals:
- Demo, practical demonstration of a TEM: instrument components, alignment, etc.
- Hands-on training for students: sample loading, instrument alignment and data acquisition.
- Sample preparation for different types of materials
- Practical work with TEMs
- Demonstration of advanced Transmission Electron Microscopy techniques

**Literature**


**Notice**

No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.

**Methods and Concepts in Human Systems Neuroscience and Motor Control (4 credits)**

This course provides hands-on experience with measurement and analysis methods relevant for Humans Systems Neuroscience and Motor control (nerve-brain stimulation, EMG, EEG, psycho-physical paradigms etc). Students learn scientific material, set up experiments, perform measurements in the lab, analyse data, apply statistics and write short reports or essays.

**Objective**

This course will prepare students for experimental work as it is typically done during the master thesis. The goal is to gain hands-on experience with measurement and analysis methods relevant for Humans Systems Neuroscience and Motor control (for example peripheral nerve stimulation, electrical and magnetic brain stimulation, EMG, EEG, psycho-physical paradigms etc). Students will learn how to perform small scientific projects in this area. Students will work individually or in small groups and solve scientific problems which require them to perform measurements in human participants, extract relevant readouts from the data, apply appropriate statistics and interpret the results. They will also be required to write small essays and reports and they will get feedback on their writing throughout the course.
Students are required to have successfully completed the course "Neural control of movement and motor learning" and to have basic knowledge of applied statistics.

**Applied Human Research Project Management**

**376-0816-00L**

**Abstract** This course equips the students with several key principles such as good clinical practice, ethical study requirements, reproducible data management and effective oral, graphical, and written communication to design and manage good quality, ethically sound human research studies and represents a 101-toolkit of transferable research management skills/digital tools.

**Objective** The overall goal of this course is to integrate transferable principles of human research project management into preparation, conduction, and dissemination of own/future research projects and beyond. The following objectives are part of this course:
- Create/select well-founded research hypothesis and study designs for a specific research topic
- Apply universal good clinical practice guidelines in future research projects
- Integrate well-documented data management and open science principles into future research projects
- Integrate principles of effective communication in speaking, writing and graphical illustrations of future research idea/output

**Content** The course will cover the following topics:
- Introduction to different study designs and ethical requirements thereof in Switzerland
- Introduction to literature search and searching platforms
- How to collect and sort publications/ keep up to date on research topic
- Inputs on critically evaluating papers
- How to pre-define study requirements to "future-proof" the research (hypothesis, sample size definition, pre-registration)
- Principles of reproducible and integral study documentation and data management (e.g., definition of source files, SOP/WI, Master Trial File, metafiles)
- FAIR principles and open science
- Design principles and free digital tools for graphical illustrations
- Effective summarizing of research output/topic in an abstract and pitch presentation

**Human Factors I**

**376-1177-00L**

**Abstract** Strategies of human-system-interaction, individual needs, physical & mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people's health, well-being, and satisfaction as well as the overall system performance.

**Objective** The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications. Students are expected to learn about how to enable an efficient and qualitatively high standing interaction between human and the environment, considering costs, benefits, health, and safety as well. Thus, ergonomic design and evaluation process of products, tasks, and environments may be promoted in different disciplines. The goal is achieved in addressing a broad variety of topics and embedding the discussion in macroscopic factors such as the behavior of consumers and objectives of economy.

**Content**
- Physiological, physical, and cognitive factors in sensation, perception, and action
- Body sizes and functional anthropometry, Digital Human Models
- Experimental techniques in assessing human performance, well-being, and comfort
- Usability engineering in system designs, product development, and innovation
- Human information processing and biological cybernetics
- Interaction among consumers, environments, behavior, and tasks

**Literature**
- Gavriel Salvendy, Handbook of Human Factors and Ergonomics, 4th edition (2012), is available on NEBIS as electronic version and for free to ETH students
- Further textbooks are introduced in the lecture
- Brochures, checklists, key articles etc. are uploaded in ILIAS

**Applications of Cybernetics in Ergonomics**

**376-1179-00L**

**Abstract** Cybernetics systems have been studied and applied in various research fields, such as for applications in ergonomics. Topics discussed in this lecture (man-machine-interaction, performance in multi-modal interactions, quantification in gestalt principles for the use in product development, information processing) are deepened with exercises conducted at our labs.

**Objective** To learn and practice cybernetics principles in interface designs and product development.

**Content**
- Fitt's law applied in manipulation tasks
- Hick-Hyman law applied in design of the driver assistance systems - Vigilance applied in quality inspection
- Accommodation/vergence crosslink function
- Cross-link models in neurobiology- the ocular motor control system
- Human performance in optimization of production lines

**Literature**

**Development of the Nervous System (University of Zurich)**

**376-1305-00L**

**Abstract** The lecture will cover molecular and cellular processes underlying the development of the nervous system (neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation). The importance of these processes in the context of developmental diseases is discussed.

**Objective** On successful completion of the module the student should be able to
- relate structure and function of the nervous system to its development - apply principles of molecular, cellular, and developmental biology to the development of the nervous system
- identify key steps in development underlying neurological syndromes and diseases

**Key skills**
- On successful completion of the module the student should be able to
  - interpret and critically evaluate original research reports
  - apply knowledge and relate experimental approaches from molecular, cellular and developmental biology to the developing nervous system.

**Content** The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.
In this seminar, we consider how the human brain processes social information. The approach focuses on exploring the neural bases of social cognition in healthy individuals, as well as providing case studies from atypical populations, whose pathologies are typified by dysfunction in social information processing, such as autism spectrum disorder and schizoaffective disorder.

Abstract
The course covers the physiology of nerve cells, from the single cell through the neuronal network to the systemic level. The focus is on molecular and cellular mechanisms – synaptic transmission, signal transduction, gene expression, synaptic plasticity – are introduced. Afterwards, their significance for selected neurophysiological processes (learning/memory, sleep, sensory) will be illuminated.

Objective
Based on an understanding of molecular and cellular mechanisms, the aim is to provide a deeper insight into neurophysiological processes underlying complex brain functions – learning/memory, sleep, sensory.

Content
First, basic molecular and cellular mechanisms in nerve cells (excitability, neurotransmission, signal transduction, gene expression, synaptic plasticity) are introduced. Afterwards, their significance for selected neurophysiological processes (learning/memory, sleep, sensory) will be illuminated.

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on Moodle.

Competencies

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376-1309-00L Disorders of Social Cognition

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>- To familiarise students with forms of social cognition in humans, as well as the neural systems that support social cognition.</td>
</tr>
<tr>
<td>- To critically evaluate theories and data relating to Social Cognition and Social Neuroscience.</td>
</tr>
<tr>
<td>- To relate how knowledge of typical brain function can inform our understanding of individuals who process social information differently, and vice versa.</td>
</tr>
<tr>
<td>- To develop effective scientific communication skills in oral and written formats.</td>
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</tbody>
</table>

Content
This seminar will consider how the human brain understands and organises social behaviour. The approach will focus on exploring the neural bases of social cognition in healthy individuals, as well as providing case studies from atypical populations, whose pathologies are typified by dysfunction in social information processing. Examples of such pathologies include autism spectrum disorder, schizophrenia and attention deficit hyperactivity disorder. By examining healthy and atypical populations, this module will highlight how disorders of social cognition can inform the understanding of healthy brain function, as well as how understanding healthy brain function can inform disorders of social cognition.

376-1311-00L Neuroscience Journal Club

<table>
<thead>
<tr>
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<tbody>
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Content
This Neuroscience Journal Club is designed for Master and PhD students interested in neuroscience. Students will critically read and review topical research articles and present appropriate background, the article itself, and their critique of the work. The diversity of topics selected will make this an important learning opportunity for the presenters and attendees with regard to the latest techniques and approaches in neuroscience.

Introductory Lectures: In the first lecture, students will receive a general introduction to the topic “Neurobiology of Stress”, and learn the key skills to critically analyze and review a scientific paper. In the second lecture, the instructors will give a journal club presentation to provide an example of how a “journal club” should be structured. All other lectures are devoted to the journal club presentations given by the students. Depending on the number of enrolled students, groups of 1-3 students will select papers from a pre-selected list of high-impact publications. Each week, one group presents their paper, the presenters should show up 15-20 minutes before their scheduled presentation to set up their laptop.

Active participation: Each week, students that are not presenting are expected to read the article in its entirety in a critical manner and submit questions about the article online ahead of class, participation in class will be assessed.

Workload: 2h of class per week (attendance in person required), plus 8h for preparing your own journal club (1/2 per semester), plus 2h for reading other group’s paper and asking questions (1/week, 13 in total).

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We recommend that students have a solid background in neuroscience.

Recommended ETH classes are:
- Neuroanatomy & Neurophysiology (376-0007-00L) (or similar)
- Anatomy and Physiology 1 & 2 (376-0151-00L + 376-0152-00L) (or similar)
- Neural Systems for Sensory, Motor and Higher Brain Functions (376-1305-01V / Bio343) (or similar)
- Translational Neuroscience (376-1307-00 V) (or similar)

376-1414-00L Current Topics in Brain Research (HS) W 1 credit 1.5K I. Mansuy, further lecturers
Abstract
Different national and international scientific guests are invited to present and discuss their actual scientific results.
Objective
To exchange scientific knowledge and data and to promote communication and collaborations among researchers.
Content
Different scientific guests working in the field of molecular cognition, neurochemistry, neuromorphology and neurophysiology present their latest scientific results.
Lecture notes
no handout
Literature
no literature
Prerequisites / notice
Some of the seminars will be shared with the Institute of Neuroinformatics (INI) of UZH.

376-1504-00L Physical Human Robot Interaction (pHRI) W 4 credits 2V+2U O. Lambercy, P. Wolf
Abstract
This course focuses on the emerging, interdisciplinary field of physical human-robot interaction, bringing together themes from robotics, real-time control, human factors, haptics, virtual environments, interaction design and other fields to enable the development of human-oriented robotic systems.
Objective
The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.
Content
This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in device design for humans such as transparency and stability analysis, safety hardware and procedures. The course is organized into lectures that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical human-robot interaction, laboratory sessions and lab visits.

Students will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. Here the salient features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic paddle (https://relab.ethz.ch/downloads/open-hardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

Lecture notes
Will be distributed on Moodle before the lectures.
Literature

Prerequisites / notice
The registration is limited to 26 students.
There are 4 credit points for this lecture.
The lecture will be held in English.
The students are expected to have basic control knowledge from previous classes.
http://www.relab.ethz.ch/education/courses/phri.html

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Problem-solving assessed
Project Management assessed
Social Competencies
Communication assessed
Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking assessed
Self-direction and Self-management fostered

376-1651-00L Ethics of Life Sciences and Biotechnology
W 3 credits 2V A. Blasimme, E. Vayena

Abstract
This semester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their technological application. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences.

Objective
This course is tailored to students who want to become familiar with the analysis of ethical issues in all the different domains of life sciences and biotechnology. The course aims at equipping students with the necessary knowledge and analytic skills to understand, discuss and address the ethical aspects of science and technology in the domain of human health. The specific learning objectives of this course are:

A. Identify ethical issues in life sciences and biotechnology.
B. Analyze and critically discuss ethical issues in life sciences and biotechnology.
C. Become aware of relevant legal and public policy frameworks.
D. Distinguish different ethical approaches and argumentative strategies in applied ethics.
E. Recognize how ethical issues relate to different accounts of technology and innovation.
F. Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
G. Autonomously anticipate ethical issues.
H. Propose and communicate solutions to ethical challenges and dilemmas.
Content
The course starts off with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain of applied ethics. The students will also be introduced to current theoretical accounts of technology and will start to appreciate the relevance of ethics especially with respect to new and emerging technologies. Usable analytic tools will also be provided, thus enabling the students to engage with the discipline in a practical way from the very onset of the semester.
The course will continue with thematic sessions covering a broad variety of topics all of which are relevant to the different study tracks offered by the department. In particular, the course will cover the following domains: digital health technologies and medical AI; food, nutrition and healthy longevity; biomedical engineering; genetics; neuroscience and Neurotechnologies; medical robotics; disability and rehabilitation; environmental ethics. The course will also include sessions on cross-cutting ethically relevant aspects of health sciences and technologies, namely: access to innovation, translational research, and the relation between science and public policy.
All the topics of the course will be illustrated and interactively discussed through many case studies, offering the students the opportunity to prepare and present them, and to use them in individual as well as group exercises. Throughout the course, the students will have multiple opportunities to experiment with ethical argumentation and to practice their evolving skills.

Competencies
Subject-specific Competencies: Concepts and Theories assessed
Method-specific Competencies: Analytical Competencies assessed, Media and Digital Technologies fostered, Problem-solving fostered
Social Competencies: Communication assessed, Cooperation and Teamwork fostered, Leadership and Responsibility fostered, Self-presentation and Social Influence fostered, Sensitivity to Diversity fostered
Personal Competencies: Adaptability and Flexibility fostered, Critical Thinking fostered, Integrity and Work Ethics assessed, Self-awareness and Self-reflection assessed

376-1664-00L Ethics in Drug Development
W 3 credits 2V A. Blasimme, E. Vayena, to be announced
Abstract
This course provides a thorough exploration of drug development and involved ethical issues as well as critical analysis of ethical challenges and practical skills to resolve them. It includes elements of drug discovery, preclinical and clinical research ethics, alternative regulatory pathways and ethics of drug pricing and develops a solid grasp of ethical complexity as well as practical skills.

Objective
This course is tailored to D-HEST students who want to become familiar with pharmaceutical development and its ethical implications. By the end of this course, students will have developed a comprehensive understanding of the ethical complexities and challenges in drug development. They will be equipped with the knowledge and analytical skills to navigate ethical reasoning and contribute to the responsible advancement of pharmaceutical research. The specific learning objectives of the course are:

- Discuss relevant legal and public policy frameworks in drug development, ensuring an understanding of the broader regulatory context within which policy and regulatory decisions are made.
- Recognize and identify ethical dilemmas inherent to drug development, fostering a heightened awareness of ethical considerations across various stages of the process.
- Identify and discuss ethical issues in drug development in light of recent advances in the field of artificial intelligence.
- Critically analyze ethical challenges within drug development, enabling them to discuss complex issues, evaluate competing ethical perspectives, and form reasoned judgments.
- Understand the ethical theories and principles that underpin drug regulation.
- Evaluate the ethical implications of alternative pathways, such as Accelerated Approval and Compassionate Use, equipping students to assess potential benefits, risks, and societal consequences.
- Assess the ethical dimensions of drug pricing decisions and their impact on equity and accessibility, encouraging thoughtful reflection on the broader societal implications of pricing strategies.

Content
- Principles of biomedical ethics and how they relate pharmaceutical innovation
- Introduction to drug development, with a focus on the Swiss regulatory ecosystem
- Current trends and impediments to effective drug development, including the use of AI in drug discovery
- Translational medicine and its ethical implications
- Ethical Aspects of pre-clinical research, including animal replacement technologies like organoids and organ chips
- Ethical aspects of clinical research
- Special regulatory pathways: expanded access / compassionate use
- Special regulatory pathways: accelerated approval
- Drug development and public health. emergency use of new drugs
- Drug pricing: introduction to its regulatory and ethical aspects

551-0309-00L Concepts in Modern Genetics
W 6 credits 4V Y. Barral, A. Hajnal, O. Voinnet, University lecturers
Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module BIC348 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.
Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Problem-solving

Social Competencies

- Communication
- Cooperation and Teamwork

Personal Competencies

- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

Lecture notes

Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien".

Literature

- Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020

Prerequisites / notice

For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Problem-solving

Social Competencies

- Communication
- Cooperation and Teamwork

Personal Competencies

- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

Abstract

Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Objective

Basic knowledge of the mechanisms and the regulation of an immune response.

Content

- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histocompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Lecture notes

- Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020

Prerequisites / notice

For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

Social Competencies

- Communication
- Cooperation and Teamwork

Personal Competencies

- Adaptability and Flexibility
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

Abstract

Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

Content

- Cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.
- Characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.
- Structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Lecture notes

- Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Literature

- Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice

To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Problem-solving

Social Competencies

- Communication
- Cooperation and Teamwork

Personal Competencies

- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

Note:

- 551-0317-00L Immunology I
- 551-0319-00L Cellular Biochemistry (Part I)
- 551-0320-00L Molecular Biology of Foodborne Pathogens
- 752-4009-00L General Microbiology
Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Communication

Essentials in Translational Science

M. Grossmann

Communication

Creative Thinking

Lecture notes

Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Literature

Recommendations will be given in the first lecture

Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break!

Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0300-00L</td>
<td>Essentials in Translational Science</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>J. Goldhahn</td>
</tr>
<tr>
<td>376-0302-01L</td>
<td>GCP Basic Course (Modules 1 and 2)</td>
<td>O</td>
<td>1</td>
<td>1G</td>
<td>G. Senti, C. Fila, R. Grossmann</td>
</tr>
</tbody>
</table>

The course is designed for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).
Students majoring in Rehabilitation and Inclusion: At least 3 CP of the courses in this focus area must be selected.

### Electives

#### Rehabilitation Technology

**Students majoring in Rehabilitation and Inclusion:** At least 3 CP of the courses in this focus area must be selected.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>363-0790-00L</td>
<td>Technology Entrepreneur</td>
<td>W</td>
<td>2</td>
<td>F. Hacklin</td>
</tr>
<tr>
<td>Abstract</td>
<td>Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding. This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are success factors in the creation of new firms, including founding, financing and growing a venture. A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases.</td>
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<tr>
<td>Objective</td>
<td>This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures.</td>
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<tr>
<td>Content</td>
<td>Weekly sessions - recorded. 10+ sessions carried out by guest lecturers: experts in the broad field of technology entrepreneurship (e.g., serial entrepreneurs, venture capitalists, (E)MBA professors, company builders, patent experts, scale-up executives, …). Final session: multiple choice semester assignment (100% of grade). Typical lecture format (2h): 15': Introduction 60': Guest testimonial 15': Discussion related to topic (in groups) 10': Plenary discussion 20': Q&amp;A with (guest) lecturer</td>
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<tr>
<td>Competencies</td>
<td>Lecture slides and case material</td>
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<td>Competencies</td>
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<td>Concepts and Theories</td>
<td>assessed</td>
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<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
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<tr>
<td>Social Competencies</td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<td>Social Competencies</td>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
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### Electives

#### Wearable and Mobile Technologies of the Future - Focus on Sports and Health

**Students majoring in Rehabilitation and Inclusion:** At least 3 CP of the courses in this focus area must be selected.

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>376-1176-00L</td>
<td>Wearable and Mobile Technologies of the Future -</td>
<td>W</td>
<td>4</td>
<td>C. Menon, C. Ahmadizadeh, C. Cheteau</td>
</tr>
<tr>
<td>Abstract</td>
<td>Focus on Sports and Health</td>
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<tr>
<td>Abstract</td>
<td>This course focuses on the progress in the field of wearable and unobtrusive technologies for sports and health. Topics as monitoring heart health and blood pressure, biofeedback and improvement of motor skills and performance are covered. The focus lies on learning about the principles and design of the new generation of non-invasive technologies in fitness-, athletic and medical applications.</td>
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<td>Competencies</td>
<td>Lecture slides and case material</td>
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<td>Competencies</td>
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<td>Concepts and Theories</td>
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<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
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</table>
Objective 1:
Acquire knowledge about the latest technological advancements in wearable and unobtrusive technologies for sport and health.

Objective 2:
Acquire skills to design novel non-invasive technologies for sport and health.

Content
The course consists of two modules.

Module 1: Movement.
This module provides the scientific background needed to understand the principles that current technologies investigating movement rely on. The latest technological advancements to track parameters of gait and running, improve posture as well as to monitor overall body movement and provide feedback on motion during sport, rehabilitation or at work will be investigated. The focus will be on wearable-related (e.g., textile-based) technologies.

Module 2: Cardiac.
This module focuses on the latest technologies for monitoring the cardiac cycle and blood pressure. The module starts by succinctly providing background information on cardiac physiology and then briefly introduces conventional technologies used in daily practice. This module subsequently focuses on the latest technologies and the latest data analysis techniques to monitor the cardiac cycle for assisting individuals in sport activities or monitoring their health conditions.

Prerequisites / notice
- Students should be proficient in programming (any language).
- Note: assignments will be in MATLAB. Students are expected to learn MATLAB on their own if not experienced with this programming language.
- Course prerequisites:
  - For Biomedical Engineering Master’s: none
  - For ITET Master’s: none
  - For D-MAVT Master’s and PhD students:
    - If BSc in electrical/mechanical engineering or computer science: none
    - If any other BSc program: 376-0022-00L (Imaging and Computing in Medicine) or 376-1983-00L (Foundations of Data Science)

376-1219-00L Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions

Abstract
Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

Objective
Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.

Content
Introduction, problem definition, overview
Rehabilitation of visual function
- Anatomy and physiology of the visual sense
- Technical aids (glasses, sensor substitution)
- Retina and cortex implants
Rehabilitation of hearing function
- Anatomy and physiology of the auditory sense
- Hearing aids
- Cochlea Implants
Rehabilitation and use of kinesthetic and tactile function
- Anatomy and physiology of the kinesthetic and tactile sense
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
Rehabilitation of vestibular function
- Anatomy and physiology of the vestibular sense
- Rehabilitation strategies and devices (e.g. BrainPort)
Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter
Brain stimulation and recording
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces

Autumn Semester 2024
Literature

Introductory Books:


Selected Journal Articles and Web Links:


Prerequisites / notice

Target Group:
- Students of higher semesters and PhD students of
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich
- Students of other departments, faculties, courses are also welcome

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed

Method-specific Competencies
- Communication fostered
- Leadership and Responsibility fostered
- Creative Thinking fostered
- Critical Thinking assessed
- Integrity and Work Ethics fostered

Social Competencies

Personal Competencies

Abstract

Artificial Intelligence in Rehabilitation and Healthcare 3 credits D. F. Paez Granados

Students will delve into AI fundamentals (e.g., regression, classification, and deep neural networks) and their role in patient monitoring & personalized rehab. Collaborative projects offered by MedTech companies provide hands-on experience in developing and evaluating AI-driven solutions. This course will emphasise AI’s explainability and ethical dimensions fostering its critical analysis.
1. Evaluate the effectiveness of AI tools and algorithms in the context of rehabilitation and healthcare, and suggest modifications or improvements as needed.

2. Understand the ethical and legal considerations surrounding the use of AI in rehabilitation and healthcare and apply this knowledge to ensure patient privacy and data security.

3. Identify potential limitations and risks of using AI in rehabilitation and healthcare and propose strategies to mitigate these challenges.

4. Collaborate effectively with other students on group projects that involve developing and implementing AI-based rehabilitation and healthcare solutions.

In the class ‘Artificial Intelligence (AI) in Rehabilitation and Healthcare’, we will explore the integration of advanced technology in the field of rehabilitation. The class consists of both theoretical and practical components. In the theoretical part, students are introduced to the fundamental concepts of artificial intelligence, including regressions and classification in machine learning, deep neural networks, and large language models. They will explore the applications of AI in rehabilitation and healthcare, including patient monitoring, personalized treatment plans, and predictive analytics.

In the practical component, each student will work with one of the clinics or technology companies to identify real-world problems and gain hands-on experience in developing AI in rehabilitation and healthcare. The practical work will be done in the course room with student assistants and experts from the companies. They will use Python as main language on their own laptops with ready to use Jupiter notebooks that could have access to our lab’s server if needed for computational resources. They will directly start using programming languages and tools to build models, analyze data, and create algorithms that can be used to improve patient outcomes.

Throughout the class, students are encouraged to think critically about the ethical implications of using AI in rehabilitation. They examine the potential benefits and risks of using advanced technology in patient care and explore ways to mitigate potential negative outcomes.

Practical problems partners: Schweizer Paraplegiker-Stiftung, Lake Lucerne Institute, Balgrist Uni-versity Hospital, Ortho-Team Luzern, Akina AG, and Leitwert AG.

Recommended courses:
- 252-0842-00L Programmieren und Problemlösen

**Rehabilitation Medicine**

**Students majoring in Rehabilitation and Inclusion: At least 3 CP of the courses in this focus area must be selected.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0225-00L</td>
<td>Critical Appraisal of Evidence for Exercise in Health and Disease</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>E. Giannoni, E. de Bruin, R. Knols</td>
</tr>
</tbody>
</table>

**Abstract**

This course will discuss the mechanisms and latest evidence-based recommendations of physical activity and exercise for a series of conditions and populations. In the second part of each lecture session, published randomized controlled trials of the respective lecture’s topic will be discussed and critically appraised based on established tools.

**Objective**

On completion of this course students will be able to:
1. understand the role of physical activity and sedentary behavior in the maintenance of health and the etiology, prevention and treatment of disease
2. synthesize effective physical activity and exercise interventions for the prevention and management of several diseases and populations
3. evaluate recent evidence regarding physical activity and exercise interventions

**Content**

New trends in physical activity for prevention and rehabilitation

Introduction to critical appraisal tools
Exercise for Cancer Rehabilitation
Exercise for Musculoskeletal Rehabilitation (Focus on Osteoarthritis and Low Back Pain)
Exercise in Parkinson’s disease
Exercise for Rehabilitation of Metabolic Disorders (Focus on Obesity and Diabetes type 2)
Exercise for age-related diseases and disorders, Part A (Focus on Frailty and Falls)
Exercise for Stroke Rehabilitation
Exercise in Dementia and Mild Cognitive Impairment
Exercise for Children’s Rehabilitation (Focus on Cerebral Palsy)
Exercise for age-related diseases and disorders, Part B (Focus on Sarcopenia and Osteoporosis)
Exercise in Multiple Sclerosis
Exercise for Cardiovascular Rehabilitation (Focus on Heart Failure)

**Literature**


**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: fostered
- **Method-specific Competencies**
  - Analytical Competencies: fostered
  - Decision-making: fostered
  - Problem-solving: fostered
- **Personal Competencies**
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered

**Abstract**

This course provides a holistic, clinical view on the in- and outpatient rehabilitation process of neurological diseases with a special focus on movement deficits. Pharmacological, training and medical device-supported interventions with their potential and limitations are discussed from a clinical perspective along the patient journey – covering the different phases of inpatient rehab.
Within the scope of this lecture you will learn the basic principles of trauma biomechanics. Based on examples from sports, you will get to know different mechanisms that can possibly result in injury. Investigating the background and cause of injury should allow you to assess the injury risk for sports activities. Furthermore you should be able to develop measures to prevent such injury.

Students are expected to:
- develop a holistic, clinical view on the different phases of neurorehabilitation
- understand how motor deficits develop, which pathology to the central nervous system causes which type of deficit and how each deficit can be treated
- understand different patient journeys in dependence on the underlying deficits and individual personal and environmental factors
- discuss and interpret the impact of clinical trial findings for rehabilitation

The course provides a condensed overview on physical medicine and different rehabilitation types (geriatric, internistic and oncological, cardiovascular, musculoskeletal, neurological, pediatric, paraplegiologic, psychosomatic, pulmonal), as well as main challenges and future trends from a clinical perspective. Students will have opportunity to gain insight into rehabilitation clinics on-site.

Students will
- understand how the Swiss rehabilitation landscape is built and financed
- get to know the different rehabilitation types, their specific challenges and discuss potential solutions
- comprehend future trends in rehabilitation and identify required actions
- gain insight into rehabilitation clinics and hands-on experience

The course introduces the basic principles of injury mechanics and rehabilitation focusing on sports injuries. Furthermore possibilities to prevent injuries are discussed. Thereby the lecture focuses on sports injuries.

Within the scope of this lecture you will learn the basic principles of trauma biomechanics. Based on examples from sports, you will get to know different mechanisms that can possibly result in injury. Investigating the background and cause of injury should allow you to assess the injury risk for sports activities. Furthermore you should be able to develop measures to prevent such injury.

Students are expected to:
- understand different patient journeys in dependence on the underlying deficits and individual personal and environmental factors
- discuss and interpret the impact of clinical trial findings for rehabilitation

The course presents origins and prevention of different physical, sensory, mental impairments, their treatments, and methods of assistance in public and home environments. Rehabilitation is put into a larger context providing insights into healthcare systems, health economy, accessibility, barrier-free architecture, para-sports, legal & regulatory aspects, disability policy, and inclusion.

This course work is required. The mark of this course work contributes to the final credits for this lecture. Details will be given during the first lecture.

A course work is required. The mark of this course work contributes to the final credits for this lecture. Details will be given during the first lecture.

Students majoring in Rehabilitation and Inclusion: At least 3 CP of the courses in this focus area must be selected.

Students are expected to:
- gain insight into rehabilitation clinics and hands-on experience
- comprehend future trends in rehabilitation and identify required actions
- gain insight into rehabilitation clinics and hands-on experience

This knowledge and awareness should be presented in a multi-modal way using interactive tools and organizing group/plenar discussions.
The course will cover the following topics:

- **Introduction**: definition of terms, historical and legal background, role of the UNO, WHO, ICRC
- **Origins**: reasons and origins of physical, sensory and mental impairments; surgical and pharmaceutical treatments
- **Therapy**: physical therapy, occupational therapy, speech therapy, psychotherapy
- **Technologies**: robotic-assisted therapy, Virtual Reality, muscle stimulation, Brain-Computer Interfaces (BCIs)
- **Home therapy**: personal assistance, mobile health systems, tele-monitoring, tele-therapy
- **Assistive technologies**: gait assistance, prosthesis, orthoses, seeing/hearing aids, etc.
- **Social inclusion**: definition of normality and belongingness, social behaviours, UN-BRK, etc.
- **Accessibility**: national and international aspects of accessibility
- **Health economy in rehabilitation**: public and private cost models, health insurance, SUVA, IV
- **Barrier-free building and living**: environmental obstacles, norms in architecture, inclusive design
- **Parasports**: history of Olympics and Paralympics, Special Olympics, Deaflympics, Cybathlon
- **Policy**: health, social, equal opportunity, disability
- **Regulatory affairs**: ethics committees, Swissmedic, Bundesamt für Gesundheit (BAG), law and disability
- **Prevention**: primary and secondary prevention, social prevention

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<td></td>
<td>Leadership and Responsibility</td>
<td>fostered</td>
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<td>Sensitivity to Diversity</td>
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<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<td></td>
<td>Self-direction and Self-management</td>
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</tbody>
</table>

### Content

**Economic and Regulatory Principles of Rehabilitation**

**376-1221-00L**

**Abstract**

Medical health care in Switzerland is diverse and includes somatic and psychological prevention, treatment, rehabilitation and social and professional reintegration. The lecture deals with the economic and regulatory principles of medical rehabilitation and reintegration. It introduces these areas of healthcare and places them in the context of the entire care chain.

**Objective**

The students know the economic and regulatory framework conditions of medical rehabilitation and occupational and social reintegration in the Swiss health care system.

The students are familiar with the market participants and their strategies and intentions.

The students are aware of the importance of associations which, as representatives of the sector, express their views on quality and tariffs and deal with political issues. Interfaces, dependencies and cooperations between the individual actors are known.

The students will analyze the strengths and weaknesses of the Swiss health care system, also in comparison with foreign models, and will develop solutions to overcome the current problems with a focus on rehabilitation and reintegration.

The market participants such as service providers, financiers, suppliers or authorities are introduced and the mutual dependencies are shown.

The market mechanisms are presented and the range of services, financial flows, tariff situation, consolidations and regulation are discussed.

Special attention is paid to megatrends such as cost pressure, shortage of skilled workers, ambulantization, digitalization or technologization and the influence of demographic change.

**Ethics of Life Sciences and Biotechnology**

**376-1661-00L**

**Abstract**

This semester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their technological application. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences.

**Objective**

This course is tailored to students who want to become familiar with the analysis of ethical issues in all the different domains of life sciences and biotechnology. The course aims at equipping students with the necessary knowledge and analytic skills to understand, discuss and address the ethical aspects of science and technology in the domain of human health. The specific learning objectives of this course are:

A. Identify ethical issues in in life sciences and biotechnology.
B. Analyze and critically discuss ethical issues in life sciences and biotechnology.
C. Become aware of relevant legal and public policy frameworks.
D. Distinguish different ethical approaches and argumentative strategies in applied ethics.
E. Recognize how ethical issues relate to different accounts of technology and innovation.
F. Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
G. Autonomously anticipate ethical issues.
H. Propose and communicate solutions to ethical challenges and dilemmas.

**Content**

The course starts off with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain of applied ethics. The students will also be introduced to current theoretical accounts of technology and will start to appreciate the relevance of ethics especially with respect to new and emerging technologies. Usable analytic tools will also be provided, thus enabling the students to engage with the discipline in a practical way from the very onset of the semester.

The course will continue with thematic sessions covering a broad variety of topics all of which are relevant to the different study tracks offered by the department. In particular, the course will cover the following domains: digital health technologies and medical AI; food, nutrition and healthy longevity; biomedical engineering; genetics; neuroscience and Neurotechnologies; medical robotics; disability and rehabilitation; environmental ethics. The course will also include sessions on cross-cutting ethically relevant aspects of health sciences and technologies, namely: access to innovation, translational research, and the relation between science and public policy.

All the topics of the course will be illustrated and interactively discussed through many case studies, offering the students the opportunity to prepare and present them, and to use them in individual as well as group exercises. Throughout the course, the students will have multiple opportunities to experiment with ethical argumentation and to practice their evolving skills.
Abstract
Intensive discussion concerning complications of a spinal cord injury and their consequences on trainability and exercise performance of persons sitting in a wheelchair. Overview on the clinical application of exercise testing as well as on the implementation of sport scientific findings to optimise performance of individuals with spinal cord injury in rehabilitation and elite sports.

Objective
Knowledge of the pathophysiology and the concomitant complications of a spinal cord injury and the consequences for physical exercise and trainability during rehabilitation as well as in recreational and elite sport.

Content
The following issues will be discussed: Epidemiology and etiology of spinal cord injury; complications and consequences of spinal cord injury; trainability/exercise physiology and spinal cord injury; history and organisation of wheelchair sports; elite sport and spinal cord injury

Literature
General literature:
H.G. Koch, V. Geng
Querschnittlähmung verständlich erklärt (Band 1 und Band 2)
Selbstverlag Manfred-Sauer-Stiftung und Schweizer Paraplegiker-Vereinigung
ISBN 978-3-00-069888-0 (Band 1) und 978-3-00-069889-7 (Band 2)

G.A. Zäch, H. G. Koch
Paraplegie - ganzheitliche Rehabilitation
Karger-Verlag, 2006
ISBN 3-8055-7980-2

V. Goosey-Tolfrey
Wheelchair sport: A complete guide for athletes, coaches and teachers
Human Kinetics, 2010

Y.C. Vanlandewijck, W.R. Thompson
The Paralympic Athlete
Wiley-Blackwell, 2011
ISBN 978-1-4443-3404-3

Liz Broad
Sports Nutrition for Paralympic Athletes, Second Edition
CRC Press 2019

Y.C. Vanlandewijck, W.R. Thompson
Training and Coaching the Paralympic Athlete
ISBN 978-1-119-04433-8

Prerequisites / notice
Voraussetzung: Vorlesung Anatomie/Physiologie besucht!
The module "public health concepts" offers an introduction to key principles of public health. Students get acquainted with the concepts and methods of epidemiology. Students also learn to use epidemiological data for prevention and health promotion purposes. Public health concepts and intervention strategies are presented, using examples from infectious and chronic diseases.

Objective
At the end of this module students are able:
- to interpret the results of epidemiological studies
- to critically assess scientific literature
- to know the definition, dimensions and determinants of health
- to plan public health interventions and health promotion projects
- to draw a bridge from evidence to policies and politics

Content
Concepts of descriptive and analytical epidemiology, study designs, measures of effect, confounding and bias, screening, surveillance, definition of health and health promotion, health dimensions and health determinants, prevention strategies, public health interventions, public health action cycle, epidemiology and prevention of infectious and chronic diseases (HIV, COVID-19, Obesity, Iodine/PH nutrition).

Lecture notes
Handouts are provided to students in the classroom.

Competencies
Subject-specific Competencies
Concepts and Theories
Method-specific Competencies
Analytical Competencies
Decision-making

Practical Training
Practical Training only for majors mentioned below:
- Human Movement Science and Sport
- Medical Technology
- Molecular Health Sciences
- Neurosciences
- Rehabilitation and Inclusion

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>376-2110-00L</td>
<td>Practical Training 12 Weeks (Job or Research Oriented)</td>
<td>W</td>
<td>15</td>
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<td>Supervisors</td>
</tr>
<tr>
<td>Abstract</td>
<td>Practical Training Internships are either research-oriented for exercising scientific (laboratory) methods or job-related for giving insight into the future world of work (industry, services, school).</td>
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<tr>
<td>Objective</td>
<td>Students should exercise scientific working and/or get realistic insights into future jobs.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>This version of internships lasts for at least 12 weeks full time equivalent.</td>
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<tr>
<td>376-2111-00L</td>
<td>Practical Training 8 Weeks (Job or Research Oriented)</td>
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<tr>
<td>Objective</td>
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<tr>
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<td>This version of internships lasts for at least 8 weeks full time equivalent.</td>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>376-2112-00L</td>
<td>Practical Training 4 Weeks (Job or Research Oriented)</td>
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<tr>
<td>Abstract</td>
<td>Practical Training Internships are either research-oriented for exercising scientific (laboratory) methods or job-related for giving insight into the future world of work (industry, services, school).</td>
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<tr>
<td>Objective</td>
<td>Students should exercise scientific working and/or get realistic insights into future jobs.</td>
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<td>Prerequisites / notice</td>
<td>This version of internships lasts for at least 4 weeks full time equivalent.</td>
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</table>

Science in Perspective
see Science in Perspective: Language Courses ETH/UZH
see Science in Perspective: Type A: Enhancement of Reflection Capability
Recommended Science in Perspective (Type B) for D-HEST

Research Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>376-2100-00L</td>
<td>Research Internship</td>
<td>O</td>
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<td>Supervisors</td>
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<tr>
<td>Abstract</td>
<td>12-week internship intended for exercising (independent) scientific working.</td>
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<tr>
<td>Objective</td>
<td>Students shall exercise scientific working as preparation for their master thesis.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The Research Internship lasts for at least 12 weeks full time equivalent. It can be combined with the Master Thesis.</td>
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Master’s Thesis

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<th>Lecturers</th>
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<tr>
<td>376-2000-00L</td>
<td>Master’s Thesis</td>
<td>O</td>
<td>30</td>
<td>71D</td>
<td>Supervisors</td>
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</tbody>
</table>
| Abstract | Only students fulfilling the following criteria can start with their master thesis:  
a. successful completion of the bachelor programme;  
b. fulfillment of any additional requirements necessary to gain admission to the master programme. |
| Objective | The students shall demonstrate their ability to carry out a structured, scientific piece of work independently. |
| Prerequisites / notice | The Master Thesis can only be started after the Bachelor Degree was obtained and/or master admission requirements have been fulfilled. |

Course Units for Additional Admission Requirements
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>406-0253-AAL</td>
<td>Mathematics I &amp; II Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
<td>E-</td>
<td>13</td>
<td>28R</td>
<td>A. Cannas da Silva, S. Kalisman Hintz</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>Mathematics I covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems, notably through linear algebra and calculus, with an emphasis on ordinary differential equations. The main focus of Mathematics II is multivariable calculus.</td>
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<td>Objective</td>
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<td>Mathematics is of ever increasing importance to the Natural Sciences and Engineering. The key is the so-called mathematical modelling cycle, i.e. the translation of problems from outside of mathematics into mathematics, the study of the mathematical problems (often with the help of high level mathematical software packages) and the interpretation of the results in the original environment.</td>
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<td>Content</td>
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<tr>
<td></td>
<td>1. Linear Algebra and Complex Numbers: systems of linear equations, Gaussian-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, complex roots, fundamental theorem of algebra.</td>
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<td>3. Ordinary Differential Equations: separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.</td>
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<td>4. Multivariable Differential Calculus: functions of several variables, partial differentiation, curves and surfaces in space, scalar and vector fields, gradient, curl and divergence.</td>
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<td>5. Multivariable Integral Calculus: multiple integrals, line and surface integrals, work and flow, Green, Gauss and Stokes theorems, applications.</td>
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<td>6. Introduction to Partial Differential Equations: separation of variables, heat equation, wave equation, Laplace equation.</td>
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<tr>
<td></td>
<td>Lecture notes</td>
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<tr>
<td></td>
<td>See literature</td>
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<tr>
<td></td>
<td>Literature</td>
<td></td>
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<tr>
<td></td>
<td>- Bretscher, O.: Linear Algebra with Applications, Pearson Prentice Hall.</td>
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<td>Prerequisites / notice</td>
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<td></td>
<td>Prerequisites: familiarity with the basic notions from Calculus, in particular those of function, derivative and integral.</td>
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<td>Schedule and location of the assistance hours (Mathe-Lab) may be found on the Moodle webpages for the parallel courses in German:</td>
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<tr>
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<td>- 401-0251-00L Mathematik I in the Fall semester and</td>
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<td>- 401-0252-00L Mathematik II in the Spring semester.</td>
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<td></td>
<td>Competencies</td>
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<td></td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td>376-0203-AAL</td>
<td>Movement and Sport Biomechanics Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
<td>E-</td>
<td>4</td>
<td>3R</td>
<td>W. R. Taylor</td>
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<tr>
<td></td>
<td>Abstract</td>
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<tr>
<td></td>
<td>Learning to view the human body as a (bio-) mechanical system. Making the connections between everyday movements and sports activity with injury, discomfort, prevention and rehabilitation.</td>
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<td>Objective</td>
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<td>&quot;Students are able to describe the human body as a mechanical system. They analyse and describe human movements according to the laws of mechanics.&quot;</td>
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<td>Content</td>
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<td>Movement- and sports biomechanics deals with the attributes of the human body and their link to mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.</td>
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<tr>
<td>406-0062-AAL</td>
<td>Physics I Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
<td>E-</td>
<td>5</td>
<td>11R</td>
<td>A. Vaterlaus</td>
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<tr>
<td></td>
<td>Abstract</td>
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<tr>
<td></td>
<td>Introduction to the concepts and tools in physics: mechanics of point-like and rigid bodies, elasticity theory, elements of hydrostatics and hydrodynamics, periodic motion and mechanical waves.</td>
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<td>Objective</td>
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<td></td>
<td>Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve the latter. The student should acquire an overview over the basic concepts in mechanics.</td>
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<tr>
<td></td>
<td>Content</td>
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<td></td>
<td>Chapters:</td>
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<td>1, 2, 3, 4, 5, 6 (without: 6-5, 6-6, 6-8), 7, 8 (without 8-9), 9, 10 (without 10-10), 11 (without 11-7), 13 (without 13-13, 13-14), 14 (without 14-6).</td>
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</tr>
</tbody>
</table>
Literature

see "Content"

Friedhelm Kuypers
Physik für Ingenieure und Naturwissenschaftler
Band 1: Mechanik und Thermodynamik
Wiley-VCH Verlag, 2002
4th edition 2022

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies fostered
Problem-solving assessed

Personal Competencies
Self-direction and Self-management fostered

Health Sciences and Technology Master - Key for Type

| O | Compulsory |
| W+ | Eligible for credits and recommended |
| W | Eligible for credits |
| E- | Recommended, not eligible for credits |
| Z | Courses outside the curriculum |
| Dr | Suitable for doctorate |

Key for Hours

| V | lecture |
| G | lecture with exercise |
| U | exercise |
| S | seminar |
| K | colloquium |
| P | practical/laboratory course |
| A | independent project |
| D | diploma thesis |
| R | revision course / private study |

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
High-Energy Physics (Joint Master with IP Paris)

► Core Subjects

►► Core Courses in Theoretical Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0843-00L</td>
<td>Quantum Field Theory I</td>
<td>W</td>
<td>10</td>
<td>4V+2U</td>
<td>L. Senatore</td>
</tr>
<tr>
<td></td>
<td>Special Students UZH must book the module PHY551 directly at UZH.</td>
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</tbody>
</table>

**Abstract**
This course discusses the quantisation of fields in order to introduce a coherent formalism for the combination of quantum mechanics and special relativity.

**Topics include:**
- Relativistic quantum mechanics
- Quantisation of bosonic and fermionic fields
- Interactions in perturbation theory
- Scattering processes and decays
- Elementary processes in QED
- Radiative corrections

**Objective**
The goal of this course is to provide a solid introduction to the formalism, the techniques, and important physical applications of quantum field theory. Furthermore, it prepares students for the advanced course in quantum field theory (Quantum Field Theory II), and for work on research projects in theoretical physics, particle physics, and condensed-matter physics.

**Lecture notes**
Will be provided as the course progresses

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

►► Core Courses in Experimental Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0891-00L</td>
<td>Phenomenology of Particle Physics I</td>
<td>W</td>
<td>10</td>
<td>3V+2U</td>
<td>P. Crivelli, A. de Cosa</td>
</tr>
</tbody>
</table>

**Abstract**
The course focuses on the connection between particle physics theory and experimental results to provide a comprehensive modern view of the Standard Model. The covered topics are quantum electrodynamics (QED) and quantum chromodynamics (QCD).

**Objective**
The students will deepen the knowledge on particle physics acquired during their bachelor studies. They will be able to apply the basics of relativistic quantum field theory (QFT) to derive the Feynman rules and to apply those to compute QED and QCD processes. They will be able to explain and discuss the connection between theory and experiments.

**Content**
Topics to be covered in Phenomenology of Particle Physics I:
- Relativistic kinematics
- Decay rates and cross sections
- Quantisation of Klein-Gordon (boson) and Dirac (fermion)'s fields
- From the S-matrix to the Feynman rules of QED
- Scattering processes in QED/QCD and running of alpha and alpha_s
- Experimental tests of QED and QCD

**Literature**
As described in the entity: Lernmaterialien

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

**Method-specific Competencies**
- Analytical Competencies: fostered
- Problem-solving: fostered

**Social Competencies**
- Communication: fostered

**Personal Competencies**
- Creative Thinking: fostered

► Electives

►► Optional Subjects in Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0220-MSL</td>
<td>Extended Research Project</td>
<td>W</td>
<td>4</td>
<td>8A</td>
<td>Supervisors</td>
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<tr>
<td></td>
<td>This course unit can only be booked together with a research project (402-0218-MS). This extension is not available for the options Proseminars, Particle Physics at PSI, Medical Physics and Experimental Foundations of Particle Physics. The extension is only possible with the agreement of the supervising professor. The extension must be booked at the same time as the research project.</td>
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</tbody>
</table>
### Abstract
Extension of the Research Project

**Objective**

Students are enabled to:
- expand their knowledge in a specific area of physics,
- conduct a project (a) in a research laboratory or (b) on a specific topic of theoretical physics,
- discuss their project results and conclusions in a team,
- present their findings in written and oral form.

The extension allows for a more in-depth research experience.

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
</tr>
<tr>
<td>Analytical Competencies</td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
<td>Creative Thinking</td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>Problem-solving</td>
<td>Sensitivity to Diversity</td>
<td>Critical Thinking</td>
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<tr>
<td>Project Management</td>
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<td>Negotiation</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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</tbody>
</table>

### Objective

Does not take place this semester.

### Content

Recent years have witnessed incredible progress in the development of new quantum technologies driven by their application in quantum information, metrology, high precision spectroscopy and quantum sensing. This course will present how these emerging technologies are powerful tools to address open questions of the Standard Model in a complementary way to what is done at the high energy frontier.

### Prerequisites

- The preceding attendance of introductory particle physics, quantum mechanics and quantum electronics courses at the bachelor level is recommended.

### Literature

- See lecture home page: http://ihp-lx2.ethz.ch/AstroTeilchen/
Acquire an in-depth understanding and overview of the essential elements of experimental methods in particle and astroparticle physics.

Low Energy Particle Physics

**Objective**
You will be able to present and discuss:
- the principle of the experiments
- the underlying technique and methods
- the context and the impact of these experiments on particle physics

**Content**
Low energy particle physics provides complementary information to high energy physics with colliders. At the Large Hadron Collider one directly searches for new particles at energies up to the TeV range. In a complementary way, low energy particle physics indirectly probes the existence of such particles and provides constraints for "new physics", making use of high precision and high intensities.

Besides the sensitivity to effects related with new physics (e.g. lepton flavor violation, symmetry violations, CPT tests, search for electric dipole moments, new low mass exchange bosons etc.), low energy physics provides the best test of QED (electron g-2), the best tests of bound-state QED (atomic physics and exotic atoms), precise determinations of fundamental constants, information about the CKM matrix, precise information on the weak and strong force even in the non-perturbative regime etc.

Starting from a general introduction on high intensity/high precision particle physics and the main characteristics of muons and neutrinos and their production, we will then focus on the discussion of fundamental problems and ground-breaking experiments:

- search for rare decays and charged lepton flavor violation
- electric dipole moments and CP violation
- spectroscopy of exotic atoms and symmetries of the standard model
- what atomic physics can do for particle physics and vice versa
- neutron decay and primordial nucleosynthesis
- atomic clock
- Penning traps
- Ramsey spectroscopy
- Spin manipulation
- neutron-matter interaction
- ultra-cold neutron production
  - various techniques: detectors, cryogenics, particle beams, laser cooling....

**Literature**
Golub, Richardson & Lamoreaux: "Ultra-Cold Neutrons"
Rauch & Werner: "Neutron Interferometry"
Carlile & Willis: "Experimental Neutron Scattering"
Byrne: "Neutrons, Nuclei and Matter"
Klapdor-Kleingrothaus: "Non Accelerator Particle Physics"

**Prerequisites / notice**
Einführung in die Kern- und Teilchenphysik / Introduction to Nuclear- and Particle-Physics

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**Experimental Methods and Instruments of Particle Physics**

**Objective**
Acquire an in-depth understanding and overview of the essential elements of experimental methods in particle and astroparticle physics.

**Content**
1. Examples of modern experiments
2. Introduction to particle sources and accelerators
4. Detailed analysis of non-electronic, noble element, solid state, scintillator-based and Cherenkov particle detectors
5. Experimental techniques for particle tracking, calorimetry and identification
6. Monte Carlo simulations, trigger and data acquisition system readout

**Lecture notes**
Slides are handed out regularly

**Literature**
H.Kolanoski and N.Wermes, "Particle Detectors: Fundamentals and Applications".
C.Grupen and B.Schwartz, "Particle Detectors".
G.F.Knoll, "Radiation Detection and Measurements".

---

**Neutrino Physics**

**Abstract**
Theoretical basis and selected experiments to determine the properties of neutrinos and their interactions (mass, spin, helicity, chirality, oscillations, charge-parity violation, interactions with leptons and quarks) and implications on physics beyond the Standard Model of elementary particles as well as on Cosmology.
Critically analyze and elaborate the neutrino production and detection techniques.

Analyze the phenomenology of neutrino oscillations and its implication on the physics Beyond the Standard Model of particles.

Derive the main concepts of the theory of neutrino masses within and beyond the Standard Model of particles and analyze the experimental techniques related to the measurement of the neutrino masses.

Describe the role of neutrinos in Cosmology and make connections with current and future neutrino experiments.

Review the experimental configurations and analyze the challenges in searches for leptonic Charge-Parity symmetry violation and the measurement of the neutrino mass hierarchy.

1. Introduction to Neutrinos and Neutrino Sources;
2. Neutrino Detectors;
3. Neutrino Interactions;
4. Neutrino Oscillations;
5. Nature of Neutrino masses;
6. Neutrinos in Cosmology;
7. Search for leptonic Charge Parity violation and precision measurement of the neutrino oscillation probability.

A. Rubbia, “Phenomenology of Particle Physics”, Cambridge University Press.


**Competencies**

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies
- Problem-solving

**Personal Competencies**

- Creative Thinking
- Critical Thinking

**402-0777-00L Particle Accelerator Physics and Modeling I**

**Objective**

You obtain a theoretical understanding of the building blocks of particle accelerators. Modern numerical analysis tools allows you to model state-of-the-art particle accelerators. We will develop a Julia simulation tool (JuliAccel.jl) that reflects the theory from the lecture.

**Content**

Here is the rough plan of the topics, however the actual pace may vary relative to this plan.

- Recap of Relativistic Classical Mechanics and Electrodynamics
- Building Blocks of Particle Accelerators
- Lie Algebraic Structure of Classical Mechanics and Application to Particle Accelerators
- Symplectic Maps & Analysis of Maps
- Symplectic Particle Tracking
- Collective Effects
- Linear & Circular Accelerators

**Lecture notes**

Lecture notes

**Prerequisites / notice**

Physics, Computational Science (RW) at MSc. Level

This lecture is also suited for PhD. students.

**402-0836-16L Quantum Simulations of Gauge Theories**

**Abstract**

Divided into three parts, the course introduces various aspects of lattice quantum field theory (QFT), gauge symmetries, quantum simulators, and implementation schemes. Other than highlighting the strengths and weaknesses of the lattice formulation of QFTs suitable for Monte Carlo simulations, the course discusses practical realization of quantum simulators for gauge theories.

**Objective**

After acquiring the foundations on lattice formulation of gauge theories, and challenges of conventional Monte Carlo simulation approaches, the students will learn about different strategies for quantum simulation of gauge theories and their implementation on digital and analog quantum devices.

**Content**

1. Background and Motivation
   1.1 From Quantum Field Theories to Lattice field theories;
   1.2 Lattice Gauge Theories - Lagrangian formulation, gauge symmetries, observables;
   1.3 Monte Carlo simulations, sign problems, and complex actions.
   2. Road-map for Quantum Simulation of Gauge Theories
   2.1 Hamiltonian formulation, Wilson’s formulation, and the infinite Hilbert spaces;
   2.2 Finite Hilbert spaces: Z(N) gauge theories. Dualizing the Ising model and relation with the toric code;
   2.3 Finite Hilbert spaces: Quantum link models for Abelian gauge theories;
   2.4 Finite Hilbert spaces: Quantum link models for non-Abelian gauge theories;
   2.5 Exploring the physics of gauge theories - phases, dynamics, and thermalization;
   2.6 Exploring methods for gauge theories - exact diagonalization, tensor networks, Monte Carlo.
   3. Quantum Simulation Approaches and Platforms
   3.1 Digital vs. analog quantum simulations;
   3.2 Proposals for simulations of gauge theories, realization, and perspectives.

**Literature**

Quantum chromodynamics on the lattice (Christof Gattringer, Christian B. Lang. Series Title: Lecture Notes in Physics. DOI: https://doi.org/10.1007/978-3-642-01850-3)


**402-0830-00L General Relativity**

**Abstract**

Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations of the theory as well as the underlying physical principles and concepts. It covers selected applications, such as the Schwarzschild solution and gravitational waves.
Objective
Basic understanding of general relativity, its mathematical foundations (in particular the relevant aspects of differential geometry), and some of the phenomena it predicts (with a focus on black holes).

Content
Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations, such as differentiable manifolds, the Riemannian and Lorentzian metric, connections, and curvature. It discusses the underlying physical principles, e.g., the equivalence principle, and concepts, such as curved spacetime and the energy-momentum tensor. The course covers some basic applications and special cases, including the Newtonian limit, post-Newtonian expansions, the Schwarzschild solution, light deflection, and gravitational waves.

Literature
Suggested textbooks:
- C. Misner, K. Thorne and J. Wheeler: Gravitation
- S. Carroll - Spacetime and Geometry: An Introduction to General Relativity
- S. Weinberg - Gravitation and Cosmology

402-0845-61L Effective Field Theories for Particle Physics

W 6 credits 2V+1U A. Signer

Objective
This course covers the basic concepts of effective field theories (EFTs) and dispersion theory. We will start by introducing the core concept of constructing EFTs and apply them to the low-energy description of the weak interaction and the effective description of heavy physics beyond the Standard Model.

Content
- Introduction to Effective Field Theories
- Decoupling and matching
- Renormalization group resummation
- The Standard Model Effective Field Theory (SMEFT)
- Chiral Lagrangians
- Unitarity of the S-matrix
- Analyticity and dispersion relations

Prerequisites / notice
QFT-I (mandatory) and QFT-II (highly recommended)

402-0851-00L QCD: Theory and Experiment

W 3 credits 3G A. Gehrmann-De Ridder, R. Wallny

Does not take place this semester.

Objective
Knowledge acquired on basics of perturbative QCD, both of theoretical and experimental nature. Ability to perform simple calculations of perturbative QCD, as well as to understand modern publications on theoretical and experimental aspects of perturbative QCD.

Content
QCD Lagrangian and Feynman Rules
QCD running coupling
Parton model
DGLAP
Basic processes
Experimental tests at lepton and hadron colliders
Measurements of the strong coupling constant

Prerequisites / notice
Will be given as block course, language: English.
For students of both ETH and University of Zurich.

402-0870-00L Introduction to Quantum Electrodynamics

W 6 credits 2V+1U A. Lazopoulos

Objective
This course provides a pedagogical introduction to Quantum Electrodynamics.

Content
The course will cover:
- an introduction to QED as the quantum theory of interactions of light and matter.
- Feynman rules for QED
- Amplitudes and cross sections for simple processes in QED
- Gauge invariance and the Ward identity
- Ultraviolet singularities and Renormalization
- Infrared singularities and their cancelation
- The Uehling potential and the Lamb shift
- Anomalous magnetic moments

Literature
Will be provided at the Moodle site for the course.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving
The course gives an introduction to symmetry groups in physics. It explains the relevant mathematical background (finite groups, Lie groups and algebras as well as their representations), and illustrates their important role across modern physics.

The aim of the course is to give a self-contained introduction into finite group theory as well as Lie theory from a physicists point of view. Abstract mathematical constructions will be illustrated with examples from physics.

Finite group theory, including representation theory and character methods; applications to crystallography and solid state physics. The symmetric group and the structure of its representations; applications to identical particles. Clifford algebras; application to relativistic wave equations equations. Simple Lie algebras and their finite-dimensional representations. Description of representations of SU(N) in terms of Young diagrams; applications in particle physics.

The course presents the quantum field theory of the strong interaction (quantum chromodynamics, QCD) and discusses its applications to particle physics observables.

The course aims to familiarize the students with the concepts and applications of QCD and to introduce them to modern techniques for computations in QCD.

Content:
- Review of non-Abelian gauge theories
- Renormalization of QCD and running coupling constant
- Jet observables in e^+e^- annihilation
- QCD at lepton-proton colliders
- Multiparticle production
- Spinor-helicity formalism
- Perturbation theory techniques: loops and phase space

The course assumes prior knowledge of the content of the quantum field theory 1+2 lectures.

String theory is an attempt to quantise gravity and unite it with the other fundamental forces of nature. It is related to numerous interesting topics and questions in quantum field theory. In this course, an introduction to the basics of string theory is provided.

Within this course, a basic understanding and overview of the concepts and notions employed in string theory shall be given. More advanced topics will be touched upon towards the end of the course briefly in order to foster further research.

- mechanics of point particles and extended objects
- string modes and their quantisation; higher dimensions, supersymmetry
- critical dimension and no-ghost theorem
- D-branes, T-duality
- two-dimensional conformal field theories

M.B. Green, J.H. Schwarz, E. Witten, Superstring Theory I, CUP (1987).

Recommended: Quantum Field Theory I (in parallel)

Introduction to differential manifolds and differential geometry.

Introduce the language, tools, and basic results of differentiable manifolds, tensors, Riemannian geometry, and related geometric structures. Relate geometric intuition to formulas involving curvature, derivatives and tensors.

Learn to compute, describe, prove, and solve problems in the language of differential geometry.
Content
Submanifolds of $\mathbb{R}^n$, immersions, submersions, and embeddings, Sard's Theorem, abstract differentiable manifolds, charts, vector fields and flows, vector bundles, tensor fields, covariant derivatives, parallel transport, Riemannian metrics, geodesics, Riemann curvature tensor, Complete manifolds, Hopf-Rinow theorem. Many examples including curves, surfaces, hyperbolic space, $S^3$, the unit quaternions, the Gauss-Bonnet theorem, etc.

Literature
John M. Lee: Introduction to Smooth Manifolds
John M. Lee: Introduction to Riemannian Manifolds

This following books were inherited from before. The only one I know is DoCarmo.
- Manfredo P. do Carmo: Differential Geometry of Curves and Surfaces
- S. Montiel, A. Ros: Curves and Surfaces
- S. Kobayashi: Differential Geometry of Curves and Surfaces
- Wolfgang Kühnel: Differentialgeometrie, Kurven-Flächen-Mannigfaltigkeiten
- Dennis Barden & Charles Thomas: An Introduction to Differential Manifolds

Competencies
401-3461-00L Functional Analysis I
At most one of the three course units (Bachelor Core Courses)
401-3461-00L Functional Analysis I
401-3531-00L Differential Geometry I
401-3601-00L Probability Theory
can be recognised for the Master's degree in Mathematics or Applied Mathematics. In this case, you cannot change the category assignment by yourself in myStudies but must take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

Abstract
Baire category; Banach and Hilbert spaces, bounded linear operators; basic principles: Uniform boundedness, open mapping/closed graph theorem, Hahn-Banach; convexity; dual spaces; weak and weak* topologies; Banach-Alaoglu; reflexive spaces; compact operators and Fredholm theory; closed graph theorem; spectral theory of self-adjoint operators in Hilbert spaces. Basics of Sobolev spaces.

Objective
Acquire a good degree of fluency with the fundamental concepts and tools belonging to the realm of linear Functional Analysis, with special emphasis on the geometric structure of Banach and Hilbert spaces, and on the basic properties of linear maps.

Literature
Recommended references include the following:

Prerequisites / notice
Solid background on the content of all Mathematics courses of the first two years of the undergraduate curriculum at ETH. Most important: fluency with point set topology and measure theory, in part. Lebesgue integration and $L^p$ spaces.

Proseminars and Semester Papers
Detailed information at:
https://www.phys.ethz.ch/studies/master/semester-projects.html

Number Title Type ECTS Hours Lecturers
402-0218-MSL Research Project W 8 credits 15A Supervisors

Abstract
Students conduct a small research project within a research group or carry out a guided self-study of original papers on a given theoretical topic. The results are submitted in a written report and an oral presentation.

Objective
Students are enabled to:
- expand their knowledge in a specific area of physics,
- conduct a project (a) in a research laboratory or (b) on a specific topic of theoretical physics,
- discuss their project results and conclusions in a team,
- present their findings in written and oral form.
Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

402-0219-MSL Research Project II

To register, please contact the study administration at studies.physics@ethz.ch

Abstract
Students conduct a small research project within a research group or carry out a guided self-study of original papers on a given theoretical topic. The results are submitted in a written report and an oral presentation.

Objective
Students are enabled to:
- expand their knowledge in a specific area of physics,
- conduct a project (a) in a research laboratory or (b) on a specific topic of theoretical physics,
- discuss their project results and conclusions in a team,
- present their findings in written and oral form.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Science in Perspective

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-PHYS

Master’s Thesis

Number Title Type ECTS Hours Lecturers
402-2000-00L Scientific Works in Physics O 0 credits D. Kienzler

Abstract
Target audience: Master students who cannot document to have received an adequate training in working scientifically.

Directive

Abstract
Literature Review; ETH-Library, Journals in Physics, Google Scholar; Thesis Structure: The IMRAD Model; Document Processing: LaTeX and BibTeX, Mathematical Writing, AVETH Survival Guide; ETH Guidelines for Integrity; Authorship Guidelines; ETH Citation Etiquettes; Declaration of Originality.

Objective
Basic standards for scientific works in physics: How to write a Master Thesis. What to know about research integrity.

462-0900-00L Master’s Thesis

Further information:
www.phys.ethz.ch/phys/education/master/msc-theses

Abstract
The Master’s thesis is normally conducted in the fourth semester and concludes the degree programme. With the Master’s thesis students verify their ability to undertake independent and scientifically structured work in the area of high energy physics.
Objective

Students are enabled to:
- solve a complex problem by applying theoretical and experimental methods and skills,
- articulate their beliefs and thoughts on a scientific subject, appreciate the positions of others and revisit their own positions based on new insights,
- contribute constructively to the projects of a diverse research team,
- actively participate in a scientific discourse on a specific area of physics and present positions based on scientific arguments.

Prerequisites / notice

The time limit for completing the Master's thesis is six months.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
<td></td>
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<tr>
<td>Analytical Competencies</td>
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<tr>
<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<tr>
<td>Project Management</td>
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Method-specific Competencies

<table>
<thead>
<tr>
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<tr>
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<td>Project Management</td>
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Social Competencies

<table>
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<tr>
<th>Communication</th>
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<tbody>
<tr>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
</tr>
<tr>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
</tr>
<tr>
<td>Negotiation</td>
<td>fostered</td>
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Personal Competencies

<table>
<thead>
<tr>
<th>Adaptability and Flexibility</th>
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</thead>
<tbody>
<tr>
<td>Creative Thinking</td>
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<tr>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
</tr>
<tr>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
</tr>
<tr>
<td>Self-direction and Self-management</td>
<td>assessed</td>
</tr>
</tbody>
</table>

High-Energy Physics (Joint Master with IP Paris) - Key for Type

| O   | Compulsory                  |
| W+  | Eligible for credits and recommended |
| W   | Eligible for credits        |
|     | E-  Recommended, not eligible for credits |
|     | E.  Recommended, not eligible for credits |
|     | Z   Courses outside the curriculum |
|     | Dr  Suitable for doctorate  |

Key for Hours

| V   | lecture                          |
| G   | lecture with exercise            |
| U   | exercise                         |
| S   | seminar                          |
| K   | colloquium                       |
|     | P    practical/laboratory course |
|     | A    independent project         |
|     | D    diploma thesis              |
|     | R    revision course / private study |

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Human Medicine Bachelor

Bachelor Studies (Programme Regulations 2022)

First Year Courses

First Year Examinations

First Year Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>377-0105-00L</td>
<td>Musculoskeletal System</td>
<td>O</td>
<td>5 credits</td>
<td>5V</td>
<td>J. Goldhahn, O. Distler, M. Ganter, C. Maake, M. Steinwachs, further lecturers</td>
</tr>
</tbody>
</table>

**Abstract**
Structure and function of the human musculoskeletal system including its major disorders (acute and chronic).

**Objective**
- The students are able to participate in team discussions with correct technical language in the clinical daily routine.
- The students are able to describe the function of the musculoskeletal system of healthy people in a physiologically correct way.
- The students are able to contribute to a therapy plan based on their knowledge of the regenerative capacity of the different tissues in the musculoskeletal system.
- The students recognize pain as a leading symptom in diagnostics and successful therapy.
- The students can assign and compare treatment methods for the most common acute and chronic clinical pictures.

**Content**
The students learn about the structure and function of the musculoskeletal system and important disorders on the basis of exemplary clinical pictures.
They also learn:
- About its tissue types as well as its function and regeneration.
- Important acute and chronic clinical pictures and their therapeutic principles.
In addition, further clinical pictures are presented in the form of seminars.

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

**Abstract**
Structure and function of the central and peripheral nervous system including its major disorders.

**Objective**
Upon successful completion of this module, students should be able to:
1. distinguish important cell types of the nervous system (neurons, glial cells) on the basis of their structure and function;
2. correctly describe neurophysiological basics of stimulus conduction and processing in the peripheral and central nervous system;
3. correctly name the organ structures and circuits involved in the development of the peripheral and central nervous system;
4. associate the different brain areas with corresponding functions in homeostasis, sensory, motor and cognitive functions;
5. identify clinical pictures associated with the loss of function of certain structures of the central and peripheral nervous system and to understand the mode of action of current therapeutic approaches.

**Content**
In this module, students get an overview of the structure (anatomy) and function (physiology) of the peripheral and central nervous system as well as selected neurological diseases (pathophysiology).
The module is subdivided into a total of six subject areas:
1. basics of neurophysiology, stimulus conduction and processing using the example of the motor end plate, peripheral nervous system, associated clinical pictures (myasthenia gravis)
2. structure, circuits and pathways in the spinal cord, spinal nerves, motor stimulus conduction in the spinal cord, spinal cord lesions and pain
3. anatomy and function of the brain stem and cranial nerves and their significance for motor and sensory functions, lesions (brain stem syndromes)
4. anatomy and function of basal ganglia, thalamus and hypothalamus, control of the autonomic nervous system (homeostasis, food and water intake), basal ganglia defects using Parkinson's disease as an example
5. anatomy and function of the cerebellum and vestibular system, fine control of motor functions, associative learning, cerebellar symptoms (ataxias), organ of equilibrium
6. anatomy and function of the cerebrum, sensory and motor processing, cognition, learning and memory, neurodegenerative (Alzheimer) and neuropsychiatric (schizophrenia) disorders

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>551-0033-00L</td>
<td>Molecular Genetics and Cell Biology</td>
<td>O</td>
<td>5 credits</td>
<td>5G</td>
<td>J. Corn, F. Allain, K. Köhler</td>
</tr>
</tbody>
</table>

**Abstract**
This course teaches the basic principles of evolution, cell biology, molecular biology, genetics and developmental biology using the example of humans.

**Objective**
1) Students can explain the importance of evolution for the development of humans and diseases.
2) The students know the cell as the smallest unit of the body. They can explain how the functions of the cell are disturbed in certain diseases and where therapies intervene. They can describe the multiplication of cells in the body and show how errors in this multiplication can lead to diseases.
3) The students know DNA as the basis of life. They can explain how the DNA information is stored and how this information can be reproduced and protected from damage. They can describe how the information is read and translated into proteins. They can explain which mechanisms at the level of DNA, RNA and proteins can cause diseases.
4) Students can explain which technologies can be used to diagnose and treat diseases.
5) Students can explain how people differ genetically and know the molecular basis of these differences. They can explain how these differences can lead to diseases and why some of these differences do not affect diseases.
6) The students know the molecular causes of the most common hereditary diseases and can determine the probability of occurrence and transmission to offspring.
7) Students can explain the biochemical and molecular basis of human reproduction and know the basic principles of human embryonic development. The students can explain which mechanisms can be disturbed by a faulty development.

**Lecture notes**
See Moodle

**Literature**
- "Biology - How life works", Morris et al.
- "Evolutionary Analysis", Herron & Freeman
- "Genetics: From Genes To Genomes", Goldberg & Fischer
- "Molecular Biology of the Cell", Alberts et al.

**Prerequisites / notice**
The lecture is accompanied by exercises on Moodle, group projects and mid-terms (learning elements). Upon successful completion of the learning elements (at least 80% of the total possible points must be achieved), students can receive bonus points, which can be credited towards the grade of the final examination. Acquiring points from the group projects and the mid-terms requires on-site participation (no online participation possible). Acquiring bonus points is not a prerequisite for taking part in the final exam.
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Social Competencies
Communication assessed

Personal Competencies
Creative Thinking assessed
Critical Thinking fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Social Competencies
Communication assessed

Personal Competencies
Creative Thinking assessed
Critical Thinking fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Analytical Competencies assessed

Personal Competencies
Critical Thinking fostered
Self-direction and Self-management fostered

Social Competencies
Communication fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered

Chemistry (for Medical Students) O 4 credits 3V+1U S. Wolfrum

Abstract
The lecture teaches the most important fundamental concepts in chemistry (atomic structure, chemical bonds, thermodynamics and kinetics of chemical reactions, acid-base equilibria, types and reactivity of organic compounds, stereochemistry, biomolecules). Connections of chemical processes with medically important biochemical, physiological, and pharmacological questions are highlighted.

Objective
Understanding the importance of chemical processes in human physiology and in the diagnosis and treatment of human disease.

Content
The lecture elaborates the fundamental concepts of chemistry. The organization of the lecture is guided by the two textbooks "Chemie für Mediziner" by Zeeck et al. and Schmuck et al., respectively, referred to below. Accordingly, the following major subject areas will be covered: Atomic structure, periodic table of the elements, types of chemical bonds, states of matter, heterogeneous equilibria, thermodynamics and kinetics of chemical reactions, salt solutions, acids and bases, oxidation and reduction, metal complexes, fundamentals of organic chemistry, important classes of organic compounds and their reactivities, stereochemistry, amino acids and peptides, carbohydrates, lipids, heterocycles, spectroscopy in chemistry and medicine.

Lecture notes
Scripts for individual subject areas will be provided electronically prior to the corresponding lectures.

Literature
There are no English translations of these textbooks.

Prerequisites / notice
There are no specific requirements.

529-5000-00L Chemistry (for Medical Students) O 4 credits 3V+1U S. Wolfrum

401-0281-00L Mathematics I O 4 credits 3V+1U S. Kalisnik Hintz

Abstract
Introduction of mathematics as the universal language for scientific facts: The lecture aims on one hand at learning and exercising the mathematical trade and in the other hand at applying the learnt concept to medical, biological, chemical and mechanical problems.

Objective
Simple and complex facts can be described and analysed using mathematical tools.
Introduction to calculus in one dimension.
Used concepts: the notion of a function, of the derivative and the integral, the idea of a differential equation, complex numbers, Taylor polynomials and Taylor series.
Applications e.g. to prognoses, modeling action and dosage of drugs or tumor growth.

Content
Functions of one variable: the notion of a function, of the derivative, the idea of a differential equation, complex numbers, Taylor polynomials and Taylor series. The integral of a function of one variable.

Literature
G. B. Thomas, M. D. Weir, J. Hass: Analysis 1, Lehr- und Übungsbuch, Pearson-Verlag

Additional reading suggestions will be indicated during the lecture

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving fostered

Social Competencies
Communication fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered

First Year Examination Block 2

Number Title Type ECTS Hours Lecturers
401-0281-00L Mathematics I O 4 credits 3V+1U S. Kalisnik Hintz

Additional First Year Courses

Number Title Type ECTS Hours Lecturers

Abstract
Fundamental principles of human medicine, Basic Life Support (BLS) and introduction to histology and microscopy.
Objective
After completion of the course, the students:
- have a basic understanding of elementary building blocks and processes as a basis for human medicine, e.g. cell structure and cycle.
- know basic terminology of anatomy.
- understand the process of medical care from first aid to rehabilitation.
- understand the advantages and disadvantages of emergency diagnostics, especially ultrasound.
- know the basics of microscopy and histology.
- have learned the basics of Basic Life Support:
  - recognize the symptoms of cardiovascular arrest.
  - alarm in an emergency according to the situation.
  - if available, they organize an AED and use it correctly and as quickly as possible.
  - perform sufficient chest compressions on the phantom.
  - perform effective ventilation on the phantom using a pocket mask.
  - will identify possible ventilation complications. Under certain circumstances, they will not attempt further ventilation.
  - will identify the limits of cardiopulmonary resuscitation.
- under stress, they do not risk their own or other "helpers" lives.

Content
Based on a complex clinical case, students are familiarized with the course of medical care from initial treatment to rehabilitation. Basic terms, modules and processes are introduced. In addition, the students experience the basics of imaging techniques, especially ultrasound. The students complete the Basic Life Support course. After this training sequence, all participants should be able to initiate resuscitation measures in private and in-hospital settings. The students experience learning, teaching and working in the hospital sector as a social process and teamwork in which all senses and a wide range of skills are needed.

In addition, the students experience in three workshops the basic process of a psychotherapeutic intervention with the concepts of clinical reasoning, therapeutic aspects and therapy progression. An intensive course in microscopy/histology enables students to perform microscopy independently and to understand histological sections of a histological sample, but also online.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>377-0111-00L</td>
<td>Medical Interviewing Technique</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>S. Markum, K. Weiss, to be announced</td>
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</tbody>
</table>

Abstract
Interviewing techniques to acquire medically relevant information and building an adequate physician-patient relationship.

Objective
The students know:
- the components of a strucured medical interview

The students can:
- perform a strucured medical interview
- initiate an adequate relation to patients

Content
Mixed teaching methods, including lectures and training in groups with real patients and simulated patients.

Second Year Courses
Organ Systems, Clinical Practice and Natural Sciences
Examination Block A

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
</table>

Abstract
This course will focus on the components and functions of the hematopoietic and the immune systems and on diseases affecting or caused by these systems.

Objective
1. The organization and development of hematopoiesis including hematopoietic stem cell development; the role of hematopoietic growth and transcription factors in hematopoiesis; the role of hemoglobin in health and disease; erythrocyte physiology and iron metabolism; the principles of blood groups and blood transfusions; the principles of coagulation and the pharmacology of coagulation; the role of platelets and pharmacological platelet inhibition; to define thrombophilia and to understand thrombotic events; the role of leukocytes in health and disease; the analysis of blood samples; the principles of hematopoietic stem cell transplantation.

2. The development of the immune system; the structure and function of primary and secondary lymphoid organs; the cellular and molecular mechanisms of the innate and adaptive immune systems; the effector mechanisms of immune responses against pathogens; basic concepts of immune-mediated diseases (allergy and autoimmunity), tumor immunology, immunodeficiency, organ transplantation; basic knowledge of therapies.

Content
1. Introduction to hematopoiesis, hematopoietic growth factors, hematopoietic transcription factors, erythrocyte physiology, blood groups, blood transfusion, iron metabolism, platelets, coagulation cascade, fibrinolysis, hemoglobin, hemoglobinopathies, leukocytes (granulocytes, monocytes), clinical presentation of neutropenia, pharmacology of hemostasis, clinical presentation of thrombophilia, basics of hematopoietic stem cell transplantation, some aspects of laboratory medicine in hematology, virtual microscopy of blood and bone marrow smears.

2. Structure and anatomical position of primary and secondary lymphoid organs, cells and molecules of the innate immune system, T and B cells, development and receptor diversity, major histocompatibility complex (MHC) and antigen presentation, effector B cells and antibodies, effector T cells, regulatory T cells and cytokines, allergy and hypersensitivities, autoimmunity and anti-inflammatory drugs, transplantation and immunosuppressive drugs, immunodeficiency, immune response in cancer and immunotherapies.

Lecture notes
The course is supported by a Moodle page through which students have access to all necessary documentation.

Literature
The essential course material will be available on the course's Moodle Page in the form of lesson handouts

Suggested reference books include:
Blood: Hoffbrand's Essential Haematology
Immune system: Herbert Hof, Rüdiger Dörries; unter Mitarbeit von: Gernot Geginat, Dirk Schlüter and Constanze Wendt Medizinische Mikrobiologie Thieme 2017

Prerequisites / notice
The immune system part of this course builds on the content of the "Infection" course.

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>377-0301-02L</td>
<td>Nutrition and Digestion</td>
<td>O</td>
<td>5</td>
<td>5V</td>
<td>W. Langhans, L. Käser, C. Stockmann</td>
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</tbody>
</table>

Abstract
This module imparts basic knowledge about the morphology and function of the digestive system and the importance of nutrition for health. One focus is on the understanding of the relationships among food intake, digestion, nutrient absorption and metabolism including the disturbances of these processes and the related diseases.
The aim of this module is that the students know and understand the morphology and function of the digestive system including its associated glands as well as the importance of nutrition for health. In particular, the students shall understand the relationships between food intake and digestion as well as absorption and metabolism of particular nutrients. This knowledge shall enable the students to deduct the pathophysiology and pathology of the most important diseases of the digestive system and shall give them an idea of the pertinent diagnostics and therapy.

### Subject-specific Competencies

- Concepts and Theories
- Analytical Competencies
- Problem-solving

### Method-specific Competencies

- Techniques and Technologies

### Objectives

Upon successful completion of this module, students should:

- be able to explain the systematics of the endocrine system;
- know the structure and function of the hypothalamus, pituitary gland, adrenal gland, endocrine pancreas, thyroid gland, ovaries, testes;
- know the principles and regulation of bone, calcium and phosphate metabolism, energy balance, glucose metabolism, lipid metabolism, blood pressure;
- know the hormonally regulated metabolic processes (carbohydrates, protein and fat);
- know the most important endocrine diseases and tumors, their development, clinic, diagnostics and therapy;
- know the most important measures for the prevention of metabolic diseases and the underlying mechanisms.

### Content

In this module, students learn about anatomy, physiology, and pathophysiology of the endocrine glands, as well as the clinical, diagnostic, therapeutic, and preventive aspects of the most important endocrine diseases. This includes:

- Systematics of the endocrine system: structure and anatomical location of the various endocrine glands.
- Neuronal innervation and vascular supply area of the endocrine glands.
- Hormone classes: Protein and polypeptide hormones, amino and amino acid derivatives steroid hormones, biosynthesis of protein and polypeptide hormones, biosynthesis of amino and amino acid derivatives, biosynthesis of steroid hormones, storage of hormones, secretion of hormones, transport of hormones, half-lives, degradation and excretion of hormones.
- Transmission of information by hormones: hormone action at receptors, structure and function of membrane-associated hormone receptors, structure and function of nuclear receptors, regulation of hormone secretion.
- Structure and function of the hypothalamus, structure and function of the pituitary gland.
- Structure and function of the thyroid gland, under- and over-functioning of the thyroid gland, principles of diagnostics and therapy of thyroid diseases. Symptoms, medical history and clinical examination of thyroid diseases.
- Bones, calcium and phosphate metabolism.
- Regulation of glucose, lipid and protein metabolism, eating disorders, etiology, diagnostics, therapy and prevention of adipositas.
- Structure and function of the adrenal gland, pathogenesis, principles of diagnostics and therapy of diseases with hyper- and hypofunction of the adrenal gland. Symptoms, anamnesis and clinical examination in case of hyper- and hypofunction of the adrenal gland.
- Structure and function of the ovaries and testis, principles of reproductive physiology.

### Literature

The essential course material will be available on the course's Moodle Page in the form of scripts and lesson handouts. The course does not have an “official” textbook, but students may find a general reference book on the topic interesting. For this purpose the text "Endokrinologie und Stoffwechsel" von Stefan Fischli und Giatgen A. Spinas (Herausgeber), Thieme Verlag, may be helpful.

### Prerequisites / Notice

The course builds on the content of the "Chemie für Mediziner", "Biochemie", "Pathobiochemie", "Pharmakologie für Mediziner" and "Molekulare Genetik und Zellbiologie" course and "Nutrition and Digestion".

### Examination Block B

#### Number

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0083-00L</td>
<td>Physics I</td>
<td>O</td>
<td>4 credits</td>
<td>3V+1U</td>
<td>K. S. Kirch</td>
</tr>
</tbody>
</table>

### Objective

This course is an introduction to classical physics, with special focus on applications in medicine.

### Content

General introduction; Positron-Emission-Tomography as appetizer, including ionising radiation; kinematics of a point mass; dynamics of a point mass (Newton's axioms and forces); physical work, power and energy; conservation of linear and angular momentum; oscillations and waves; mechanics of a rigid body; fluid mechanics; introduction to electricity.

### Literature

"Physik für Mediziner, Biologen, Pharmazeuten", von Alfred Trautwein, Uwe Kreibig, Jürgen Hüttermann; De Gruyter Verlag.

### Prerequisites / Notice

Voraussetzung Mathematik I-II (Studiengänge Gesundheitswissenschaften und Technologie bzw. Humanmedizin) / Mathematik-Lernveranstaltungen des Basisjahres (Studiengänge Chemie, Chemieingenieurwissenschaften bzw. Interdisziplinäre Naturwissenschaften)
Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective.

Methods: Anatomical dissection of human bodies.

Objective
Learning and understanding of the detailed composition and function of the healthy human body and its components. Learning of selected examples of relevant radiographic anatomy and their implication in clinical medical work.

Content
Topographic – and radiographic anatomy of selected anatomical regions. Students dissect these regions and discuss important clinical content with aid of assistants.

Prerequisites / notice
Voraussetzungen:
LE 377-0105-00L Bewegungsapparat
LE 377-0107-00L Nervensystem
LE 377-0201-00L Herz-Kreislauft-System
LE 377-0203-00L Atmungs-System
LE 377-0205-00L Nieren und Hombostase

Courses in Medical Sciences
Core Courses 2nd Year

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-0683-00L</td>
<td>Statistics II</td>
<td>O</td>
<td>3</td>
<td>2V+1U</td>
<td>B. Ineichen</td>
</tr>
</tbody>
</table>

Abstract
Extension of statistics for medical students. This lecture is based on the content of Statistics I. The focus will be on the understanding and the concrete application of statistical methods, as they are used in medical research. Exercises will be solved using the statistical programming environment R.

Objective
After this course you will understand the concept of a broad selection of statistical methods (see also Content). Furthermore, you will know when to use which method. Especially, you will be able to read, understand, and scrutinise the results from such methods, whether these results are written or graphical.

Content
The course will cover the following topics.
- For the part on regression: simple linear regression; multiple regression (including factors and interactions); model selection; logistic regression (including odds ratio and their interpretation); Bayes inference.
- For the part on data: categorical data (including univariate tests); power analysis (including a guide on writing an ethics proposal); dealing with missing values.
- For the part on further methods: supervised vs unsupervised learning; dimensional reduction (including PCA and tSNE); survival analysis (including Kaplan-Meier curves and logrank test).

Prerequisites / notice
Required: Statistics I

Compensatory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<tbody>
<tr>
<td>376-0021-00L</td>
<td>Materials and Mechanics in Medicine</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>M. Zenobi-Wong, J. G. Snedeker</td>
</tr>
</tbody>
</table>

Abstract
Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective.

Objective
Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Content
Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

Lecture notes
course website on Moodle

Literature

Frontiers in Nanotechnology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>376-1103-00L</td>
<td>Frontiers in Nanotechnology</td>
<td>W</td>
<td>4</td>
<td>4V</td>
<td>V. Vogel, further lecturers</td>
</tr>
</tbody>
</table>

Abstract
Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.

Objective
Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within manmade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

Content
Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues.

Lecture notes
All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.
### 376-1714-00L Biocompatible Materials

**W 4 credits 3V**  
K. Maniura, M. Rottmar, M. Zenobi-Wong

**Abstract**  
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

**Objective**  
The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

**Content**  
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Special focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed. A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Lecture notes**  
Handouts are deposited online (moodle).

**Literature**  

(available online via ETH library)

### 376-1721-00L Bone Biology: Basics, Research and Clinics

**W 2 credits 2V**  
E. Wehrle, G. A. Kuhn, to be announced

**Abstract**  
The course gives an introduction into bone biology and provides an overview on current research methods and clinical approaches. Emphasis is put on skeletal development and metabolism, osteoporosis as well as fracture healing. Each topic is structured into three parts: basics, research and clinics.

**Objective**  
After completing the Bone Biology course, students will be able to:
1. Remember and apply basics in bone biology and disease
2. Remember clinical features and surgical approaches
3. Select adequate research methods and approaches
4. Evaluate publications on topics presented in the lecture

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: fostered

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: fostered
  - Project Management: fostered

- **Social Competencies**
  - Communication: fostered
  - Cooperation and Teamwork: assessed
  - Leadership and Responsibility: fostered
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered

- **Personal Competencies**
  - Adaptability and Flexibility: fostered
  - Creative Thinking: fostered
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

### 376-1651-00L Clinical and Movement Biomechanics

**W 4 credits 3G**  
D. K. Ravi, S. H. Hosseini Nasab, R. List, further lecturers

**Abstract**  
Measurement and modeling of the human movement during daily activities and in a clinical environment. The students are able to analyse the human movement from a technical point of view, to process the data and perform modeling with a focus towards clinical application.

**Objective**  
This course includes study design, measurement techniques, clinical testing, accessing movement data and anaysis as well as modeling with regards to human movement.

**Content**

1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. Concepts of ligand-based and structure-based virtual screening to identify potential drug candidates, and understand possibilities and limitations of computer-assisted drug design in pharmaceutical chemistry. As a result, they are prepared for professional assessment of computer-assisted drug design studies in medicinal chemistry projects.
3. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.
4. A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Lecture notes**  
Handouts are deposited online (moodle).

**Literature**  
- available online via ETH library

### 535-0022-00L Computer-Assisted Drug Design

**W 1 credit 1V**  
S. Riniker, G. Landrum

**Abstract**  
The lecture series provides an introduction to computer applications in medicinal chemistry. The topics cover molecular representations and similarity, ligand-based virtual screening, and structure-based virtual screening. All theoretical concepts and algorithms presented are illustrated by practical applications and case studies.

**Objective**  
The students will learn how molecules can be represented in computers and how molecular similarity is calculated. They will learn the concepts of ligand-based and structure-based virtual screening to identify potential drug candidates, and understand possibilities and limitations of computer-assisted drug design in pharmaceutical chemistry. As a result, they are prepared for professional assessment of computer-assisted drug design studies in medicinal chemistry projects.

**Content**

1. Concepts and Theories
2. Decision-making
3. Media and Digital Technologies
4. Problem-solving
5. Project Management
6. Communication
7. Leadership and Responsibility
8. Self-presentation and Social Influence
9. Sensitivity to Diversity
10. Adaptability and Flexibility
11. Creative Thinking
12. Critical Thinking
13. Integrity and Work Ethics
14. Self-awareness and Self-reflection
15. Self-direction and Self-management

**Recommended textbooks:**
Assessed Concepts and Theories

535-0250-00L

**Biotransformation of Drugs and Xenobiotics**

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**Abstract**

Knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism.

**Objective**

Goals: knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism.

**Content**

Major reactions of biotransformation, Major enzymes and reaction partners involved in the biotransformation of drugs and xenobiotics. Toxic reactions of metabolites. Factors which affect the biotransformation.

**Lecture notes**

Biotransformation of drugs and xenobiotics

**Literature**


**Competencies**

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535-0310-00L

**Glycobiology in Drug Development**

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**Abstract**

Protein-based drugs constitute around 25% of new approvals and most of them are glycoproteins. Using selected examples of prominent glycoprotein drugs, the course aims at providing insight into glycosylation-activity relationships and into biotechnological production and analytics.

**Objective**

Students gain basic knowledge in "pharmaceutical glycobiology". This implies knowing and understanding:
- major mechanisms underlying the roles of glycosylation for the biological/therapeutic actions of glycoproteins (glycosylation-function relationships) using prominent examples of glycoprotein drugs.
- the major types of protein-linked glycans and the biosynthetic pathways for their formation
- how glycoprotein drugs are produced (including the most important expression systems used), glycoengineered and analysed (quality control).

Students are able to apply this knowledge in solving simple problems in glycoprotein drug development (on paper).

Students gain the ability to reflect on roles of glycosylation in various biological contexts.

**Lecture notes**

The slides used for the lectures will be provided online

**Literature**

- recent publications as cited/proposed on the lecture slides

**Prerequisites**

Requirements: Basic knowledge in immunology, molecular biology, protein and carbohydrate chemistry, analytical techniques. Basic knowledge in pharmacology.

**Competencies**

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535-0423-00L

**Drug Delivery and Drug Targeting**

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**Abstract**

The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.

**Objective**

The students dispose of an overview on current principles and systems for the controlled delivery and targeting of drugs. The focus of the course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines.

**Content**

The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.

**Lecture notes**

Selected lecture notes, documents and supporting material will be directly provided or may be downloaded from the course website.

**Literature**


Further references will be provided in the course.
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered
- Self-direction and Self-management: fostered

551-0307-00L Molecular and Structural Biology I: Protein Structure and Function

D-BIOL students are obliged to take part I and part II (next semester) as a two-semester course.

Abstract
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

Objective
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

Lecture notes
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.

Literature
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

551-0309-00L Concepts in Modern Genetics

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree/courses/special-students/special-students-university-of-zurich.html

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

551-0313-00L Microbiology (Part I)

Abstract
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Objective
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Content
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Lecture notes
Updated handouts will be provided during the class.

Literature
Current literature references will be provided during the lectures.

Prerequisites / notice
- English
- The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.
### Courses in Organ Systems and Clinical Practice

#### Additional Courses 3rd Year

<table>
<thead>
<tr>
<th>Number</th>
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<td>4</td>
<td>5</td>
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<td>P. Imesch, G. Hasenberg, B. Leeners, C. Maake, R. Messmer, I. Zemp</td>
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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1337 of 2653
Abstract

In this module we lay the anatomical and physiological foundations for the subject of "reproduction". The associated clinical challenges are conveyed from different points of view and with different actors. The content is chronologically prepared and shows the normal female cycle and her disorders as well as the pregnancy and related issues to the obstetrics. Students will have the opportunity to work with prospective midwives to learn basic skills of normal birth through a simulation.

Objective

- **Anatomy**
  - Knowledge of the function of the female and male sexual organs
  - Explaining the development of the maternal and fetal parts of the placenta
  - Explaining the anatomy of the pelvis and the pelvic floor
- **Gynecology**
  - Recognizing gynecological emergencies
  - Listing of the various types of bleeding in an irregularities
  - Overview of the benign tumors of the uterus and ovaries as well as the malignant tumors of the cervix and the endometrium
- **Reproductive Endocrinology**
  - Outlining of the main regulatory hormones of the female cycle and explaining their effects
  - Listing of the most important sterility factors
  - Discussing the main contraceptive methods with their mechanisms of action and contraceptive safety
- **Physiological situations in obstetrics**
- **Knowledge of the physiological processes and adaptation processes during pregnancy**
- **Determination of birth process**
- **Being aware of the meaning of the puerperium**

Content

This module gives the anatomical and physiological foundations for the subject of "reproduction". The associated clinical challenges are conveyed from different points of view and with different actors. The content is chronologically prepared and shows the normal female cycle and her disorders as well as the pregnancy and related issues to the obstetrics. Students will have the opportunity to work with prospective midwives to learn basic skills of normal birth through a simulation.

**Prerequisites / notice**

**Voraussetzungen:**
LE 377-0105-00L Bewegungssapparat
LE 377-0107-00L Nervensystem
LE 377-0201-00L Herz-Kreislauf-System
LE 377-0203-00L Atmungs-System
LE 377-0205-00L Nieren und Homöostase
LE 377-0301-01L Blut, Immunsystem
LE 377-0301-02L Ernährung und Verdauung
LE 377-0301-03L Endokrinologie, Stoffwechsel
LE 377-0401-00L Sinnesorgane
LE 377-0403-00L Haut und Anhangsorgane

**377-0503-01L Geriatrics**

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<tr>
<td>Abstract</td>
<td>Fundamentals and relevance of the aging process, as well as its biochemical, physiological and evolutionary basis. Insights into its individual as well as economic impact, including interventional and pharmacological treatment options.</td>
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<td>Objective</td>
<td>Upon successful completion of the module, students should be able to</td>
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<td>1. correctly describe the biological bases of the aging process;</td>
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<td>2. derive physical and pharmacological choices to modulate the aging process;</td>
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<td>3. understand the social and psychological implication of aging;</td>
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<td>4. describe the specificities of geriatric medicine in the stationary setting;</td>
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<td>5. identify the age-specific differences in both diagnostics and therapeutics.</td>
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<td>Content</td>
<td>Fundamentals and relevance of the aging process, as well as its biochemical, physiological and evolutionary basis. Insights into its individual as well as economic impact, including interventional and pharmacological treatment options.</td>
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<td>LE 377-0301-03L Endokrinologie, Stoffwechsel</td>
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<td>LE 377-0403-00L Haut und Anhangsorgane</td>
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**377-0503-02L Rheumatology**

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<tbody>
<tr>
<td>Abstract</td>
<td>Disease patterns from the field of rheumatology. The main focus is on inflammatory diseases, including soft tissue and bone diseases.</td>
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<tr>
<td>Objective</td>
<td>At the end of the module, students should be able to do the following:</td>
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<td>list the typical symptoms and manifestations of the disease patterns;</td>
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<td>list the clinical examinations of the clinical pictures and explain the findings;</td>
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<td>-</td>
<td>list and justify further clarifications (such as laboratory tests, imaging, etc.) of the clinical pictures;</td>
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<td>recognize the respective clinical pictures of this topic block based on the symptoms, clinical examinations, findings and further clarifications;</td>
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<td>list the possible treatment options for the disease patterns and explain the indication, prevention and risk factors;</td>
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<td>Early detection of clinical pictures that require rapid therapy, identification of further steps for clarification and therapy;</td>
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<td>describe the causes and pathophysiological basis of the disease patterns.</td>
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<tr>
<td>Content</td>
<td>Overview Rheumatology, Rheumatoid Arthritis, M. Still, Spondyloarthritis, SAPHO Syndrome, Infectious and Crystal Arthritis, Juvenile Idiopathic Arthritis, CRPS, Soft Tissue Diseases, Myopathies, Bone Diseases, Vasculitis, Collagenosis, Drug Therapy in Rheumatology, Ergonomics, Occupational Reintegration.</td>
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<td>LE 377-0401-00L Sinnesorgane</td>
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<td>LE 377-0403-00L Haut und Anhangsorgane</td>
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</table>
Abstract
The module Paediatrics describes the peculiarities of the paediatric anamnesis as well as selected topics of the healthy and sick child. The focus is on the newborn, development in the first years of life and adolescence. Infections, congenital heart and the most common respiratory diseases are described throughout the different age stages.

Objective
• Knowledge of the paediatric aspects of the medical history
• Knowledge of the enormous variety of child development (inter- and intra-individual variability)
• Milestone concept: Assessment of the stage of development of a child in the first years of life
• Landmark concept: first knowledge of the demilitation on normality versus disorder
• Getting to know frequent developmental pediatric disorders
• Knowledge of the most common congenital heart defects
• Getting to know and recognize respiratory diseases of the upper and lower respiratory tract

Content
It describes the peculiarities of the pediatric anamnesis as well as selected topics of the healthy and sick child. The focus is on the newborn, development in the first years of life and adolescence. Infections, congenital heart, and the most common respiratory diseases are described throughout the different age stages.

Prerequisites / notice
Prerequisites:
LE 377-0105-00L Bewegungsapparat
LE 377-0107-00L Nervensystem
LE 377-0201-00L Herz-Kreislauf-System
LE 377-0203-00L Atmungs-System
LE 377-0205-00L Nieren und Harnostase
LE 377-0301-01L Blut, Immunsystem
LE 377-0301-02L Ernährung und Verdauung
LE 377-0301-03L Endokrinologie, Stoffwechsel
LE 377-0401-00L Sinnesorgane
LE 377-0403-00L Haut und Anhangsorgane

Abstract
Pathology is the study of causes and effects of disease. This module pathology describes the pathogenetic processes and pathomorphological changes that occur in healthy and diseased tissues and cells of the human body. The module covers basic anatomical and surgical pathology and will cover the current and future possibilities of diagnostic practice in pathology.

Objective
After successfully completing the «General Pathology» module, students should be able to
1. to describe the goals and methods of pathoanatomical diagnostics and in reference to clinical practice.
2. to name the general causes and mechanisms of disease development and the associated pathomorphological changes in cells and tissues.
3. to fundamentally link the general causes and mechanisms of disease development with the therapeutic approaches that arise from them.
4. to describe the mechanisms of general inflammation, cell damage and circulatory pathology and relate them to the pathogenesis of specific diseases.
5. to explain the basics of the classification of benign and malignant tumors.
6. to describe the value of pathoanatomical and molecular diagnostics for the predictive and prognostic stratification of patients and to fundamentally relate them to clinical therapy decisions.

After successfully completing the «Surgical Pathology» module, students should be able to
1. to name the most important organ-specific diseases of the nervous system, the endocrine system, the cardiovascular system, the respiratory system, the digestive system, the urogenital system, the musculoskeletal system and the skin and to describe their characteristic macroscopic and microscopic manifestations.
2. to relate the etiology and pathogenesis of the most important organ-specific diseases to their morphological appearance and clinical presentation.
3. to describe the etiopathogenesis of the most important organ-specific diseases and to understand the relation to the mode of action of common therapeutic approaches.
4. to describe the fundamental importance of pathology and molecular diagnostics for personalized medicine and to describe specific application examples.
In the module "General Pathology" general causes and mechanisms of disease development and the associated pathomorphological changes in cells and tissues are discussed. Basics, current and future possibilities of pathoanatomical diagnostics are presented. The module "General Pathology" provides the basics for understanding the diseases treated in "Special Pathology".

The general pathology part covers the main topics:
1. revision and in-depth histology
2. introduction to pathology, histopathological and macroscopic tissue evaluation, postmortem diagnostics
3. introduction to causes and mechanisms of disease development
4. inflammation theory
5. cell damage and circulation pathology
6. general tumor theory
7. predictive pathology

In the module "Special Pathology" you will learn about the most important organ-specific diseases. Each half-day is built around a complex of topics related to special pathology, and is implemented using various teaching methods. The most important part is the main lecture, in which we systematically discuss the diseases of the organs and organ systems with you. Using macroscopic and microscopic slides, we will show you the relation to pathophysiology, symptomatology and medical diagnostics. We establish clinical references by broadcasting the mortality conference at the USZ. An integrated revision course and exercises based on PathoMaps offer you the opportunity to link the subject matter of the lecture with already known contents, to structure it further and to clarify open points together. A special lecture on molecular pathology, digital pathology and bioinformatics will introduce you to future technologies that are of particular importance for modern medicine.

The special pathology part covers the main topics:
1. upper and lower respiratory tract
2. upper gastrointestinal tract
3. lower gastrointestinal tract
4. liver, gall bladder, pancreas
5. kidney, draining urinary tract
6. male sexual organs, prostate
7. future technologies (molecular pathology, digital pathology, bioinformatics)
8. blood and bone marrow, lymphatic system
9. endocrine organs
10. skin, bones, joints, soft tissue
11. female sexual organs, mamma
12. neuropathology

**Prerequisites / notice**

**Voraussetzungen:**
LE 377-0105-00L Bewegungsapparat
LE 377-0107-00L Nervensystem
LE 377-0201-00L Herz-Kreislauf-System
LE 377-0203-00L Atmungs-System
LE 377-0205-00L Nieren und Homöostase
LE 377-0301-01L Blut, Immunsystem
LE 377-0301-02L Ernährung und Verdauung
LE 377-0301-03L Endokrinologie, Stoffwechsel
LE 377-0401-00L Sinnesorgane
LE 377-0403-00L Haut und Anhangsorgane

**377-0511-00L Emergency Medicine**

**O 2 credits 2P M. Guigli Poretti**

**Abstract**
By focusing on the 20 most frequent emergencies, the students will learn how to make quick decisions including diagnostic strategy and therapeutic measures. In practical exercises the students practice interprofessional aspects and discuss legal and ethical questions of emergency medicine.

**Objective**
Perform a triage based on the assessment of the vital signs.
Collect a targeted anamnesis (max. 5-6 questions) of a patient and/or family member
Determine the status of a patient with the necessary clinical examinations.
Determine a differential diagnosis based on the targeted anamnesis and the status.
Interpret the vital signs of a patient
Interpret the results of the paraclinical examinations and confirm/reject the differential diagnosis.
Based on the differential diagnosis, determine the necessary paraclinical examinations
Determine the next steps (treatment in hospital / by family doctor / immediate measures)
Identify possible therapeutic measures

**Content**
Mornings – case discussions & lectures entire group:
- Hypo / Hyperglycemia
- Principles of poisoning
- Acute Dyspnoea
- Cough
- Acute Diarrhoea
- Gastrointestinal bleeding
- Acute Kidney injury
- Hypertensive Crisis
- Acute Headache
- Coma
- Chest Pain
- Syncope
- Acute Abdominal pain
- Acute blood loss
- Common Trauma
- Head Trauma
- Fever in child
- Crying child
- Seizures and convulsions
- Dyspnoea in child

Afternoon – 4 smaller groups rotating:
- Emergency room (Hospital Lugano)
- Emergency call-center / Ambulance (Croce Verde - Lugano)
- Simulation center (Lugano)
- Case discussion (Bellinzona)
- BLS Refresh

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1340 of 2653
Advances in our knowledge of cancer genetic and the cancer immunology are changing the ways by which clinicians treat various types of cancer. The students develop the basics of medical law, clinical ethics and communication needed for central applications in the clinic. They learn how to analyze and modify an interprofessional patient-path according to the personal patient situation. An exemplary patient case follows each session of the modules, to align the theoretical inputs with the corresponding patient case. An important aspect will be documented and reflected in a written assignment. During the self-study time, the students bring “their own patient” from their private environment and accompany her/him during the patient-path. Within this framework the individual path including all health professionals involved, will be analyzed. In a written assignment, the students actively participate in interprofessional sessions, are open to other viewpoints, and consider these for the care and safety of the patient.

### Prerequisites / notice

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>377-0513-00L Ethics, Legal Aspects and Communication</th>
<th>377-0515-00L Patient Journeys</th>
<th>377-0517-00L Oncology</th>
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<tr>
<td>Voraussetzungen:</td>
<td>O 4 credits</td>
<td>O 3 credits</td>
<td>O 2 credits</td>
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<td></td>
<td>2G T. Krones, B. Tag, further lecturers</td>
<td>3G C. Schlegel, C. Bachmann, E. Kut Bacs, G. Mang, D. Stämpfli, further lecturers</td>
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<td>2V A. Alimonti, A. Calcinotto, A. Fontecedro-Curioni, J.-P. Theurillat, to be announced</td>
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</table>

### Objective

**377-0513-00L Ethics, Legal Aspects and Communication**
- Know about ethical and legal basics of diagnostics and therapy and how these principles are put into practice.
- Knowledge and use of central communication skills with patients, health care teams and the public.
- Understand and describe the connections of ethics, law and communication and reflect on the implementation in clinical practice.
- Apply the concept of evidence based decision aids.
- Apply specific communication skills in simple clinical cases (informed consent, shared decision making, breaking bad news, communication of medical mistakes, Advance care Planning).
- Understand the concept and needs of vulnerable patients and address the concept ethically, legally and communicate adequately.
- Know about the necessity of interprofessional collaboration in the process of dealing with ethically and juridically complex cases and practice first steps.

**377-0515-00L Patient Journeys**
- Overview of clinical ethical cases.
- Basics in medical ethics and professional communication.
- Knowledge and application of concepts as informed consent, possible alternative juridical instruments.
- Knowledge and Application of Shared Decision Making.
- Knowledge and application of advance care planning, concept of advance directives, treatment of patients incapable of decision making.
-Breaking bad news, difficult prognoses.
- Concept of vulnerability, special needs.
-Differences of research/clinical, concept of evidence-based and presonalized medicine.
-Conflicts of interests in therapy and research.
-Basics on interprofessional cooperation in ethically and legally challenging situations.
-Goal of care approach; dealing with end of life decisions.
-Diagnostic and misdiagnosis, systems of avoidance of medical mistakes.

**377-0517-00L Oncology**
- Knowledge and use of central communication skills with patients, health care teams and the public.
- Principles of evidence based decision aids.
- Knowledge and use of central communication skills with patients, health care teams and the public.
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- Knowledge and use of central communication skills with patients, health care teams and the public.
Content

Basic knowledge in oncology
1. The cancer outbreak and its prevention
2. Tumor diagnostic, imaging and screening
3. Basic principle of cancer management and tumor recurrence
4. Clinical application: a clinical case study

Experimental immuno-oncology
1. Hallmarks of Cancer
2. The promise of Immuno-oncology
3. Experimental Immunotherapies: Checkpoint Blockade and CAR T cells
4. From Bedside to Bench to Bedside (Journal Club)

Targeted therapy
1. Cancer Genomics and Epigenomics
2. Basic knowledge of signal transduction and cancer metabolism
3. From Arsenic Trioxide and Glivec to modern targeted therapies
4. Mechanism of resistance to targeted therapies

Oncology practice
1. Basic and clinical application: Chemotherapy
2. Basic and clinical application: Radiotherapy
3. Clinical application: Evidence Based Medicine in oncology
4. Design and analysis of Clinical Trial
5. Clinical application: Immunotherapy
6. Clinical application: Target Therapy
7. From Symptoms to diagnosis
8. Oncology Emergency

Prerequisites / notice

Prerequisites:
LE 377-0105-00L Bewegungsapparat
LE 377-0107-00L Nervensystem
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LE 377-0301-02L Ernährung und Verdaugung
LE 377-0301-03L Endokrinologie, Stoffwechsel
LE 377-0401-00L Sinnesorgane
LE 377-0403-00L Haut und Anhangsorgane
LE 377-0519-00L Ultrasound Basics

Zurich Ultrasound-Modell (ETH/SGUM/UZH) for ultrasound profiles (curricular) and SGUM certificate basic course abdomen during medical studies (SGUM-Young Sonographers, facultative) with E-Learning and 8 hours practical teaching with 4 students per machine and instructor (curricular), as well as facultative 8 more hours practice and OSCE in the following semester.

Objective
Ultrasound basics
- Understanding of basic ultrasound physics.
- Basic ultrasound anatomy abdomen.
- To know and to do a typical Abdomen and soft-tissue ultrasound examination.
- Classical ultrasound pathology (Ascites, pleural effusion, gallstones, urinary retention ...).
- Know the most important artefacts and relevance for ultrasound imaging.
- SGUM basic abdomen certificate successful determination

Content
Modules curricular teaching ETHZ
- 1+2 Anatomy
- 3+4 Liver, biliary tract, pleura, rips, lung
- 5+6 Pancreas, spleen, adrenals, abdominal vessels
- 7+8 kidneys, bladder, neck, lymphnodes, FAST
- SGUM – Young Sonographers (facultative in the 6th Semester BSc Human Medicine)
- 9+10
- 10+11
- 11+12
- 13+14

Prerequisites / notice
Ultrschall Theorie
Voraussetzung:
LE 377-0311-00L Praktikum klinische Anatomie

Courses in Medical Sciences

Core Courses 3rd Year

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>252-0866-00L</td>
<td>Foundations of Computer Science for Human Medicine</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>M. Dahinden, L. E. Fässler</td>
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</table>

Abstract
This course provides important basic concepts for interdisciplinary programming projects with Python.

Objective
Students learn to...
- encode a problem into a program, test the program, and correct errors.
- understand and improve existing code.
- deal with the complexity of real data.
- store data in a suitable data structure.
- implement models from the natural sciences as a simulation.
- explain and apply standard algorithms and evaluate their efficiency.

Content
1. Variables, data types
2. Control structures, logic
3. Sequential data types, search- and sort algorithms, sequence analysis
4. Functions, modules, simulation and cellular automata

Lecture notes
All learning materials will be provided during the course.
Literature

Prerequisites / notice
This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

377-0523-00L Medical Technology I
O 3 credits 4G
R. Gassert, O. Lambercy

Abstract
The course will guide students through the user-centered development and evaluation process of a medical engineering system for arm movement support. It will introduce the fundamentals of data acquisition, signal processing and control engineering, complemented by hands-on experience with sensors/signals, actuators, signal processing, feedforward/feedback control as well as 3D design/printing.

Objective
The course enables students to:
- prepare for the collaboration with engineers, and understand their approach to the analysis and characterization of technical challenges
- describe the user-centered design and evaluation process of a medical engineering system
- explain the fundamentals of data acquisition, signal processing and controls engineering
- interpret measurements of physiological signals and analyze these for noise contributions
- acquire practical experience with sensors/signals, actuators, signal processing, controls as well as 3D design/printing

Content
The course covers the interdisciplinary elements of a medical engineering development and its evaluation, ranging from human factors to sensor and actuator technologies, (real-time) signal processing, control engineering basics as well as safety/ethical aspects. It is framed around the electrophysiological assessment and robotic movement support following spinal cord injury, and complemented with practical training on a didactic elbow exoskeleton.

Prerequisites / notice
Voraussetzungen:
LE 402-0083-00L Physik I
LE 402-0684-00L Physik II

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: assessed

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Self-direction and Self-management: fostered

376-0021-00L Materials and Mechanics in Medicine
W 4 credits 3G
M. Zenobi-Wong, J. G. Snedeker

Abstract
Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Objective
Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Content
Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

Lecture notes
course website on Moodle

Literature

376-1103-00L Frontiers in Nanotechnology
W 4 credits 4V
V. Vogel, further lecturers

Abstract
Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.
Objective: Building upon advanced technologies to create, visualize, analyze, and manipulate nano-structures, as well as to probe their nanochemistry, nano-mechanics, and other properties within manmade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

Content: Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

Lecture notes: All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.

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### 376-1651-00L Clinical and Movement Biomechanics

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<tr>
<td>D. K. Ravi, S. H. Hosseini Nasab, R. List, further lecturers</td>
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**Abstract:** Measurement and modeling of the human movement during daily activities and in a clinical environment.

**Objective:** The students are able to analyze the human movement from a technical point of view, to process the data and perform modeling with a focus towards clinical application.

**Content:** This course includes study design, measurement techniques, clinical testing, accessing movement data and analysis as well as modeling with regards to human movement.

**Lecture notes:** Handouts are deposited online (moodle).

**Literature:**

(available online via ETH library)

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### 376-1714-00L Biocompatible Materials

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<td>K. Maniura, M. Rottmar, M. Zenobi-Wong</td>
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**Abstract:** Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

**Objective:** The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

**Content:** Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

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### 376-1721-00L Bone Biology: Basics, Research and Clinics

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<td>E. Wehrle, G. A. Kuhn, to be announced</td>
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**Abstract:** The course gives an introduction into bone biology and provides an overview on current research methods and clinical approaches. Emphasis is put on skeletal development and metabolism, osteoporosis as well as fracture healing. Each topic is structured into three parts: basics, research and clinics.

**Objective:** After completing the Bone Biology course, students will be able to:
1. Remember and apply basics in bone biology and disease
2. Remember clinical features and surgical approaches
3. Select adequate research methods and approaches
4. Evaluate publications on topics presented in the lecture
The students will learn how molecules can be represented in computers and how molecular similarity is calculated. They will learn the concepts of ligand-based and structure-based virtual screening to identify potential drug candidates, and understand possibilities and limitations of computer-assisted drug design in pharmaceutical chemistry. As a result, they are prepared for professional assessment of computer-assisted drug design studies in medicinal chemistry projects.

The topics include molecular representations and similarity, ligand-based virtual screening (similarity search, QSAR, etc.) and structure-based virtual screening (docking, physics-based models).

Recommended textbooks:

Knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism.

Major reactions of biotransformation. Major enzymes and reaction partners involved in the biotransformation of drugs and xenobiotics. Toxic reactions of metabolites. Factors which affect the biotransformation.


Protein-based drugs constitute around 25% of new approvals and most of them are glycoproteins. Using selected examples of prominent glycoprotein drugs, the course aims at providing insight into glycosylation-activity relationships and into biotechnological production and analytics.

Students gain basic knowledge in "pharmaceutical glycobiochemistry". This implies knowing and understanding:
- major mechanisms underlying the roles of glycosylation for the biological/therapeutic actions of glycoproteins (glycosylation-function relationships) using prominent examples of glycoprotein drugs.
- the major types of protein-linked glycans and the biosynthetic pathways for their formation
- how glycoprotein drugs are produced (including the most important expression systems used), glycoengineered and analysed (quality control).

Students are able to apply this knowledge in solving simple problems in glycoprotein drug development (on paper). Students gain the ability to reflect on roles of glycosylation in various biological contexts.
Drugs Delivery and Drug Targeting

**Abstract**
The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.

**Objective**
The course focuses on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on antitumor drugs, therapeutic peptides, proteins, nucleic acids and vaccines.

**Content**
The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of delivery systems.

**Lecture notes**
Selected lecture notes, documents and supporting material will be directly provided or may be downloaded from the course website.

**Literature**

Further references will be provided in the course.

**Molecular and Structural Biology I: Protein Structure and Function**

**Abstract**
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

**Objective**
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

**Lecture notes**
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.

**Literature**
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.
Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed

Method-specific Competencies
Analytical Competencies
Problem-solving
assessed

Social Competencies
Communication
Cooperation and Teamwork
fostered

Personal Competencies
Creative Thinking
Critical Thinking
Self-awareness and Self-reflection
Self-direction and Self-management
assessed
fostered
fostered

551-0313-00L Microbiology (Part I) W 3 credits 2V W.-D. Hardt, L. Eberl, B. Nguyen, J. Piel, M. Pilhofer, A. Vagstad

Abstract
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Objective
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Content
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Lecture notes
Updated handouts will be provided during the class.

Literature
Current literature references will be provided during the lectures.

Prerequisites / notice
The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

551-0319-00L Cellular Biochemistry (Part I) W 3 credits 2V U. Kutay, F. Allain, T. Kleele, I. Zemp

Abstract
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Content
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Lecture notes
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Literature
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed

701-2413-00L Evolutionary Genetics W 6 credits 4V T. Städler, A. Widmer, S. Fior, M. Fischer, J. Stapley

Abstract
The concept course ‘Evolutionary Genetics’ consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics (emphasis on basic concepts) and ecological genetics (more emphasis on evolutionary and ecological processes of adaptation and speciation).

Objective
The aim of the course is to provide students with a solid introduction to the fields of population genetics, quantitative genetics, and ecological genetics. The concepts and research methods developed in these fields have undergone profound transformations; they are of fundamental importance in our understanding of evolutionary processes, both past and present. Students should gain an appreciation for the concepts, methods and explanatory power of evolutionary genetics.

Content
Population genetics - Types and sources of genetic variation; randomly mating populations and the Hardy-Weinberg equilibrium; effects of inbreeding, natural selection; random genetic drift and effective population size; gene flow and hierarchical population structure; molecular population genetics: neutral theory of molecular evolution and basics of coalescent theory.

Quantitative genetics - Continuous variation; measurement of quant. characters; genes, environments and their interactions; measuring their influence; response to selection; inbreeding and crossbreeding, effects on fitness; Fisher’s fundamental theorem.

Ecological Genetics - Concepts and methods for the study of genetic variation and its role in adaptation, reproductive isolation, hybridization and speciation.

Lecture notes
Handouts

Literature
Molecular Biology of Foodborne Pathogens

The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

**Objective**

Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

**Content**

Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

**Lecture notes**

Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

**Prerequisites / notice**

Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break!

**Further Modules**

This course cannot be counted towards the Bachelor Human Medicine. However, the students receive a certificate for completion of each Skills Lab.

**Bachelors Studies (Programme Regulations 2018)**

Courses in Organ Systems and Clinical Practice

**Additional Courses 3rd Year**

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<td>P. Imesch, G. Hasenberg, B. Leeners, C. Maake, R. Messmer, N. Ochsenbein-Kölble</td>
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**Abstract**

In this module we lay the anatomical and physiological foundations for the subject of "reproduction". The associated clinical challenges are conveyed from different points of view and with different actors. The content is chronologically prepared and goes from the normal cycle of the woman and her disorders to the pregnancy and related issues to the obstetrics.

**Objective**

- Anatomy
  - Knowledge of the function of the female and male sexual organs
  - Explaining the development of the maternal and fetal parts of the placenta
  - Explaining the anatomy of the pelvis and the pelvic floor
  - Gynecology
  - Recognizing gynecological emergencies
  - Listing of the various types of bleeding irregularities
  - Overview of the benign tumors of the uterus and ovaries as well as the malignant tumors of the cervix and the endometrium
  - Reproductive Endocrinology
  - Outlining the main regulatory hormones of the female cycle and explaining their effects
  - Listing of the most important sterility factors
  - Discussing the main contraceptive methods with their mechanisms of action and contraceptive safety
  - Physiological situations in obstetrics
  - Knowledge of the physiological processes and adaptation processes during pregnancy
  - Determination of birth process
  - Being aware of the meaning of the puerperium

**Content**

This module gives the anatomical and physiological foundations for the subject of "reproduction". The associated clinical challenges are conveyed from different points of view and with different actors. The content is chronologically prepared and shows the normal female cycle and her disorders as well as the pregnancy and related issues to the obstetrics. Students will have the opportunity to work with prospective midwives to learn basic skills of normal birth through a simulation.
Abstract
Fundamentals and relevance of the aging process, as well as its biochemical, physiological and evolutionary basis. Insights into its individual as well as economic impact, including interventional and pharmacological treatment options.

Objective
Upon successful completion of the module, students should be able to
1. correctly describe the biological bases of the aging process;
2. derive physical and pharmacological choices to modulate the aging process;
3. understand the social and psychological implication of aging;
4. describe the specificities of geriatric medicine in the stationary setting;
5. identify the age-specific differences in both diagnostics and therapeutics.

Content
Fundamentals and relevance of the aging process, as well as its biochemical, physiological and evolutionary basis. Insights into its individual as well as economic impact, including interventional and pharmacological treatment options.
Pathology is the study of causes and effects of disease. This module pathology describes the pathogenetic processes and pathomorphological changes that occur in healthy and diseased tissues and cells of the human body. The module covers basic anatomical and surgical pathology and will cover the current and future possibilities of diagnostic practice in pathology.

After successfully completing the «General Pathology» module, students should be able to

1. to describe the goals and methods of pathoanatomical diagnostics and in reference to clinical practice.
2. to name the general causes and mechanisms of disease development and the associated pathomorphological changes in cells and tissues.
3. to fundamentally link the general causes and mechanisms of disease development with the therapeutic approaches that arise from them.
4. to describe the mechanisms of general inflammation, cell damage and circulatory pathology and relate them to the pathogenesis of specific diseases.
5. to explain the basics of the classification of benign and malignant tumors.
6. to describe the value of pathoanatomical and molecular diagnostics for the predictive and prognostic stratification of patients and to fundamentally relate them to clinical therapy decisions.

After successfully completing the «Surgical Pathology» module, students should be able to

1. to name the most important organ-specific diseases of the nervous system, the endocrine system, the cardiovascular system, the respiratory system, the digestive system, the urogenital system, the musculoskeletal system and the skin and to describe their characteristic macroscopic and microscopic manifestations.
2. to relate the etiology and pathogenesis of the most important organ-specific diseases to their morphological appearance and clinical presentation.
3. to describe the etiopathogenesis of the most important organ-specific diseases and to understand the relation to the mode of action of common therapeutic approaches.
4. to describe the fundamental importance of pathology and molecular diagnostics for personalized medicine and to describe specific application examples.

In the module “General Pathology” general causes and mechanisms of disease development and the associated pathomorphological changes in cells and tissues are discussed. Basics, current and future possibilities of pathoanatomical diagnostics are presented. The module “General Pathology” provides the basics for understanding the diseases treated in “Special Pathology”.

The general pathology part covers the main topics:
1. revision and in-depth histology
2. introduction to pathology, histopathological and macroscopic tissue evaluation, postmortem diagnostics
3. introduction to causes and mechanisms of disease development
4. inflammation theory
5. cell damage and circulation pathology
6. general tumor theory
7. predictive pathology

In the module “Special Pathology” you will learn about the most important organ-specific diseases. Each half-day is built around a complex of topics related to special pathology, and is implemented using various teaching methods. The most important part is the main lecture, in which we systematically discuss the diseases of the organs and organ systems with you. Using macroscopic and microscopic slides, we will show you the relation to pathophysiology, symptomatology and medical diagnostics. We establish clinical references by broadcasting the mortality conference at the USZ. An integrated revision course and exercises based on PathoMaps offer you the opportunity to structure it further and to clarify open points together. A special lecture on molecular pathology, digital pathology and bioinformatics will introduce you to future technologies that are of particular importance for modern medicine.

The special pathology part covers the main topics:
1. upper and lower respiratory tract
2nd upper gastrointestinal tract
3. lower gastrointestinal tract
4. liver, gall bladder, pancreas
5. kidney, draining urinary tract
6. male sexual organs, prostate
7. future technologies (molecular pathology, digital pathology, bioinformatics)
8. blood and bone marrow, lymphatic system
9. endocrine organs
10. skin, bones, joints, soft tissue
11. female sexual organs, mamma
12. neuropathology

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>Voraussetzungen:</th>
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<td>LE 377-0105-00L Bewegungsapparat</td>
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<td>LE 377-0107-00L Nervensystem</td>
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<td>LE 377-0201-00L Herz-Kreislauf-System</td>
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<td>LE 377-0205-00L Nieren und Homöostase</td>
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<tr>
<td>LE 377-0301-01L Blut, Immunsystem</td>
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<tr>
<td>LE 377-0301-02L Ernährung und Verdauung</td>
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<td>LE 377-0301-03L Endokrinologie, Stoffwechsel</td>
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<td>LE 377-0401-00L Sinnesorgane</td>
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<tr>
<td>LE 377-0403-00L Haut und Anhangsorgane</td>
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</table>
Emory Medicine

Abstract
By focusing on the 20 most frequent emergencies, the students will learn how to make quick decisions including diagnostic strategy and therapeutic measures. In practical exercises the students practice interprofessional aspects and discuss legal and ethical questions of emergency medicine.

Objective
- Perform a triage based on the assessment of the vital signs.
- Collect a targeted anamnesis (max. 5-6 questions) of a patient and/or family member.
- Determine the status of a patient with the necessary clinical examinations.
- Interpret the vital signs of a patient.
- Interpret the results of the paraclinical examinations and confirm/reject the differential diagnosis.
- Based on the differential diagnosis, determine the necessary paraclinical examinations.
- Determine the next steps (treatment in hospital / by family doctor / immediate measures).
- Detect possible therapeutic measures.

Content

Mornings - case discussions & lectures entire group:
- Hypo / Hyperglycemia
- Principles of poisoning
- Acute Dyspnoea
- Cough
- Acute Diarrhoea
- Gastrointestinal bleeding
- Acute Kidney injury
- Hypertensive Crisis
- Acute Headache
- Coma
- Chest Pain
- Syncope
- Acute Abdominal pain
- Acute blood loss
- Common Trauma
- Head Trauma
- Fever in child
- Crying child
- Seizures and convulsions
- Dyspnoea in child

Afternoon – 4 smaller groups rotating:
- Emergency room (Hospital Lugano)
- Emergency call-center / Ambulance (Croce Verde - Lugano)
- Simulation center (Lugano)
- Case discussion (Bellinzona)
- BLS Refresh

Ethics, Legal Aspects and Communication

Abstract
The students develop the basics of medical law, clinical ethics and communication needed for central applications in the clinic. They learn which relevant legal framework conditions are to be observed in everyday clinical practice and how, in communication with patients, the principles of self-determination, patient well-being and damage avoidance are practically implemented.

Objective
After passing the modul successfully, students should be able to
- Know about ethical and legal basics of diagnostics and therapy and how these principles are put into practice.
- Know and use of central communication skills with patients, health care teams and the public.
- Understand and describe the connections of ethics, law and communication and reflect on the implementation in clinical practice.
- Apply the concept of evidence based decision aids.
- Apply specific communication skills in simple clinical cases (informed consent, shared decision making, breaking bad news, communication of medical mistakes, Advance Care Planning).
- Understand the concept and needs of vulnerable patients and address the concept ethically, legally and communicate adequately.
- Know about the necessity of interprofessional collaboration in the process of dealing with ethically and juridically complex cases and practice first steps.

Content
- Overview of clinical ethical cases.
- Basics in medical ethics and professional communication.
- Knowledge and application of concepts as informed consent, possible alternative medical instruments.
- Knowledge and application of Shared decision Making.
- Knowledge and application of advance care planning, concept of advance directives, treatment of patients incapable of decision making.
- Breaking bad news, difficult prognoses.
- Concept of vulnerability, special needs.
- Differences of research/clinical, concept of evidence-based and personalized medicine.
- Conflicts of interests in therapy and research.
- Basics on interprofessional cooperation in ethically and legally challenging situations.
- Goal of care approach, dealing with end of life decisions.
- Difficult diagnoses and misdiagnosis, systems of avoidance of medical mistakes.

Patient Journeys

Abstract
The modul deals with the importance of patient care by combining patient and interprofessional perspectives as well as the cooperation with other healthcare professions, at any moment (out- and inpatient treatment) as the patient progress along a care pathway.
Objective
- The students are able to analyze an interprofessional patient-path and modify it according to the personal patient situation.
- Students deal with other health professionals and together plan an appropriate patient-path.
- The students are able to take different perspectives (patient, family etc.) and consider them while planning a patient-path.
- Students actively participate in interprofessional sessions, are open to other viewpoints, and consider these for the care and safety of the patients.

Content
Based on various patient situations, students learn how an interprofessional patient-path looks like.
During the self-study time, the students bring “their own patient” from their private environment and accompany her/him during the patient-path. Within this framework the individual path including all health professionals involved, will be analyzed. In a written assignment, the most important aspects will be documented and reflected.

An exemplary patient case follows each session of the modules, to align the theoretical inputs with the corresponding patient case.
During the first session, the students analyze various internet platforms such as NetDoktor and learn how to deal with an informed patient. In addition, together with pharmacy students, the students get to know the different roles of the pharmacy. In further sessions, the students learn which responsibilities, tasks and competences, various health professionals have, during the care of the patients on their path.
In addition, the students have the opportunity to visit a rural hospital in another canton and become acquainted with the importance of the free choice of doctors and treatments in other Cantons.

Prerequisites / notice
Voraussetzungen:
LE 377-0105-00L Bewegungsapparat
LE 377-0107-00L Nervensystem
LE 377-0201-00L Herz-Kreislauf-System
LE 377-0203-00L Atmungs-System
LE 377-0205-00L Nieren und Hombostase
LE 377-0301-01L Blut, Immunsystem
LE 377-0301-02L Ernährung und Verdauung
LE 377-0301-03L Endokrinologie, Stoffwechsel
LE 377-0401-00L Sinnesorgane
LE 377-0403-00L Haut und Anhangsorgane

377-0517-00L Oncology
Objective
- Students are able to analyze an interprofessional patient-path and modify it according to the personal patient situation.
- Students deal with other health professionals and together plan an appropriate patient-path.
- The students are able to take different perspectives (patient, family etc.) and consider them while planning a patient-path.
- Students actively participate in interprofessional sessions, are open to other viewpoints, and consider these for the care and safety of the patients.

Content
Basic knowledge in oncology
1. The cancer outbreak and its prevention
2. Tumor diagnostic, imaging and screening
3. Basic principle of cancer management and tumor recurrence
4. Clinical application: a clinical case study

Experimental immuno-oncology
1. Hallmarks of Cancer
2. The promise of Immuno-oncology
3. Experimental Immunotherapies: Checkpoint Blockade and CAR T cells
4. From Bedside to Bench to Bedside (Journal Club)

Targeted therapy
1. Cancer Genomics and Epigenomics
2. Basic knowledge of signal transduction and cancer metabolism
3. From Arsenic Trioxide and Glivec to modern targeted therapies
4. Mechanism of resistance to targeted therapies

Oncology practice
1. Basic and clinical application: Chemotherapy
2. Basic and clinical application: Radiotherapy
3. Clinical application: Evidence Based Medicine in oncology
4. Design and analysis of Clinical Trial
5. Clinical application: Immunotherapy
6. Clinical application: Target Therapy
7. From Symptoms to diagnosis
8. Oncology Emergency

Prerequisites / notice
Prerequisites:
LE 377-0105-00L Bewegungsapparat
LE 377-0107-00L Nervensystem
LE 377-0201-00L Herz-Kreislauf-System
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LE 377-0301-03L Endokrinologie, Stoffwechsel
LE 377-0401-00L Sinnesorgane
LE 377-0403-00L Haut und Anhangsorgane

377-0519-00L Ultrasound Basics
Abstract
Zurich Ultrasound-Modell (ETH/SGUM/UZH) for ultrasound profiles (curricular) and SGUM certificate basic course abdomen during medical studies (SGUM-Young Sonographers, facultative) with E-Learning and 8 hours practical teaching with 4 students per machine and instructor (curricular), as well as facultative 8 more hours practice and OSCE in the following semester.

Objective
Ultrasound basics
- Understanding of basic ultrasound physics.
- Basic ultrasound anatomy abdomen.
- To know and to do a typical Abdomen and soft-tissue ultrasound examination.
- Classical ultrasound pathology (Aszites, pleural effusion, gallstones, urinary retention …).
- Know the most important artefacts and relevance for ultrasound imaging.
- SGUM basic abdomen certificate successful determination

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Content

- Modules curricular teaching ETHZ
  - 1+2 Anatomy
  - 3+4 Liver, biliary tract, pleura, rips, lung
  - 5+6 Pancreas, spleen, adrenals, abdominal vessels
  - 7-8 kidneys, bladder, neck, lymphnodes, FAST
- SGUM – Young Sonographers (facultative in the 6th Semester BSc Human Medicine)
  - 9+10
  - 10+11
  - 11+12
  - 13+14

Prerequisites / notice

Ultrasschall Theorie

Voraussetzung:
LE 377-0311-00L Praktikum klinische Anatomie

Courses in Medical Sciences

Core Courses 3rd Year

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<td>2</td>
<td>2G</td>
<td>M. Dahinden, L. E. Fässler</td>
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</tbody>
</table>

Abstract

This course provides important basic concepts for interdisciplinary programming projects with Python.

Objective

Students learn to:
- encode a problem into a program, test the program, and correct errors.
- understand and improve existing code.
- deal with the complexity of real data.
- store data in a suitable data structure.
- implement models from the natural sciences as a simulation.
- explain and apply standard algorithms and evaluate their efficiency.

Content

1. Variables, data types
2. Control structures, logic
3. Sequential data types, search- and sort algorithms, sequence analysis
4. Functions, modules, simulation and cellular automata

Lecture notes

All learning materials will be provided during the course.

Literature


Prerequisites / notice

This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking assessed
- Critical Thinking assessed
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

377-0523-00L Medical Technology I

Abstract

The course will guide students through the user-centered development and evaluation process of a medical engineering system for arm movement support. It will introduce the fundamentals of data acquisition, signal processing and control engineering, complemented by hands-on experience with sensors/signals, actuators, signal processing, feedforward/feedback control as well as 3D design/printing.

Objective

The course enables students to:
- prepare for the collaboration with engineers, and understand their approach to the analysis and characterization of technical challenges
- describe the user-centered design and evaluation process of a medical engineering system
- explain the fundamentals of data acquisition, signal processing and controls engineering
- interpret measurements of physiological signals and analyze these for noise contributions
- acquire practical experience with sensors/signals, actuators, signal processing, controls as well as 3D design/printing

Content

The course covers the interdisciplinary elements of a medical engineering development and its evaluation, ranging from human factors to sensor and actuator technologies, (real-time) signal processing, control engineering basics as well as safety/ethical aspects. It is framed around the electrophysiological assessment and robotic movement support following spinal cord injury, and complemented with practical training on a didactic elbow exoskeleton.

Prerequisites / notice

Voraussetzungen:
LE 402-0083-00L Physik I
LE 402-0684-00L Physik II
All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 handouts are deposited online (moodle). The course covers the following topics:

Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-properties. Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will start with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications. The course will then proceed to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced mathematics, novel technologies and new methods to address major medical challenges.

Each lecturer will first give an overview of the state-of-the-art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different disciplines will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each enrolled student will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.
Knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, 

The lecture series provides an introduction to computer applications in medicinal chemistry. The topics cover molecular representations and similarity, ligand-based virtual screening (similarity search, QSAR, etc.) and structure-based virtual screening. All theoretical concepts and algorithms presented are illustrated by practical applications and case studies.

The students will learn how molecules can be represented in computers and how molecular similarity is calculated. They will learn the concepts of ligand-based and structure-based virtual screening to identify potential drug candidates, and understand possibilities and limitations of computer-assisted drug design in pharmaceutical chemistry. As a result, they are prepared for professional assessment of computer-assisted drug design studies in medicinal chemistry projects.

The topics include molecular representations and similarity, ligand-based virtual screening (similarity search, QSAR, etc.) and structure-based virtual screening (docking, physics-based models).

Script will be available.

Recommended textbooks:

Competencies

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<th>Competency Type</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Personal Competencies</th>
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<td>Media and Digital Technologies</td>
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<td>Communication</td>
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<td>Integrity and Work Ethics</td>
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535-0250-00L  

Biotransformation of Drugs and Xenobiotics  

W 1 credit  

S.-D. Krämer

Objective  

Goals: knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism.

Content  

Major reactions of biotransformation. Major enzymes and reaction partners involved in the biotransformation of drugs and xenobiotics. Toxic reactions of metabolites. Factors which affect the biotransformation.

Lecture notes  

Biotransformation of drugs and xenobiotics

Recommended textbooks:


Competencies

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<th>Competency Type</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Personal Competencies</th>
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Protein-based drugs constitute around 25% of new approvals and most of them are glycoproteins. Using selected examples of prominent glycoprotein drugs, the course aims at providing insight into glycosylation-activity relationships and into biotechnological production and analytics.

### Content

**Objective**

Students gain basic knowledge in “pharmaceutical glycobiology”. This implies knowing and understanding:

- Major mechanisms underlying the roles of glycosylation for the biological/therapeutic actions of glycoproteins (glycosylation-function relationships) using prominent examples of glycoprotein drugs.
- The major types of protein-linked glycans and the biosynthetic pathways for their formation
- How glycoprotein drugs are produced (including the most important expression systems used), glycoengineered and analysed (quality control).

Students are able to apply this knowledge in solving simple problems in glycoprotein drug development (on paper).

Students gain the ability to reflect on roles of glycosylation in various biological contexts.

**Lecture plan:**

1. Glycans - information carriers in biology and pharmacotherapy
2. Glucocerebrosidase and the biosynthesis of N-glycans
3. Improving the therapeutic profile of monoclonal antibodies by glycoengineering
4. Mucin-type O-glycans and sialylation as gCQA of glycoprotein hormone drugs
5. GCOA analysis of glycoprotein hormone drugs (sialylated glycoproteins)
6. EPO "the same but different"

**Lecture notes**

The slides used for the lectures will be provided online

**Literature**

- Recent publications as cited/proposed on the lecture slides

**Prerequisites / notice**

Requirements: Basic knowledge in immunology, molecular biology, protein and carbohydrate chemistry, analytical techniques. Basic knowledge in pharmacology.

### Competencies

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Problem-solving
- Communication
- Critical Thinking
- Integrity and Work Ethics

**Method-specific Competencies**

- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Social Competencies**

- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Personal Competencies**

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

### Literature

- Further references will be provided in the course.

### Data: 15.06.2024 12:39

Autumn Semester 2024
Information for UZH students: Enrolment to this course unit is only possible at ETH. No enrolment to module BIO348 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.

Competencies
Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence

Personal Competencies
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

Literature
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

551-0313-00L  
Cellular Biochemistry (Part I)

Abstract
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

Content
Structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Lecture notes
Updated handouts will be provided during the class.

551-0319-00L  
Evolutionary Genetics

Abstract
The concept course 'Evolutionary Genetics' consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics (emphasis on basic concepts) and ecological genetics (more emphasis on evolutionary and ecological processes of adaptation and speciation).
Objective

The aim of the course is to provide students with a solid introduction to the fields of population genetics, quantitative genetics, and ecological genetics. The concepts and research methods developed in these fields have undergone profound transformations; they are of fundamental importance in our understanding of evolutionary processes, both past and present. Students should gain an appreciation for the concepts, methods and explanatory power of evolutionary genetics.

Content

Population genetics - Types and sources of genetic variation; randomly mating populations and the Hardy-Weinberg equilibrium; effects of inbreeding; natural selection; random genetic drift and effective population size; gene flow and hierarchical population structure; molecular population genetics: neutral theory of molecular evolution and basics of coalescent theory.

Quantitative genetics - Continuous variation; measurement of quant. characters; genes, environments and their interactions; measuring their influence; response to selection; inbreeding and crossbreeding, effects on fitness; Fisher's fundamental theorem.

Ecological Genetics - Concepts and methods for the study of genetic variation and its role in adaptation, reproductive isolation, hybridization and speciation.

Lecture notes

Handouts

Literature


Competencies

Subject-specific Competencies

Concepts and Theories

Concepts and Theories

Techniques and Technologies

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Analytical Competencies

Personal Competencies

Critical Thinking

Critical Thinking

752-4009-00L Molecular Biology of Foodborne Pathogens

W 3 credits 2V M. Loessner, A. Harms, M. Schuppler, E. Slack

Abstract

The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Objective

Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content

Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment ? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Lecture notes

Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Prerequisites / notice

Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break !

Further Modules

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>377-0682-00L Skills Lab (Autumn Semester)</td>
<td>W 0 credits 1U</td>
<td>M. Useini, C. Schiegel</td>
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Abstract

The Skills Lab MED is available to medical students at ETH as a place to learn and practice practical skills and abilities. Various courses are continuously offered in peer tutoring or with lecturers.

Content

The following skills are offered:

- Placement of a peripheral indwelling canula (in peer teaching)
- Optimization of ultrasound device settings, neck & thyroid sonography (Peer Teaching)
- Ultrasound-guided peripheral venipuncture
- Suturing course
- Wound bandage

Human Medicine Bachelor - Key for Type

O Compulsory
W+ Eligible for credits and recommended
W Eligible for credits

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<td>V lecture</td>
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<td>G lecture with exercise</td>
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<td>U exercise</td>
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<td>S seminar</td>
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<td>K colloquium</td>
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P practical/laboratory course
A independent project
D diploma thesis
R revision course / private study

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

Do you want to be able to query your own data productively and efficiently in your future semester projects, bachelor's thesis, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This course teaches you how to do so as well as the dos and don'ts.

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality.
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook

- Lecture material (slides).

  (It is not required to buy the book, as the library has it)

For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logics
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python
Competencies | Subject-specific Competencies | Concepts and Theories | assessed |
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252-0836-00L Computer Science II Z 4 credits 2V+2U R. Sasse, F. Friedrich Wicker

Abstract
The courses covers the foundations of design and analysis of algorithms and data structures, including graph theory and graph problems. It also introduces generic and parallel programming.

Objective
Understanding design, analysis and implementation of fundamental algorithms and data structures. Overview of the concepts of generic and parallel programming. Hands-on experience with implementing the aforementioned in C++.

Content
* Asymptotic runtime (algorithmic complexity)
* Fundamental algorithmic problems, e.g. searching, sorting, shortest paths, spanning trees
* Classical data structures, e.g. search trees, balanced trees, heaps, hash tables
* Graph theory and graph problems
* Problem solving strategies as design patterns for algorithms, e.g. induction, divide and conquer, backtracking, dynamic programming
* Generic programming: C++ templates higher-order functions, lambdas, closures
* Parallel programming: (in)dependence of computations, parallelism and concurrency, shared memory, races, mutual exclusion, communication and synchronisation

Knowledge obtained in the lecture is deepened through practical and/or programming exercises (C++, Code Expert).

Lecture notes
All material (slides, lecture recordings, examples, exercises, etc.) will be published on the course website.

Literature
* B. Stroustrup, A Tour of C++, 3rd Edition, Addison-Wesley, 2022

Prerequisites / notice
Prerequisite: Computer Science I

Competencies | Subject-specific Competencies | Concepts and Theories | assessed |
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252-0839-00L Informatics Z 2 credits 2G M. Dahinden, L. E. Fässler

Abstract
Students learn to apply selected concepts and tools from computer science for working on interdisciplinary projects. The following topics are covered: modeling and simulations, managing data with lists, tables and relational databases, introduction to programming.

Objective
The students learn to:
- choose and apply appropriate tools from computer science,
- process and analyze real-world data from their subject of study,
- handle the complexity of real-world data,
- query databases and understand and evaluate the corresponding database model,
- encode a problem into a program, test the program, and correct errors,
- implement models from the natural sciences as a simulation.

Content
1. Modeling and simulations
1. Data management with lists and tables
3. Data management with a relational database
4. Introduction to programming with Python 1 (variables & data types)
5. Introduction to programming with Python 2 (control structures & logic)
6. Introduction to programming with Python 3 (sequential data structures)

Lecture notes
All materials for the lecture are available at www.evim.ethz.ch

Literature

Prerequisites / notice
This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.
### Competencies

**Subject-specific Competencies**
- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Social Competencies**
- Communication
- Cooperation and Teamwork

**Personal Competencies**
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

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### 252-0845-00L Computer Science I

**Z** 5 credits 2V+2U  M. Lüthi, A. Streich

**Abstract**
The course covers the basic concepts of computer programming.

**Objective**
Basic understanding of programming concepts. Students will be able to write and read simple programs and to modify existing programs. In the course "Computer Science I", the competency of programming is taught, applied and examined. Furthermore modeling is taught and applied.

**Content**
- variables, types, control structures, functions, scoping, recursion, object-oriented programming. The programming language is Python.

**Lecture notes**
The slides and lecture notes will be made available for download on the course website.

**Literature**
- Learn to Code by Solving Problems
- A Python Programming Primer
- Python Crash Course
- A Hands-On, Project-Based Introduction to Programming
- Eric Matthes
- Python for Data Analysis
- Data wrangling with pandas, NumPy & Jupyter, 3rd Edition
- Wes McKinney

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### 252-0847-00L Computer Science

**Z** 5 credits 2V+2U  M. Fischer, F. Friedrich Wicker

**Abstract**
The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.

**Objective**
Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens "behind the scenes" when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.

**Content**
- fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.

**Lecture notes**
Lecture slides and all other material will be made available for download on the course web page.

**Literature**
- Bjarne Stroustrup: Einführung in die Programmierung mit C++, Pearson Studium, 2010
- Andrew Koenig and Barbara E. Moo: Accelerated C++, Addison-Wesley, 2000

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### 252-0852-00L Foundations of Computer Science

**Z** 4 credits 2V+2U  M. Dahinden, L. E. Fässler

**Abstract**
This course provides selected computer science concepts for interdisciplinary projects.

The following topics are covered: introduction to programming, sequence analysis, modeling and simulations, introduction matrices, managing data with with relational databases.

**Objective**
Students learn to...
- encode a problem into a program, test the program, and correct errors.
- understand and improve existing code.
- deal with the complexity of real data.
- store data in a suitable data structure.
- query databases and understand and evaluate the corresponding database model.
- implement models from the natural sciences as a simulation.
- run random experiments and interpret the results.
- explain and apply standard algorithms and evaluate their efficiency.
The general goal of the course consists in presenting ways to teach fundamentals of computer science, which are closely related to natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

In a semester exercise, the students develop and document an adaptive teaching unit for computer science. They learn to employ the didactics methods and techniques that are introduced at the beginning of the semester.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.

The course covers the didactics of logic, of cryptology, of finite state automata, of computability and of the introduction to programming. The students develop the understanding of fundamental scientific concepts such as algorithm, program, complexity, determinism, computation, automata, verification, testing, security of a cryptosystem and secure communication. They reflect on ways to embed them into a scientifically sound and didactically sustainable mathematics course.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support.

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The main topics of the course unit "Computer Science in Secondary School Mathematics" represent a scientific and didactic added value for mathematics classes.

The course covers the didactics of logic, of cryptology, of finite state automata, of computability and of the introduction to programming. The students develop the understanding of fundamental scientific concepts such as algorithm, program, complexity, determinism, computation, automata, verification, testing, security of a cryptosystem and secure communication. They reflect on ways to embed them into a scientifically sound and didactically sustainable mathematics course.

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Abstract

The unit "Computer Science in Secondary School Mathematics" addresses key contributions of computer science to general education, the tight relations between the algorithmic and the mathematical way of thinking, and the thoughtful choice of computer science topics for high school mathematics classes.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

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The course covers the didactics of logic, of cryptology, of finite state automata, of computability and of the introduction to programming. The students develop the understanding of fundamental scientific concepts such as algorithm, program, complexity, determinism, computation, automata, verification, testing, security of a cryptosystem and secure communication. They reflect on ways to embed them into a scientifically sound and didactically sustainable mathematics course.

In a semester exercise, the students develop and document an adaptive teaching unit for computer science. They learn to employ the didactics methods and techniques that are introduced at the beginning of the semester.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.

The main topics of the course unit "Computer Science in Secondary School Mathematics" represent a scientific and didactic added value for mathematics classes.

The course covers the didactics of logic, of cryptology, of finite state automata, of computability and of the introduction to programming. The students develop the understanding of fundamental scientific concepts such as algorithm, program, complexity, determinism, computation, automata, verification, testing, security of a cryptosystem and secure communication. They reflect on ways to embed them into a scientifically sound and didactically sustainable mathematics course.

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The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.
Objective
Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens "behind the scenes" when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.

Content
The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.

Lecture slides and all other material will be made available for download on the course web page.

Creative Thinking
Z
6 credits
Computer Science I
fostered

Bjarne Stroustrup: Einführung in die Programmierung mit C++, Pearson Studium, 2010


Andrew Koenig and Barbara E. Moc: Accelerated C++, Addison-Wesley, 2000

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies assessed
Problem-solving assessed

Social Competencies
Communication fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking fostered

252-0832-00L Computer Science I
Abstract
The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.

Objective
Primary educational objective is to learn programming with C++. When successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens "behind the scenes" when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.

Content
The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.

Lecture slides and all other material will be made available for download on the course web page.

Bjarne Stroustrup: Einführung in die Programmierung mit C++, Pearson Studium, 2010
Andrew Koenig and Barbara E. Moc: Accelerated C++, Addison-Wesley, 2000

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies assessed
Problem-solving assessed

252-0232-00L Software Engineering
Abstract
This course introduces both theoretical and applied aspects of software engineering. It covers:

- Software Architecture
- Informal and formal Modeling
- Design Patterns
- Software Engineering Principles
- Code Refactoring
- Program Testing

Objective
The course has two main objectives:

- Obtain an end-to-end (both, theoretical and practical) understanding of the core techniques used for building quality software.
- Be able to apply these techniques in practice.

Content
While the lecture will provide the theoretical foundations for the various aspects of software engineering, the students will apply those techniques in project work that will span over the whole semester - involving all aspects of software engineering, from understanding requirements over design and implementation to deployment and change requests.

Lecture slides and all other material will be made available for download on the course web page.

Will be announced in the lecture

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed
Project Management assessed

Personal Competencies
Critical Thinking fostered
Self-direction and Self-management fostered

| Generally Accessible Seminars and Colloquia |
|---|---|---|---|---|
| Number | Title | Type | ECTS | Hours | Lecturers |

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1363 of 2653
Computer Science Colloquium

**Abstract**
Invited talks, covering the entire scope of computer science. External Listeners are welcome at no charge. A detailed schedule is published at the beginning of each semester.

**Objective**
Top international computer scientists take the floor at the distinguished computer science colloquium. Our guest speakers present impacting topics across various areas of the discipline. The colloquium series is held every semester and also includes inaugural and farewell lectures of the department's professors. The colloquium is a noteworthy event for all graduate students. Outside attendance is equally welcome.

**Content**
Renowned international computer scientists take the floor at our distinguished colloquium series, to present topics across all areas of computer science.

---

Colloquium on Mathematics, Computer Science, and Education

**Subject didactics for mathematics and computer science teachers.**

**Abstract**
Didactics colloquium

---

**Computer Science (General Courses) - Key for Type**

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
<th>Eligibility</th>
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</thead>
<tbody>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
<td>W+</td>
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<tr>
<td>O</td>
<td>Compulsory</td>
<td>W</td>
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<td></td>
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<td>E-</td>
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**Key for Hours**

<table>
<thead>
<tr>
<th>Letter</th>
<th>Description</th>
<th>Eligibility</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td>P</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
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<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
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<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
<td></td>
</tr>
</tbody>
</table>

**ECTS**
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Computer Science Bachelor

First Year Examinations

First Year Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0025-01L</td>
<td>Discrete Mathematics</td>
<td>O</td>
<td>7</td>
<td>4V+2U</td>
<td>U. Maurer</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>Content: Mathematical reasoning and proofs, abstraction. Sets, relations (e.g. equivalence and order relations), functions, (un-)countability, number theory, algebra (groups, rings, fields, polynomials, subalgebras, morphisms), logic (propositional and predicate logic, proof calculi).</td>
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<td>Objective</td>
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<td>The primary goals of this course are (1) to introduce the most important concepts of discrete mathematics, (2) to understand and appreciate the role of abstraction and mathematical proofs, and (3) to discuss a number of applications, e.g. in cryptography, coding theory, and algorithm theory.</td>
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<td></td>
<td>Content</td>
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<td></td>
<td>See course description.</td>
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<td></td>
<td>Lecture notes</td>
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<td></td>
<td>available (in english)</td>
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<td></td>
<td>Competencies</td>
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<td>Subject-specific Competencies</td>
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<td></td>
<td>Concepts and Theories</td>
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<td>assessed</td>
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<td>Techniques and Technologies</td>
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<td></td>
<td>assessed</td>
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<td>Method-specific Competencies</td>
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<td></td>
<td>Analytical Competencies</td>
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<td>assessed</td>
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<td></td>
<td>Decision-making</td>
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<td>fostered</td>
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<td></td>
<td>Problem-solving</td>
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<td>assessed</td>
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<td></td>
<td>Personal Competencies</td>
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<td></td>
<td>Adaptability and Flexibility</td>
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<td></td>
<td>fostered</td>
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<td></td>
<td>Creative Thinking</td>
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<td></td>
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<td>fostered</td>
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<td>Critical Thinking</td>
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<td>fostered</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
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<td>fostered</td>
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<td></td>
<td>Self-direction and Self-management</td>
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<td></td>
<td>fostered</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<td></td>
<td>The lecture slides are available for download on the course page.</td>
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<td></td>
<td>Literature</td>
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<td>See the course page for up-to-date information.</td>
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<td></td>
<td>Prerequisites / notice</td>
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<td></td>
<td>There are no special prerequisites. Students are expected to enroll in the other courses offered to first-year students of computer science.</td>
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</tbody>
</table>

| 252-0027-00L | Introduction to Programming | O    | 7    | 4V+2U | M. Fischer, M. Schwerhoff |
|              | **Abstract**                |      |      |       |                  |
|              | Introduction to fundamental concepts of modern programming and operational skills for developing high-quality programs, including large programs as in industry. The course introduces software engineering principles with an object-oriented approach based. |
|              | **Objective**               |      |      |       |                  |
|              | Many people can write programs. The "Introduction to Programming" course goes beyond that basic goal: it teaches the fundamental concepts and skills necessary to perform programming at a professional level. As a result of successfully completing the course, students master the fundamental control structures, data structures, reasoning patterns and programming language mechanisms characterizing modern programming, as well as the fundamental rules of producing high-quality software. They have the necessary programming background for later courses introducing programming skills in specialized application areas. |
|              | **Content**                 |      |      |       |                  |
|              | Basics of object-oriented programming. Objects and classes, Pre- and postconditions, class invariants, design by contract. Fundamental data structures and algorithms. Recursion, Inheritance and interfaces, basic concepts of Software Engineering such as the software process, specification and documentation, debugging, reuse and quality assurance. |
|              | **Lecture notes**           |      |      |       |                  |
|              | The lecture slides are available for download on the course page. |
|              | **Literature**              |      |      |       |                  |
|              | See the course page for up-to-date information. |
|              | **Competencies**            |      |      |       |                  |
|              | Subject-specific Competencies|      |      |       |                  |
|              | Concepts and Theories        |      |      |       | assessed         |
|              | Techniques and Technologies  |      |      |       | assessed         |
|              | Method-specific Competencies |      |      |       |                  |
|              | Analytical Competencies      |      |      |       | assessed         |
|              | Decision-making              |      |      |       | fostered         |
|              | Media and Digital Technologies|  |       |       | assessed         |
|              | Problem-solving              |      |      |       | assessed         |
|              | Project Management           |      |      |       | fostered         |
|              | Personal Competencies        |      |      |       |                  |
|              | Creativity and Flexibility   |      |      |       | fostered         |

| 252-0026-00L | Algorithms and Data Structures | O    | 7    | 3V+2U+1A | J. Lengler, D. Steurer |
|              | **Abstract**                 |      |      |       |                  |
|              | The course provides the foundation of the design and analysis of algorithms. The material is introduced using classical algorithmic problems including graph problems. The necessary basic introduction to graph theory is provided as part of this course. |
|              | **Objective**                |      |      |       |                  |
|              | An understanding of the design and analysis of fundamental algorithms and data structures. A basic understanding of graph theory and several basic graph algorithms. |
|              | **Content**                  |      |      |       |                  |
|              | This course is an introduction into the design and analysis of algorithms. On the one hand this includes classical algorithm design patterns including induction, divide-and-conquer and dynamic programming. We study these using classical example such as searching and sorting. On the other hand the course covers the interaction between algorithms and data structures including linked lists, search trees, heaps, and union-find structures. A particular focus are graph algorithms for shortest path and minimal spanning tree problems. We provide the necessary introduction into graph theory as part of this course. |
|              | **Lecture notes**            |      |      |       |                  |
|              | A complete script in German is under development. A complete draft is already available on the course website. |
|              | **Literature**               |      |      |       |                  |
|              | Abgesehen vom Skript und Vorlesungsunterlagen empfehlen wir die folgenden Bücher als zusätzliches Nachschlagewerk. |

| 401-0131-00L | Linear Algebra               | O    | 7    | 4V+2U | B. Gärtner, R. Weismantel |
|              | **Abstract**                 |      |      |       |                  |
|              | Introduction to linear algebra: vectors and matrices, solving systems of linear equations, vector spaces and subspaces, orthogonality and least squares, determinants, eigenvalues and eigenvectors, singular value decomposition and linear transformations. Applications in and links to computer science will be presented in parallel. |
|              | **Objective**                |      |      |       |                  |
|              | - Understand and apply fundamental concepts of linear algebra |
|              | - Learn about applications of linear algebra in computer science |
|              | **Content**                  |      |      |       |                  |
|              | Vectors and matrices, solving systems of linear equations, vector spaces and subspaces, orthogonality and least squares, determinants, eigenvalues and eigenvectors, singular value decomposition and linear transformations. Applications in and links to computer science. |
|              | **Literature**               |      |      |       |                  |

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First Year Examination Block 2

Offered in the spring semester.

Basic Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0057-00L</td>
<td>Theoretical Computer Science</td>
<td>O</td>
<td>7</td>
<td>4V+2U</td>
<td>D. Komm, H.-J. Böckenhauer, J. Hromkovic</td>
</tr>
<tr>
<td>Abstract</td>
<td>Concepts to cope with: a) what can be accomplished in a fully automated fashion (algorithmically solvable) b) How to measure the inherent difficulty of tasks (problems) c) What is randomness and how can it be useful? d) What is nondeterminism and what role does it play in CS? e) How to represent infinite objects by finite automata and grammars?</td>
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<tr>
<td>Objective</td>
<td>Learning the basic concepts of computer science along their historical development</td>
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<tr>
<td>252-0061-00L</td>
<td>Systems Programming and Computer Architecture</td>
<td>O</td>
<td>7</td>
<td>4V+2U</td>
<td>A. Klimovic, T. Roscoe</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to systems programming. C and assembly language, floating point arithmetic, basic translation of C into assembler, compiler optimizations, manual optimizations. How hardware features like superscalar architecture, exceptions and interrupts, caches, virtual memory, multicore processors, devices, and memory systems function and affect correctness, performance, and optimization.</td>
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</tr>
</tbody>
</table>
Objective

The course objectives are for students to:

1. Develop a deep understanding of, and intuition about, the execution of all the layers (compiler, runtime, OS, etc.) between programs in high-level languages and the underlying hardware: the impact of compiler decisions, the role of the operating system, the effects of hardware on code performance and scalability, etc.

2. Be able to write correct, efficient programs on modern hardware, not only in C but high-level languages as well.

3. Understand Systems Programming as a complement to other disciplines within Computer Science and other forms of software development.

Content

This course provides an overview of "computers" as a platform for the execution of (compiled) computer programs. This course provides a programmer's view of how computer systems execute programs, store information, and communicate. The course introduces the major computer architecture structures that have direct influence on the execution of programs (processors with registers, caches, other levels of the memory hierarchy, supervisor/kernel mode, and I/O structures) and covers implementation and representation issues only to the extend that they are necessary to understand the structure and operation of a computer system.

The course attempts to expose students to the practical issues that affect performance, portability, security, robustness, and extensibility. This course provides a foundation for subsequent courses on operating systems, networks, compilers and many other courses that require an understanding of the system-level issues. Topics covered include: machine-level code and its generation by optimizing compilers, address translation, input and output, trap/event handlers, performance evaluation and optimization (with a focus on the practical aspects of data collection and analysis).

Lecture notes

- C programming
- Integers
- Pointers and dynamic memory allocation
- Basic computer architecture
- Compiling C control flow and data structures
- Code vulnerabilities
- Implementing memory allocation
- Linking
- Floating point
- Optimizing compilers
- Architecture and optimization
- Caches
- Exceptions
- Virtual memory
- Multicore
- Devices

Literature

The course is based in part on "Computer Systems: A Programmer's Perspective" (3rd Edition) by R. Bryant and D. O'Hallaron, with additional material.
1. Computing with Matrices and Vectors
1.1 Fundamentals
1.2 Software and Libraries
1.4 Computational Effort
1.5 Machine Arithmetic and Consequences

2. Direct Methods for (Square) Linear Systems of Equations
2.1 Introduction: Linear Systems of Equations
2.3 Gaussian Elimination
2.6 Exploiting Structure when Solving Linear Systems
2.7 Sparse Linear Systems

3. Direct Methods for Linear Least Squares Problems
3.1 Least Squares Solution Concepts
3.2 Normal Equation Methods
3.3 Orthogonal Transformation Methods
3.3.1 Transformation Idea
3.3.2 Orthogonal/Unitary Matrices
3.3.3 QR-Decomposition
3.3.4 QR-Based Solver for Linear Least Squares Problems
3.4 Singular Value Decomposition

4. Filtering Algorithms
4.1 Filters and Convolutions
4.2 Discrete Fourier Transform (DFT)
4.3 Fast Fourier Transform (FFT)

5. Machine Learning of One-Dimensional Data
(Data Interpolation and Data Fitting in 1D)
5.1 Abstract Interpolation (AI)
5.2 Global Polynomial Interpolation

6. Iterative Methods for Non-Linear Systems of Equations
6.1 Introduction
6.2 Iterative Methods
6.3 Fixed-Point Iterations
6.4 Finding Zeros of Scalar Functions
6.5 Newton's Method in \( \mathbb{R}^n \)
6.6 Quasi-Newton Method

Lecture notes
Lecture materials (PDF documents and codes) will be made available to the participants through the course web page and online repositories. Access information will be communicated in the beginning of the course.

Literature
M. Hanke-Bourgeois "Grundlagen der Numerischen Mathematik und des wissenschaftlichen Rechnens", BG Teubner, 2002
P. Deuflhard and A. Hohmann, "Numerische Mathematik I", DeGruyter, 2002

Prerequisites / notice
The course will be accompanied by programming exercises in C++ relying on the template library EIGEN. Familiarity with C++, object oriented and generic programming is an advantage. Participants of the course are expected to learn C++ by themselves, in case they do not know it already.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Theories assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Problem-solving assessed
Project Management fostered

Core Courses

Major: Information and Data Processing

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>252-0206-00L</td>
<td>Visual Computing</td>
<td>O</td>
<td>8</td>
<td>4V+3U</td>
<td>M. Gross, M. Pollefeys</td>
</tr>
</tbody>
</table>

Abstract
This course acquaints students with core knowledge in computer graphics, image processing, multimedia and computer vision. Topics include: Graphics pipeline, perception and camera models, transformation, shading, global illumination, texturing, sampling, filtering, image representations, image and video compression, edge detection and optical flow.

Objective
This course provides an in-depth introduction to the core concepts of computer graphics, image processing, multimedia and computer vision. The course forms a basis for the specialization track Visual Computing of the CS master program at ETH.

Content
Course topics will include: Graphics pipeline, perception and color models, camera models, transformations and projection, projections, lighting, shading, global illumination, texturing, sampling theorem, Fourier transforms, image representations, convolution, linear filtering, diffusion, nonlinear filtering, edge detection, optical flow, image and video compression.

In theoretical and practical homework assignments students will learn to apply and implement the presented concepts and algorithms.

Lecture notes
A scriptum will be handed out for a part of the course. Copies of the slides will be available for download. We will also provide a detailed list of references and textbooks.

Literature
The course provides an introduction to the field of human-computer interaction, emphasizing the central role of the user in system design. Through detailed case studies, students will be introduced to different methods used to analyze the user experience and shown how these can inform the design of new interfaces, systems, and technologies.

**Objective**
The goal of the course is that students should understand the principles of user-centred design and be able to apply these in practice. As well as understand the basic notions of Computational Design in a HCI context.

**Content**
The course will introduce students to several methods of analyzing the user experience, showing how these can be used at different stages of system development from requirements analysis through to usability testing.

Students will get experience of designing and carrying out user studies as well as analysing results. The course will also cover the basic principles of interaction design. Practical exercises related to touch and gesture-based interaction will be used to reinforce the concepts introduced in the lecture. To get students to further think beyond traditional system design, we will discuss issues related to ambient information and awareness.

### Major: Theoretical Computer Science

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<tr>
<td>252-0209-00L</td>
<td>Algorithms, Probability, and Computing</td>
<td>O</td>
<td>8 credits</td>
<td>4V+2U+1A</td>
<td>B. Gärtner, R. Kynig, A. Steger, D. Steurer</td>
</tr>
</tbody>
</table>

**Abstract**
Advanced design and analysis methods for algorithms and data structures: Randomized Search Trees, Point Location, Minimum Cut, Linear Programming, Randomized Algebraic Algorithms (matchings), Probabilistically Checkable Proofs (introduction).

**Objective**
Studying and understanding of fundamental advanced concepts in algorithms, data structures and complexity theory.

**Lecture notes**
Will be handed out.

**Literature**
- Introduction to Algorithms by T. H. Cormen, C. E. Leiserson, R. L. Rivest;
- Randomized Algorithms by R. Motwani und P. Raghavan;

### Major: Systems and Software Engineering

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<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>252-0210-00L</td>
<td>Compiler Design</td>
<td>O</td>
<td>8 credits</td>
<td>4V+3U</td>
<td>Z. Su</td>
</tr>
</tbody>
</table>

**Abstract**
This course uses compilers as examples to expose students to modern software development techniques. Tentative topics include: compiler organization, lexical analysis, top-down and bottom-up parsing, symbol tables, semantic analysis, code generation, local and global optimization, register allocation, automatic memory management.

**Objective**
Learn principles of compiler design; gain practical experience designing and implementing a medium-scale software system.

**Prerequisites / notice**
- Prerequisites: Muchnick, Advanced Compiler Design and Implementation, Morgan Kaufmann Publishers, 1997
- Prior exposure to modern techniques for program construction, knowledge of at least one processor architecture at the assembly language level.

**Competencies**
- Subject-specific Competencies: Concepts and Theories assessed, Techniques and Technologies assessed
- Method-specific Competencies: Analytical Competencies fostered, Decision-making fostered, Media and Digital Technologies fostered, Problem-solving fostered, Project Management fostered
- Social Competencies: Communication fostered, Cooperation and Teamwork fostered
- Personal Competencies: Adaptability and Flexibility fostered, Creative Thinking fostered, Critical Thinking fostered, Integrity and Work Ethics fostered, Self-awareness and Self-reflection fostered, Self-direction and Self-management fostered

252-0217-00L

**Abstract**
This course is about real computer systems, and the principles on which they are designed and built. We cover both modern OSes and the large-scale distributed systems that power today's online services. We illustrate the ideas with real-world examples, but emphasize common theoretical results, practical tradeoffs, and design principles that apply across many different scales and technologies.

**Objective**
The objective of the course is for students to understand the theoretical principles, practical considerations, performance tradeoffs, and engineering techniques on which the software underpinning almost all modern computer systems is based, ranging from single embedded systems-on-chip in mobile phones to large-scale geo-replicated groups of datacenters.

By the end of the course, students should be able to reason about highly complex, real, operational software systems, applying concepts such as hierarchy, modularity, consistency, durability, availability, fault-tolerance, and replication.
This course subsumes the topics of both “operating systems” and “distributed systems” into a single coherent picture (reflecting the reality that these disciplines are highly converged). The focus is on system software: the foundations of modern computer systems from mobile phones to the large-scale geo-replicated data centers on which Internet companies like Amazon, Facebook, Google, and Microsoft are based.

We will cover a range of topics, such as: scheduling, network protocol stacks, multiplexing and demultiplexing, operating system structure, inter-process communication, memory management, file systems, naming, dataflow, data storage, persistence, and durability, computer systems performance, remove procedure call, consensus and agreement, fault tolerance, physical and logical clocks, virtualization, and blockchains.

The format of the course is a set of about 25 topics, each covered in a lecture. A script will be published online ahead of each lecture, and the latter will consist of an interactive elaboration of the material in the script. There is no book for the course, but we will refer to books and research papers throughout to provide additional background and explanation.

We will assume knowledge of the “Systems Programming” and “Computer Networks” courses (or equivalent), and their prerequisites, and build upon them.

### Electives

Students may also choose courses from the Master’s program in Computer Science. It is their responsibility to make sure that they meet the requirements and conditions for these courses.

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<tr>
<th>Number</th>
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<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>151-0317-00L</td>
<td>Visualization, Simulation and Interaction - Virtual Reality II</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>A. Kunz</td>
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<tr>
<td>227-0085-59L</td>
<td>Hands-On Deep Learning</td>
<td>W</td>
<td>2</td>
<td>2P</td>
<td>R. Wattenhofer</td>
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<tr>
<td>227-0124-00L</td>
<td>Embedded Systems</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>M. Magno</td>
</tr>
</tbody>
</table>

**Abstract**

This lecture provides deeper knowledge on the possible applications of virtual reality, its basic technology, and future research fields. The goal is to provide a strong knowledge on Virtual Reality for a possible future use in business processes.

This lab introduces deep learning through the PyTorch framework in a series of hands-on exercises, exploring topics in computer vision, natural language processing, audio processing, graph neural networks, and representation learning. This P&AS introduces deep learning through the PyTorch framework in a series of hands-on examples, exploring topics in computer vision, natural language processing, graph neural networks, and representation learning.

With the objective to expose students to both common and cutting-edge neural architectures and to build intuition about their inner working by the means of examples.

Students learn about various network structures as building blocks and use them to solve worked examples and course challenges. After attending this course, students will be familiar with multi-layer perceptrons, convolutional neural networks, recurrent neural networks, transformer encoders, graph convolutional/isomorphism/attention networks, and autoencoders.

*Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.*

For information about the lab, please visit [https://disco.ethz.ch/courses/hs24/hodl/](https://disco.ethz.ch/courses/hs24/hodl/)

Python Notebooks will be distributed to students before every session.
An embedded system is a combination of hardware and software, either fixed in function or programmable, that is designed for a specific application scenario or for a specific task within a larger system. They are part of industrial machines such as agricultural and manufacturing equipment, automotive systems, medical equipment, household appliances, sensor networks, and the Internet of Things.

Objective

Understanding the specific requirements and problems that arise in embedded system applications.

Understanding the hardware structure of a microcontroller and an embedded system; memory architecture and memory map, internal and external peripherals, low-power and low-energy design as well as instruction sets and computational accelerators.

Understanding the firmware structure of a microcontroller and an embedded system; low-level instruction set, hardware-software interfaces, communication between components, embedded real-time operating systems, real-time scheduling, shared resources, low-power and low-energy programming as well as computational accelerators.

Using formal models and methods for designing and optimizing embedded systems.

Gaining experience with practical applications of the C programming language, embedded real-time operating systems, and debug functionalities of the associated design environment to design, implement, and verify embedded firmware.

Through project-based activities, students will gain substantial experience in applying the C programming language in the context of embedded systems. Projects will involve developing and implementing firmware, utilizing embedded real-time operating systems, and exploring the debugging functionalities within design environments. This hands-on approach aims to bridge the gap between theoretical knowledge and practical application, allowing students to experience the full lifecycle of embedded system development from design to implementation and verification.

Content

This lecture focuses on the design of embedded systems using formal models and methods.

Besides the theoretical lecture, the course contains laboratory sessions where students transfer the learned theoretical aspects into praxis by programming a microcontroller and interfacing it with sensors and actuators. Students will be exposed to a commercial microcontroller, and the development board extend with a custom-designed embedded systems educational platform.

Specifically, the following topics will be covered in the course: hardware and software structures of embedded systems, low-level instruction set, memory architecture and memory map, peripherals, hardware-software interfaces, communication between components, firmware design methodologies, firmware design using the C programming language, embedded real-time operating systems, real-time scheduling, shared resources, low-power, and low-energy designs well as computational accelerators.

Lecture notes

Lecture material, publications, exercise sheets, and laboratory documentation will be available on the course’s Moodle page.

Literature


Prerequisites / notice

Prerequisites: C programming, circuit theory, digital logic, binary number representations.

Recommended: basic knowledge of assembly programming and computer architecture.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Social Competencies

Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies

Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Autumn Semester 2024
The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.

Objective

Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monoculars of physics, math, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

Content

This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.
Abstract
Contemporary web development utilizes a technology stack that spans from back-ends to front-ends, and includes virtual server environments, document databases, back-end and front-end programming, and UI/UX design. The depth of this stack fosters separation of concern and reuse, but also amounts to a steep learning curve.

Objective
This course introduces both theoretical and applied aspects of web engineering. It covers:
- DOM, CSS, Typescript
- Frontend and backend frameworks
- Client-server communication
- Interaction design, visualization and narrative storytelling
- Security for in the context of web engineering
- Desktop applications using web development techniques

Content
The course has two main objectives:
- Obtain an end-to-end (both, theoretical and practical) understanding of the foundations of web engineering.
- Be able to apply these techniques in practice.

While the lecture will provide the theoretical foundations for the various aspects of web engineering, the students will apply those techniques in project work that will span over the whole semester - involving different aspects of web engineering.

Lecture notes
The lecture slides are available for download on the course page.

Prerequisites / notice
To contact us please us the following email: web-foundations@ethz.ch

Students should be familiar with the basics of a programming language (C, C++, Python, Java, Javascript, Typescript). The course will not teach basics of programming.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Self-awareness and Self-reflection

402-0209-00L Quantum Physics for Non-Physicists

Abstract
This is an introduction to the physics of quantum mechanics following an information-theoretical approach. We start from the basic postulates, study the behaviour of quantum systems from a single spin to entangled particles in space, and connect the learnings to groundbreaking experiments from the past and the present. This course is well-suited for students with little background in physics.

Objective
This course teaches the basics of quantum physics, and complements courses in quantum computation and information theory. Students are equipped with tools to tackle complex quantum mechanical problems and foundational questions. The course covers approximately the same content as QM1, but from an information-driven perspective.

Content
Quantum formalism, from qubits to particles in space; Time and dynamics for quantum systems; Problems in 1D; Uncertainty and open systems; Spin; Problems in 3D; Non-locality and foundational aspects of quantum theory

Lecture notes
Lecture notes will be provided.

Literature
Quantum Processes, Systems, and Information, by Benjamin Schumacher and Michael Westmoreland, available at https://www.cambridge.org/core/books/quantum-processes-systems-and-information/4E459E64E1EE7121CA2321435FAECC8A

Prerequisites / notice
This course is aimed at non-physicists, and in particular at students with a background in computer science, mathematics or engineering. Basic linear algebra and calculus knowledge is required (equivalent to first-year courses). Physics knowledge is not required. Physicists and students from a different background than outlined above are welcome at their own risk.

Note that while we follow an information-theoretical approach, this is not a course on quantum information theory or quantum computing. It therefore complements those courses offered at ETH Zurich.

This course can be taken in parallel to Quantum Information Processing I & II.
In this seminar course, we will cover fundamental and cutting-edge research papers in computer architecture. The course will consist of multiple components that are aimed at improving students' technical skills in computer architecture, critical thinking and analysis on computer architecture concepts, as well as technical presentation of concepts and papers in both spoken and written forms.

The main objective is to learn how to rigorously analyze and present papers and ideas on computer architecture. We will have rigorous presentation and discussion of selected papers during lectures and a written report delivered by each student at the end of the semester. This course is for those interested in computer architecture. Registered students are expected to attend every lecture, participate in the discussion, and create a synthesis report at the end of the course.

The core ideas behind the mathematics of dependency parsing are explored. Dependency parsing is a fundamental task in natural language processing. This seminar explores a variety of algorithms for efficient dependency parsing and their derivation in a unified algebraic framework.

The course is an introduction to research in software engineering, based on reading and presenting high quality research papers in the field. The instructor may choose a variety of topics or one topic that is explored through several papers.

The main goals of this seminar are 1) learning how to read and understand a recent research paper in computer science; and 2) learning how to present a technical topic in computer science to an audience of peers.

The technical content of this course falls into the general area of software engineering but will vary from semester to semester.
Participants learn how to systematically approach an IT problem in practice. They work in groups of three to solve a case from a

Objective
The seminar covers core concepts and ideas in the general area of machine learning systems, ranging from distributed and federated
learning systems, DevOps systems for ML, life cycle and data management systems for ML, etc.

Content
The seminar will consist of student presentations based on a list of papers that will be provided at the beginning of the course. Presentations will be done in teams. Presentations will be arranged in slots of 30 minutes talk plus 15 minutes questions. Grades will be assigned based on quality of the presentation, coverage of the topic including material not in the original papers, participation during the seminar, and ability to understand, present, and criticize the underlying technology.


case. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Objective
Participants understand the different viewpoints for IT-decisions in practice, including technical and business aspects, can effectively analyze IT questions from the different viewpoints and facilitate decision making.

Content
Participants learn how to systematically approach an IT problem in practice. They work in groups of three to solve a case from a participating company in depth, studying provided materials, searching for additional information, analyzing all in depth, interviewing members from the company or discussing findings with them to obtain further insights, and presenting and defending their conclusion to other teams, and obtain an overview of learnings from the cases other teams worked on.

Lecture notes
Methodologies to analyze the cases and create final presentations. Short overview of each case.

Prerequisites / notice
Successful completion of Lecture "Information Technology in Practice".

Competencies

Method-specific Competencies
Analytical Competencies fostered
Media and Digital Technologies fostered
Problem-solving fostered

Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

252-4811-00L Machine Learning Seminar

The seminar familiarizes students with advanced and recent ideas in machine learning. Original articles have to be presented, contextualized, and critically reviewed. The students will learn how to structure a scientific presentation in English which covers the key ideas of a scientific paper.

Content
The seminar will cover a number of recent papers which have emerged as important contributions in the machine learning research community. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications.

Literature
The papers will be presented and allocated in the first session of the seminar.

252-3400-00L Seminar on Machine Learning Systems

The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
This seminar covers core concepts and ideas in the general area of machine learning systems, ranging from distributed and federated learning systems, DevOps systems for ML, life cycle and data management systems for ML, etc.

Objective
The seminar covers core concepts and ideas in the general area of machine learning systems, ranging from distributed and federated learning systems, DevOps systems for ML, life cycle and data management systems for MLs, etc. The focus will be to cover fundamental ideas on ML systems, with an emphasis on software systems and platforms.

Content
The seminar will consist of student presentations based on a list of papers that will be provided at the beginning of the course. Presentations will be done in teams. Presentations will be arranged in slots of 30 minutes talk plus 15 minutes questions. Grades will be assigned based on quality of the presentation, coverage of the topic including material not in the original papers, participation during the seminar, and ability to understand, present, and criticize the underlying technology.

252-3811-00L Case Studies from Practice Seminar

The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
Participants will learn how to analyze and solve IT problems in practice in a systematic way, present findings to decision bodies, and defend their conclusions.

Objective
Participants understand the different viewpoints for IT-decisions in practice, including technical and business aspects, can effectively analyze IT questions from the different viewpoints and facilitate decision making.

Content
Participants learn how to systematically approach an IT problem in practice. They work in groups of three to solve a case from a participating company in depth, studying provided materials, searching for additional information, analyzing all in depth, interviewing members from the company or discussing findings with them to obtain further insights, and presenting and defending their conclusion to company representatives, the lecturer, and all other participants of the seminar. Participants also learn how to challenge presentations from other teams, and obtain an overview of learnings from the cases other teams worked on.

Lecture notes
Methodologies to analyze the cases and create final presentations. Short overview of each case.

Prerequisites / notice
Successful completion of Lecture "Information Technology in Practice".

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Decision-making assessed
Problem-solving assessed
Project Management assessed

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Customer Orientation assessed
Leadership and Responsibility assessed
Self-presentation and Social Influence assessed
Negotiation assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered
Part 1 - Discovering a modern parallel computing ecosystem

This seminar introduces students to research and innovation in the area of game technology. The objectives of this seminar are twofold: (1) to learn about recent developments in the area of game technology at the intersection of computer graphics, computer vision, human-computer interaction, virtual and augmented reality, natural language processing, and machine learning and (2) to improve the presentation and critical analysis skills.

Content

The Seminar on Game Technology offers an in-depth exploration of video games as a significant cultural asset and a major force in the global market. Over the past 30 years, the video game industry has evolved from relative obscurity into a multibillion-dollar international phenomenon. This growth has been driven by the industry’s demand for a wide range of interdisciplinary skills and its role in advancing personal computer technology, including innovations such as sound cards, graphics cards, 3D graphic accelerators, and physics cards.

Participants in this seminar will delve into various computer science fields integral to video game development. Topics include computer graphics for visual presentation, artificial intelligence, human-computer interaction in traditional games, and cutting-edge areas such as computer vision, augmented and virtual reality, and natural language processing in modern gaming concepts.

The seminar aims to introduce students to the latest research and innovations in game technology. It also provides an opportunity to explore the foundational algorithms that underpin classic games still enjoyed today. Additionally, the seminar will cover emerging topics that, while currently peripheral to game technology, hold the potential to inspire new and creative gaming concepts in the near future.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Media and Digital Technologies

Social Competencies

- Communication
- Self-presentation and Social Influence

Personal Competencies

- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Adaptability and Flexibility

- Fostered

Critical Thinking

- Fostered

Integrity and Work Ethics

- Fostered

Self-awareness and Self-reflection

- Fostered

Self-direction and Self-management

- Fostered

Minor Courses

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<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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Abstract

This course aims to cover state-of-the-art methods in modern parallel computing on Graphics Processing Unit (GPU), supercomputing and code development with applications to natural sciences and engineering.

Objective

When quantitative assessment of physical processes governing natural and engineered systems relies on numerically solving differential equations, fast and accurate solutions require performant algorithms leveraging parallel hardware. The goal of this course is to offer a practical approach to solve systems of differential equations in parallel on GPUs using the Julia language. Julia combines high-level language conciseness to low-level language performance which enables efficient code development.

The course will be taught in a hands-on fashion, putting emphasis on you writing code and completing exercises; lecturing will be kept at a minimum. In a final project you will solve a solid mechanics or fluid dynamics problem of your interest, such as the shallow water equation, the shallow ice equation, acoustic wave propagation, nonlinear diffusion, viscous flow, elastic deformation, viscous or elastic poromechanics, frictional heating, and more. Your Julia GPU application will be hosted on a git-platform and implement modern software development practices.

Content

Part 1 - Discovering a modern parallel computing ecosystem
- Learn the basics of the Julia language;
- Learn how to solve diffusion, wave propagation and advection processes;
- Implement efficient iterative algorithms;
- Get started with software development tools: git, version control.

Part 2 - Developing your own parallel algorithms on GPUs
- Implement wave propagation and porous convection;
- Apply spatial and temporal discretisation (finite-differences, various time-stepper);
- Understand the practical challenges of parallel computing: GPUs, multi-core CPUs;
- Learn about main simulation performance limiters;
- Implement software development tooling: unit tests, continuous integration (CI).

Part 3 - Multi-GPU computing projects
- Understand the practical challenges of distributed parallel computing on multi-GPUs;
- Implement shared (on CPU and GPU) and distributed memory parallelisation (multi-GPUs/CPUs);
- Automatise the software tooling using remote runners.

Final projects
- Apply your new skills in a final project;
- Implement advanced physical processes (solid and fluid dynamic - elastic and viscous solutions).

Lecture notes
Digital lecture notes, interactive Julia notebooks, online material.

Literature
Links to relevant literature will be provided during classes.

Prerequisites / notice
Completed BSc studies. Interest in and basic knowledge of numerics, applied mathematics, and physics/engineering sciences. Basic programming skills (in e.g. Matlab, Python, Julia); advanced programming skills are a plus.
## Competencies

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<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
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<td>Self-awareness and Self-reflection</td>
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<td>Project Management</td>
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<td>Self-direction and Self-management</td>
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## Abstract

The course is about digital innovation towards a circular economy in the built environment. How can we bring together two worlds that are often too distinct: low-impact construction and digital innovation? Bringing digital tools already used in other sectors into the construction sector, students will learn about circular construction (e.g., reuse of materials) through hands-on learning practices.

## Objective

In the fall semester 2024 we will focus on applying artificial intelligence (AI) and extended reality (XR) to the circular design workflow and.

The course will be taught at the Kunsthalle Zurich as part of an exhibition.

By the end of this course, students will be able to use augmented computational design enabling circular construction, with a view to environmental implications. They will be able to assess the challenges and opportunities of low-carbon, circular construction and evaluate possible solutions using digital technologies to enable a circular built environment (more specifically, with reused building materials). To achieve this, they need to be able to do the following:

1. Apply circular principles using recovered building materials.
2. Compare different digital technologies applied in circular construction (e.g., LiDAR scanning, drone imagery, photogrammetry, computational design, AI, computer vision, XR, LCA tools etc.).
3. Understand the potential and limitations of AI for circular construction, e.g. use machine learning to detect and digitize materials (computer vision) or to support creativity in the early design phases of circular construction (generative AI).
4. Communicate the importance and urgency of circular construction.
5. Assess the environmental impact implications of their design and technology decisions through a preliminary Life Cycle Assessment (LCA).

## Content

Students will receive an introduction to circular principles by experts from the building industry and visit of (de-)construction sites where circular construction is exemplified. They will explore how to use digital technologies such as LiDAR scanning, photogrammetry, scan-to-BIM, computer vision, computational design, digital fabrication, blockchain technology and learn about the design implications using reclaimed building materials. This course is meant as an overview/introduction of many digital technologies that could be useful for circularity and gives the tools to students to further study the technologies they are most interested in on their own. Creativity in writing, filmmaking, design, construction, etc. is expected from the students.

This course will give the tools to students to learn more on LCA if they wish to deepen their knowledge further.

## Lecture notes

Language: English

Courses are on Tuesday afternoons in Kunsthalle or a room at ETH, but also require out-of-the-semester work and significant homework and site visits outside of class hours.

## Literature


## Prerequisites / notice

Cancelled due to Digitalisation and Construction. Flexibility: This is a hands-on course, where students explore digital technologies and opportunities/challenges of reuse. Flexibility (e.g. adapting to unforeseen circumstances), responsibility (e.g. arriving on time for safety briefing), and spontaneity (e.g. finding innovative solutions) is expected from the students to adapt to the contingencies from demolition and construction sites with reused materials. The course is mandatory for MIBS students. If you are a first year MIBS student, please do not apply, you are automatically accepted. All other students from other departments should apply. Please only register for the course if you really intend to participate on all course dates (see course catalog). Please only register for the course if you are willing to send us a letter of motivation and really intend to participate; otherwise, you will deprive someone else of a place.

To register:
1. Enroll before 05.09.2024.
2. Send a short letter of motivation (max. 300 words) and a 1-page CV to cea-course@ibi.baug.ethz.ch by 05.09.2024.

Collaborators: Kunsthalle Zürich, ETH AI Center, Design++
Control Systems I

151-0575-00L

Signals and Systems

Abstract
Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to signals and produce other signals. In this course, we explore how signals can be represented and manipulated, and their effects on systems. We further explore how we can discover basic system properties by exciting a system with various types of signals.

Objective

Content
Lecture notes available on course website.

Prerequisites / notice
Control Systems I is helpful but not required.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

151-0591-00L

Control Systems I

Abstract

Objective
The course addresses dynamic control systems, i.e., systems that (i) evolve over time, and (ii) have control inputs and measured outputs. The main objective is to learn how to design the control inputs in such a way that the measured outputs have some desirable properties. For example, for an advanced driver assistance system, how to control acceleration so that the speed remains constant, and how to control the steering angle so that the car remains in the center of the lane.

In order to pursue this objective, the course is organized into three main parts:

1) Modeling: learn how to represent a dynamic control system in such a way that it can be treated effectively using computational and mathematical tools. This will include learning how to use computer tools like Matlab to simulate dynamic control systems.

2) Analysis: understand the basic characteristics of a system, such as its (internal and external) stability, performance, and robustness, and how the input affects the output. We will also learn to analyze systems obtained as interconnections (e.g., feedback) of two or more other systems. In particular, we will focus on tools that allow to understand how a system will behave under feedback control (i.e., closed-loop behavior), based only on its open-loop behavior.

3) Synthesis: the last part of the course will concentrate on how to design feedback control laws, in order to change the behavior of the system in a desirable way.

In this course, we will concentrate on systems that can be modeled by Ordinary Differential Equations (ODEs), and that satisfy certain other technical conditions, such as linearity and time-invariance. In addition, we will focus on systems with a Single Input and a Single Output (SISO).

This will allow us to use "classical control" tools that are very powerful and easy to use (i.e., mostly graphical), and which are really laying the foundation of any followup work on more challenging control problems.

In addition to paper-and-pencil techniques, we will leverage modern computational tools for control design, such as Matlab.

Lecture slides and additional material will be posted online.

There is no required textbook.

A nice introductory book on feedback control, available online for free, is:

Feedback Systems: An Introduction for Scientists and Engineers
Karl J. Astrom and Richard M. Murray

http://www.cds.caltech.edu/~murray/amwiki/index.php/First_Edition

Prerequisites / notice
Basic knowledge of (complex) analysis and linear algebra. Familiarity with Matlab is recommended.

For students in the bachelor's degree programme in mechanical engineering:
Precondition for this course unit are passed first year examination blocks A and B.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

Stochastic Methods for Engineers and Natural

151-0709-00L

D. W. Meyer-Massetti

W 4 credits

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed
Abstract
The course provides an introduction into stochastic methods that are applicable for the description, treatment, and modeling of systems that are subject to uncertainties or that respond to parameter changes in a chaotic manner. Corresponding systems may arise in fluid dynamics, structural mechanics, biology, electrical engineering as well as other areas.

Objective
By the end of the course you will be familiar with a range of mathematical/statistical tools that enable a quantitative treatment of problems that involve uncertainties.

Content
- Probability theory, single and multiple random variables, mappings of random variables
- Estimation of statistical moments and probability densities based on data
- Stochastic differential equations, Ito calculus, PDF evolution equations
- Monte Carlo integration with importance and stratified sampling
- Markov-chain Monte Carlo sampling
- Control-variate and multi-level Monte Carlo estimation
- Kalman filters (classical and ensemble-based)
- Statistical tests for means and goodness-of-fit

Lecture notes
Detailed lecture notes will be provided.

Literature
Some textbooks related to the material covered in the course:

Competencies
Subject-specific Competencies

Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed

Decision-making assessed

Media and Digital Technologies assessed

Problem-solving assessed

Personal Competencies

Creative Thinking assessed

Critical Thinking assessed

Integrity and Work Ethics assessed

Self-direction and Self-management assessed

227-0075-00L Electrical Engineering I W 4 credits 2V+2U J. Leuthold
Abstract
Basic course in electrical engineering with the following topics: Concepts of voltage and currents; Analyses of dc and ac networks; Series and parallel resistive circuits, circuits including capacitors and inductors; Kirchhoff's laws and other network theorems;Transient responses; Basics of electrical and magnetic fields;

Objective
Understanding of the basic concepts in electrical engineering with focus on network theory. The successful student knows the basic components of electrical circuits and the network theorems after attending the course.

Content
Diese Vorlesung vermittelt Grundlagenkenntnisse im Fachgebiet Elektrotechnik. Ausgehend von den grundlegenden Konzepten der Spannung und des Stroms wird die Analyse von Netzwerken bei Gleich- und Wechselstrom behandelt. Dabie werden folgende Themen behandelt:

Kapitel 1 Das elektrostatische Feld
Kapitel 2 Das stationäre elektrische Strömungsfeld
Kapitel 3 Einfache elektrische Netzwerke
Kapitel 4 Halbleiterbauelemente (Dioden, der Transistor)
Kapitel 5 Das stationäre Magnetfeld
Kapitel 6 Das zeitlich veränderliche elektromagnetische Feld
Kapitel 7 Der Übergang zu den zeitabhängigen Strom- und Spannungsformen
Kapitel 8 Wechselspannung und Wechselstrom

Lecture notes
Die Vorlesungssfolien werden auf Moodle bereitgestellt.

Literature
Als ausführliches Skript wird das Buch "Manfred Albach. Elektrotechnik, Person Verlag, Ausgabe vom 1.8.2011" empfohlen.

Prerequisites / notice
Für students in the bachelor's degree programme in mechanical engineering:
Precondition for this course unit are passed first year examination blocks A and B.

227-0116-00L VLSI 1: HDL Based Design for FPGAs W 6 credits 5G F. K. Gürkaynak
Abstract
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Objective
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Aneucau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Lecture notes
Textbook and all further documents in English.

Literature

Prerequisites / notice
Prerequisites:
Basics of digital circuits.

Examination:
In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

227-0731-00L Power Market I - Portfolio and Risk Management W 6 credits 4G D. Reichelt, G. A. Koeppel

Abstract
Portfolio and risk management in the electrical power business, Pan-European power market and trading, futures and forward contracts, hedging, options and derivatives, performance indicators for the risk management, modelling of physical assets, cross-border trading, ancillary services, balancing power market, Swiss market model.

Objective

Content
1. Pan-European power market and trading
   1.1. Power trading
   1.2. Development of the European power markets
   1.3. Energy economics
   1.4. Spot and OTC trading
   1.5. European energy exchange EEX

2. Market model
   2.1. Market place and organisation
   2.2. Balance groups / balancing energy
   2.3. Ancillary services
   2.4. Market for ancillary services
   2.5. Cross-border trading
   2.6. Capacity auctions

3. Portfolio and Risk management
   3.1. Portfolio management 1 (introduction)
   3.2. Forward and futures contracts
   3.3. Risk management 1 (m2m, VaR, hpfc, volatility, cVaR)
   3.4. Risk management 2 (PaR)
   3.5. Contract valuation (HPFC)
   3.6. Portfolio management 2

   2.8. Risk Management 3 (enterprise wide)

4. Energy & Finance I
   4.1. Options 1 basics
   4.2. Options 2 hedging with options
   4.3. Introduction to derivatives (swaps, cap, floor, collar)
   4.4. Financial modelling of physical assets
   4.5. Trading and hydro power
   4.6. Incentive regulation

4.6. Incentive regulation

Lecture notes
Handouts of the lecture

Prerequisites / notice
Case studies and ML exercise for Power Market can give bonus points for the exam. Guest speakers for specific topics.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Method-specific Competencies
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered

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<td>227-2037-00L</td>
<td>Physical Modelling and Simulation</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>J. Smajic</td>
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</table>

**Abstract**

This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.

**Objective**

Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

**Content**

The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or chose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

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<td>Training for Programming Coaches</td>
<td>W</td>
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<td>1S</td>
<td>M. Dahinden, L. E. Fässler</td>
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**Abstract**

The “Training for Programming Coaches” course is designed to prepare students for the role of a teaching assistant in an introductory programming course. The focus is on developing constructive coaching skills, particularly in giving effective feedback and competently conducting project presentations.

**Objective**

In this course, teaching assistants (TAs) will learn...

1. Understanding the role of teaching assistants:
   - recognising the responsibilities and expectations of teaching assistants.

2. Develop communication skills:
   - Using effective communication techniques.
   - Empathic listening and appropriate response to students' questions and concerns.

3. Giving feedback:
   - Understanding the principles of effective feedback.
   - Using methods to formulate feedback that is both developmental and motivating.
   - Avoiding common mistakes and miscommunications when giving feedback.

4. Accepting project presentations:
   - Develop criteria for evaluating and assessing project presentations.
   - Apply objective assessment techniques to ensure fairness and consistency.
   - Methods to support and develop students' presentation skills.

5. Conflict resolution:
   - recognising and addressing potential conflict situations between students and teaching assistants.
   - Developing strategies for de-escalation and conflict resolution.

6. Didactic skills:
   - Teaching basic didactic principles to support the learning process of students.
   - Designing learning experiences and using tools that promote student understanding.

**Competencies**

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<th>Subject-specific Competencies</th>
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**Abstract**

Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.
Objective

The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
1. broaden understanding of management principles and frameworks
2. advance insights into the sources of corporate and entrepreneurial success
3. develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and/or appreciate the challenges that entrepreneurs and managers deal with.

Content

The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. The theory sessions will be assessed via a multiple choice exam.

Lecture notes

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Self-presentation and Social Influence fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Self-direction and Self-management fostered

Abstract

This course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

Objective

The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.

Content

The exercise consists of delivering and submitting a "pitch" with a clear recommendation for one of the selected cases amongst those seen in Discovering Management, using your insights from Discovering Management, and an extra session on pitching.

Students have the option to either do this alone or in a group of two students.

Literature

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. Students following this course should also be enrolled for course 351-0778-00L, "Discovering Management".

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Self-presentation and Social Influence fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Self-direction and Self-management fostered

Abstract

The course introduces basic principles, problems and approaches of microeconomics. It describes economic decisions of households and firms, and their coordination through perfectly competitive markets.
### 363-0541-00L Economic Dynamics and Complexity

**Abstract**
What causes economic business cycles? How are limited resources, competition, and cooperation reflected in growth dynamics? To answer such questions, we combine macroeconomic models and methods of nonlinear dynamics. We study the role of bifurcations and control parameters for dynamic stability. Feedback cycles and coupled dynamics are reasons for limited predictability, instability and chaos.

**Objective**
Successful participant of the course is able to:
- understand the importance of different modeling approaches
- formalize and solve one- and two-dimensional nonlinear models
- identify critical conditions for stability and dynamic transitions
- analyze macroeconomic models of business cycles, supply and demand
- apply formal concepts to model economic growth and competition

**Content**
System theory sees the economy as a complex adaptive system.

- We start with a comparison of different modeling approaches, to highlight the problems and challenges of system modeling.
- The subsequent lectures then introduce different one- and two-dimensional nonlinear models with applications in economics, such as models of supply and demand, business cycles, growth and competition.
- Emphasis is on the formal analysis of these models using methods from applied mathematics and tools for solving coupled differential equations.

Weekly self-study tasks are used to apply the concepts introduced in the lectures.

**Lecture notes**
The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.

**Prerequisites / notice**
Students should be familiar with nonlinear differential equations and should have basic programming skills. All necessary details to solve nonlinear models will be provided in the course. The course will not build on mathematical proofs, optimization, statistics, efficient numerical computation and other specialized skills.

**Competencies**

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**Lecture notes**
Course material in e-learning environment https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php

**Literature**

**Prerequisites**
This course “Einführung in die Mikroökonomie” (363-1109-00L) is intended for Bachelor students and LE 363-0503-00 “Principles of Microeconomics” for Master students.

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### 363-1082-00L Enabling Entrepreneurship: From Science to Startup

**Objective**

Students should provide a brief overview (unto 1 page) of their business ideas that they would like to commercialise through the course. If they do not have an idea, they are not assessed.

**Content**

- apply formal concepts to model economic growth and competition
- analyze macroeconomic models of business cycles, supply and demand
- identify critical conditions for stability and dynamic transitions
- formalize and solve one- and two-dimensional nonlinear models
- understand the importance of different modeling approaches

**Lecture notes**
The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.

**Prerequisites**

- Students should be familiar with nonlinear differential equations and should have basic programming skills. All necessary details to solve nonlinear models will be provided in the course. The course will not build on mathematical proofs, optimization, statistics, efficient numerical computation and other specialized skills.

**Competencies**

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<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<td>Analytical Competencies</td>
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<td>Media and Digital Technologies</td>
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<td>Project Management</td>
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</tbody>
</table>

**Literature**


**Prerequisites**

- This course “Einführung in die Mikroökonomie” (363-1109-00L) is intended for Bachelor students and LE 363-0503-00 “Principles of Microeconomics” for Master students.

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required to provide a motivation letter stating why they would like to do this elective. If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

The total number of students will be limited to 50.

The students should submit the necessary information until 25 September 2024 and apply to Robin De Cock: Robin.DeCock@uantwerpen.be.

Abstract

This elective is relevant for students who have developed a technology and are keen to evaluate the steps in starting a startup. This is also relevant for students who would like to start a startup but do not have a technology, but are clear on a specific market and the impact they would like to create.

Objective

Students have technology competence or an idea that they would like to convert into a startup. They are now in the process of evaluating the steps necessary to do so. In summary:

1. Students want to become entrepreneurs.
2. The students can be from business or science & technology.
3. The course will enable the students to identify the relevance of their technology or idea from the market relevance perspective and thereby create a business case to take it to market.
4. The students will have exposure to investors and entrepreneurs (with a focus on ETH spin-offs) through the course, to gain insight to commercialise their idea.

Content

The students would cover the following topics, as they build their idea into a business case:

1. Technology excellence: this assumes that the student has achieved a certain degree of competence in the area of technology that he or she expects to bring to the market.
2. Market need and market relevance: The student would then be expected to identify the possible markets that may find the technology of relevance. Market relevance implies the process of identification of how relevant the market perceives the technology, and whether this can sustain over a longer period of time.
3. IP and IP strategy: Intellectual property, whether in the form of a patent or a trade secret, implies the secret ingredient that enables the student to achieve certain results that competitors are unable to copy. This enables the student (and subsequently the startup) to hold on to the market that they create with customers.
4. Team including future capabilities required: a startup requires multiple people with complementary capabilities. They also need to be motivated while at the same time protecting the interests of the startup.
5. Financials: There is a need of funding to achieve milestones. This includes funding for salaries and running of the company.
6. Investors and funding options: There are multiple funding options for a startup. They all come with different advantages and limitations. It's important for a startup to recognise its needs and find the investors that fit these needs and are best aligned with the vision of the founders.
7. Preparation of business case: The students will finally prepare the business case that can help them to articulate the link of the technology with the market need and its willingness to pay.
8. Legal overview, company forms and shareholders' agreements (including pitfalls)

The seminar includes talks from invited investors, entrepreneurs and legal experts regarding the importance of the various elements being covered in content, workshops and teamwork. There is a particular emphasis on market validation on each step of the journey, to ensure relevance.

Lecture notes

Since the course will revolve around the ideas of the students, the notes will be for the sole purpose of providing guidance to the students to help convert their technologies or ideas into business cases for the purpose of forming startups. Theoretical subject matter will be kept to a minimum and is not the focus of the course.

Literature

Book
Sethi, A. “From Science to Startup”
ISBN 978-3-319-30422-9

Prerequisites / notice

This course is relevant for those students who aspire to become entrepreneurs.

Students applying for this course are requested to submit a 1 page business idea or, in case they don't have a business idea, a brief motivation letter stating why they would like to do this course.

If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
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<td>Techniques and Technologies</td>
<td>Analytical Competencies</td>
<td>Cooperation and Teamwork</td>
<td>Creative Thinking</td>
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<td>Decision-making</td>
<td>Customer Orientation</td>
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<td>Decision-making</td>
<td>Media and Digital Technologies</td>
<td>Leadership and Responsibility</td>
<td>Integrity and Work Ethics</td>
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<td>Media and Digital Technologies</td>
<td>Problem-solving</td>
<td>Self-presentation and Social Influence</td>
<td>Self-awareness and Self-reflection</td>
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<tr>
<td>Problem-solving</td>
<td>Project Management</td>
<td>Sensitivity to Diversity</td>
<td>Self-direction and Self-management</td>
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<td>Project Management</td>
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<td>Negotiation</td>
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363-1163-00L Developing Digital Biomarkers
Particularly suitable for students with a technical background who are interested in healthcare.

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The course gives an introduction to digital biomarkers and provides students with the foundations to develop their own digital biomarkers. More specifically, the course will cover fundamental topics such as designing observational studies, collecting, and exploring data generated by consumer-centric devices, and applying analytical methods to predict health-related outcomes.

**Objective**

The widespread use of mobile technologies (e.g., wearable sensors, mobile applications, social media, and location-tracking technologies) has the potential to meet the health monitoring needs of the world’s aging population and the ever-growing number of chronic patients. However, this premise is based on the application of Machine Learning algorithms that allow us to use this data in many different ways. In this course we will analyze systematic ways to collect data, review the most relevant methods and applications in healthcare, discuss the main challenges they present and apply the newly gained knowledge in practical assignments.

The course has four core learning objectives. Students should:

- understand the anatomy of digital biomarkers
- understand the potential and applications of digital biomarkers
- be able to critically reflect and assess existing digital biomarkers
- be able to design and implement a digital biomarker

**Content**

The course will consist of four topic clusters that will allow the discussion of the most relevant digital biomarker applications in healthcare:

1) Digital Biomarkers: From biological to digital biomarkers. How are they motivated, defined and how can they be leveraged for monitoring? Prognostic vs. diagnostic vs. predictive biomarkers. Passive sensing vs. active sensing. Digital biomarker vs. Digital therapeutics.

2) Consumer-centric device data: Today, vast amount of physiological, environmental, and behavioral observations can be collected with consumer-centric devices. To derive clinical meaningful information from this data is, however, difficult. We will analyze strategies for extracting knowledge from those measurements.

3) Methodology: In the last decade, neural networks (also known as "deep learning") have helped push the boundaries of the state-of-the-art in a myriad of domains. They have also uncovered a number of different problems. We will discuss advantages and disadvantage as well as alternative methods for their application to digital biomarker data.

4) Applications: Digital biomarkers are still an emerging subfield, but given that longitudinal in digital biomarker data are arguably easy to acquire in large quantities, it is expected that many relevant Machine Learning applications will emerge in the near future. We will review and discuss current applications and challenges.

**Literature**


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**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Problem-solving
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Creative Thinking
- Critical Thinking
- Self-direction and Self-management

**Method-specific Competencies**

- Understanding and applying digital biomarkers in healthcare applications
- Applying Machine Learning algorithms to digital biomarker data
- Designing observational studies and collecting data
- Exploring data and deriving meaningful information

**Social Competencies**

- Self-management and self-regulation
- Collaboration and teamwork
- Communication and presentation skills
- Critical thinking and problem-solving
- Self-awareness and self-management

**Personal Competencies**

- Self-direction and self-management
- Creativity and innovation
- Decision-making and problem-solving
- Self-awareness and self-regulation
- Collaboration and teamwork
- Communication and presentation skills
- Critical thinking and problem-solving
Objective

The aim of this class is to provide students with a general overview of first and second order PDEs, and teach them how to solve some of these equations using characteristics and/or separation of variables.

Content

1.) General introduction to PDEs and their classification (linear, quasilinear, semilinear, nonlinear / elliptic, parabolic, hyperbolic)

2.) Quasilinear first order PDEs
   - Solution with the method of characteristics
   - Conservation laws

3.) Hyperbolic PDEs
   - wave equation
   - d'Alembert formula in (1+1)-dimensions
   - method of separation of variables

4.) Parabolic PDEs
   - heat equation
   - maximum principle
   - method of separation of variables

5.) Elliptic PDEs
   - Laplace equation
   - maximum principle
   - method of separation of variables
   - variational method

Literature


Prerequisites / notice

Prerequisites: Analysis I and II, Fourier series (Complex Analysis)

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Personal Competencies
Creative Thinking fostered
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

401-0625-01L Applied Analysis of Variance and Experimental Design W 5 credits 2V+1U L. Meier

Abstract
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Objective
Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Content
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Literature

Prerequisites / notice
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Personal Competencies
Creative Thinking fostered
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

401-3913-01L Mathematical Foundations for Finance W 4 credits 3V+2U D. Possamai

Abstract
First introduction to main modelling ideas and mathematical tools from mathematical finance

Objective
This course gives a first introduction to the main modelling ideas and mathematical tools from mathematical finance. It mainly aims at non-mathematicians who need an introduction to the main tools from stocharistics used in mathematical finance. However, mathematicians who want to learn some basic modelling ideas and concepts for quantitative finance (before continuing with a more advanced course) may also find this of interest. The main emphasis will be on ideas, but important results will be given with (sometimes partial) proofs.

Content
Topics to be covered include
- financial market models in finite discrete time
- absence of arbitrage and martingale measures
- valuation and hedging in complete markets
- basics about Brownian motion
- stochastic integration
- stochastic calculus: Itô's formula, Girsanov transformation, Itô's representation theorem
- Black-Scholes formula

Lecture notes
See information on course homepage

Prerequisites / notice
Prerequisites: Results and facts from probability theory as in the book "Probability Essentials" by J. Jacod and P. Protter will be used freely. Especially participants without a direct mathematics background are strongly advised to familiarise themselves with those tools before (or very quickly during) the course. (A possible alternative to the above English textbook are the (German) lecture notes for the standard course "Wahrscheinlichkeitstheorie").

For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.
401-4623-00L  Time Series Analysis

Abstract
The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

Objective
The goal of the course is to have a a good overview of the different types of time series and the approaches used in their statistical analysis.

Content
This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exibited by time series is the dependence between successive observations.

The key topics which will be covered as:
- Stationarity
- Autocorrelation
- Trend estimation
- Elimination of seasonality
- Spectral analysis, spectral densities
- Forecasting

Literature
The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis

Prerequisites / notice
Basic knowledge in probability and statistics

401-7855-00L  Computational Astrophysics (University of Zurich)

Objective
Acquire knowledge of main methodologies for computer-based models of astrophysical systems, the physical equations behind them, and train such knowledge with simple examples of computer programmes

Content
1. Integration of ODE, Hamiltonians and Symplectic integration techniques, time adaptivity, time reversibility
2. Large-N gravity calculation, collisionless N-body systems and their simulation
3. Fast Fourier Transform and spectral methods in general
4. Eulerian Hybriddynamics: Upwinding, Riemann solvers, Limilters
5. Lagrangian Hybriddynamics: The SPH method
6. Resolution and instabilities in Hybriddynamics
7. Initial Conditions: Cosmological Simulations and Astrophysical Disks
8. Physical Approximations and Methods for Radiative Transfer in Astrophysics

Literature
Galactic Dynamics (Binney & Tremaine, Princeton University Press), Computer Simulation using Particles (Hockney & Eastwood CRC press), Targeted journal reviews on computational methods for astrophysical fluids (SPH, AMR, moving mesh)

Prerequisites / notice
Some knowledge of UNIX, scripting languages (see www.physik.uzh.ch/lectures/informatik/python/ as an example), some prior experience
programming, knowledge of C, C++ beneficial

402-0809-00L  Introduction to Computational Physics

Objective
Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

Content
Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

Lecture notes
Lecture notes and slides are available online and will be distributed if desired.

Literature
Lecture recommendations and references are included in the lecture notes.

Prerequisites / notice
Lecture and exercise lessons in English, exams in German or in English

402-1701-00L  Physics I

Objective
Acquire knowledge of the basic principles regarding the physics of classical mechanics. Skills in solving physics problems.

406-0007-00L  Computational Systems Biology

Objective
The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.
Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label “Systems Biology”, focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.
The course "Didactic Basics for Student Teaching Assistants" enhance Student Teaching Assistants (Student TAs) to develop knowledge, capability and confidence to effectively plan and teach courses and exercises. Participants get trained to think critically about students’ learning and create learning situations in which students are actively engaged.

Objective

In this course Student Teaching Assistants will ...

• reflect on their approach to teaching as well as their attitude towards teaching.
• understand the basics of teaching and learning in the context of their subject.
• consciously design the introduction of their course as well as the introduction of single teaching units.
• apply classroom assessment techniques as formative assessments to measure the current status of their students.
• develop a didactic concept according to the learning objectives.
• conduct interactive sequences as learning activities.
• give and get feedback from peers and self-reflect on their teaching practice.
• feel confident to use methods for active learning scenarios in their classes.

Content

The online course provide a range of relevant topics for developing teaching competences of Student Teaching Assistants:

• Overview about how learning works. Based on these fundamentals of learning participants reflect on their role as Student TAs to feel comfortable in their new role as a teacher.
• Plan an own lesson by introducing a class and locate it in the larger topic (methods: portal and informative introduction).
• Develop learning activities in order to activate students (active learning methods).
• Giving and also getting feedback. The participants integrate this topic also in their lesson plan.

While working through the online course, Student TAs have the chance to reflect, exchange ideas with peers and plan their own teaching accordingly so that they feel confident in their role.

Prerequisites / notice

Self-paced online course with a online/face-to-face consolidation workshop.

Consolidation Workshops takes place online or in presence (you have the choice). Dates will be released at the beginning of the new semester.

You need to choose one of the dates and you will find registration details and a deadline in the Moodle course.
<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>ECTS</th>
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<tbody>
<tr>
<td>V lecture</td>
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<tr>
<td>G lecture with exercise</td>
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<td>U exercise</td>
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<td>S seminar</td>
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<td>K colloquium</td>
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<td>P practical/laboratory course</td>
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<td>A independent project</td>
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<td>D diploma thesis</td>
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<tr>
<td>R revision course / private study</td>
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</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings of students possess theoretical knowledge and practical competences to be able to cope with the psychosocial demands of teaching.

Formation of Knowledge in STEM Fields in Primary and Secondary School
Adresses to students enrolled either in Teaching Diploma* (TD) or Teaching Certificate (TC) (excluding Teaching Diploma Sport).
This course unit can only be enrolled after successful participation in the course 871-0240-00L "Human Learning (EW 1)"

Abstract
Course promotes exchange between student teachers and elementary school teachers in STEM teaching with 3 parts: 1) block seminar (ca. 16 h), 2) collaboration with elementary school teacher in a class (ca. 34 h, with approx. 50% spent in the elementary or middle school class and ca. 50% for preparation), and 3) final report (ca. 10 h). Registration implies participation in all 3 parts.

Objective
Deepening the understanding of knowledge formation and learning processes of primary and secondary students from a cognitive and developmental psychology perspective for students. The assistant ship provides didactic experience and exposure to a different school level (more heterogeneous groups such as for example low-performing to very high-performing Children, language problems etc.).

Content
Students learn more about the potential and challenges of pupils. They get to know the early stages of knowledge as well as the development of pre-concepts of students in their subject area. The seminar with a phase of cooperation consists of three phases: In the block seminar, pre-concepts are discussed in their own subject as well as theoretical inputs from developmental and cognitive psychology. During the cooperation phase, a teaching task defined by the primary and secondary school teachers is actively undertaken in a class.

Finally, a final report is written, which contains a description of the students’ level of knowledge. This seminar is only suitable for students who can adapt flexibly to the needs of pupils from lower class levels.

Prerequisites / notice
https://www.minterlink.ch/student

Competencies
- Subject-specific Competencies: Concepts and Theories, assessed
- Method-specific Competencies: Analytical Competencies, assessed
- Social Competencies: Communication, assessed
- Leadership and Responsibility, assessed
- Personal Competencies: Adaptability and Flexibility, assessed
- Self-awareness and Self-reflection, assessed

Human Learning (EW1)
This lecture is only apt for students who intend to enrol in the programs "Teaching Diploma" or "Teaching Certificate". It is about learning in childhood and adolescence.

Abstract
This course looks into scientific theories and also empirical studies on human learning and relates them to the school.

Objective
Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

Content
Thematic Schwerpunkte:
- Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen

Lernformen:

Lecture notes
Foliene werden zur Verfügung gestellt.

Literature

Prerequisites / notice
This lecture is only apt for students who intend to enrol in the programs "Lehrdiplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.

Coping with Psychosocial Demands of Teaching (EW4 W DZ)
The successful participation in EW1 ("Human Learning") and EW2 ("Designing Learning Environments for School") is recommended, but not a mandatory prerequisite.

Abstract
In this class, students will learn concepts and skills for coping with psychosocial demands of teaching.

Objective
Students possess theoretical knowledge and practical competences to be able to cope with the psychosocial demands of teaching.

(1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks).
(2) They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. illegal or psychological services).
Diploma or Teaching Certificate (excluding Teaching Diploma Sport).

This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)".

Abstract
This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.

Objective
- Get to know cognitively activating instructions in MINT subjects
- Get information about recent literature on learning and instruction

Prerequisites / notice
Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>871-0242-07L</td>
<td>Human Intelligence</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>E. Stern</td>
</tr>
</tbody>
</table>

Abstract
The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.

Objective
- Understanding of research methods used in the empirical human sciences
- Getting to know intelligence tests
- Understanding findings relevant for education

Subject Didactics and Professional Training
Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

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<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
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<tbody>
<tr>
<td>272-0101-00L</td>
<td>Subject Didactics of Computer Science I</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>D. Komm, J. Hromkovic, G. Serafini</td>
</tr>
</tbody>
</table>

Abstract
The unit "Subject Didactics of Computer Science I" addresses key contributions of computer science to general education. The course deals with the thoughtful choice of educational contents for computer science classes, which takes into account its comprehensibility for different age groups as well as didactic approaches suitable for a successful knowledge transfer.

Objective
The general objective of the course consists in highlighting the tight connection between the mathematical and algorithmic way of thinking and the approaches adopted by engineering disciplines, and in reflecting on teaching approaches for sustainable computer science teaching activities.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support.

They encourage the autonomy of the learners, manage to work with diverse target groups and to establish a positive learning environment.

The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.

Content
The course "Subject Didactics of Computer Science I" addresses key contributions of computer science to general education. The chosen topics support the young learners in developing a unique and indispensable way of thinking, in enhancing their understanding of our world as well as in achieving university education entrance qualifications.

The main topics of the course unit "Subject Didactics of Computer Science I" are the didactics of finite state automata, of formal languages and of the introduction to programming. The unit focuses on contents of computer science that contribute to general education. This involves the understanding of fundamental scientific concepts such as algorithm, complexity, determinism, computation, automata, verification, testing and programming language as well as the way to embed them into a scientifically sound and didactically sustainable computer science course.

In a semester exercise, the students develop and document an adaptive teaching unit for computer science. They learn to employ the didactics methods and techniques that are introduced at the beginning of the semester.

Lecture notes
Unterlagen und Folien werden zur Verfügung gestellt.

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1392 of 2653
The objective is for the students:

- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.
- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance from a subject-based and pedagogical angle.
- greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.
- They learn to assess pupils' work.
- They practising finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.

In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

The objective is for the students:

- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

### Prerequisites / notice

Lehrdiplom-Studierende müssen diese Lerneinheit zusammen mit dem Einführungspraktikum Informatik - 272-0201-00L - belegen.

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Project Management</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Customer Orientation</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Leadership and Responsibility</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Negotiation</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
</tr>
</tbody>
</table>

### Literature

J. Hromkovic et al.: Lehrwerksreihe " Grundlagen der Informatik für Schweizer Maturitätsschulen"
Lehrwerksreihe "Einfach Informatik"

https://einfachinformatik.inf.ethz.ch/


### Prerequisites

271-0102-00L Teaching Internship Including Examination Lessons in Computer Science

Repetition of the Teaching Internship is excluded even if Examination Lessons are to be repeated.

272-0103-00L Mentored Work Subject Didactics Computer Science

In Autumn Semester 2024, the following courses will be offered:

#### Abstract

- In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

#### Objective

- The objective is for the students:
  - to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
  - to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.
Thematic Schwerpunkte
Die Gegenständen der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.

Lernformen
Alle Studierenden erhalten ein individuelles Thema und erstellen dazu eine eigenständige Arbeit. Sie werden dabei von ihrer
Betreuungsperson begleitet. Gegebenenfalls stellen sie ihre Arbeit oder Aspekte daraus in einem Kurzvortrag vor. Die mentorierte Arbeit ist
Teil des Portfolios der Studierenden.

Literatur
Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird
sie vom Betreuer zur Verfügung gestellt.

Prerequisites / notice
Die Arbeit sollte vor Beginn des Praktikums abgeschlossen
werden.

Specialized Courses in Respective Subject with Educational Focus

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0237-00L</td>
<td>Concepts of Object-Oriented Programming</td>
<td>W</td>
<td>8</td>
<td>3V+2U+2A</td>
<td>P. Müller</td>
</tr>
</tbody>
</table>

Abstract
Course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object and class initialization, program correctness, reflection

Objective
After this course, students will:
- Have a deep understanding of advanced concepts of object-oriented programming and their support through various language features.
- Be able to understand language concepts on a semantic level and be able to compare and evaluate language designs.
- Be able to learn new languages more rapidly.
- Be aware of many subtle problems of object-oriented programming and know how to avoid them.

Content
The main goal of this course is to convey a deep understanding of the key concepts of sequential object-oriented programming and their support in different programming languages. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.

The topics discussed in the course include among others:
- The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing).
- The key problems of single and multiple inheritance and how different languages address them.
- Generic type systems, in particular, Java generics, C# generics, and C++ templates.
- The situations in which object-oriented programming does not provide encapsulation, and how to avoid them.
- The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing.
- How to maintain the consistency of data structures.

Literature
Will be announced in the lecture.

Prerequisites / notice
Prerequisites:
Mastering at least one object-oriented programming language (this course will NOT provide an introduction to object-oriented programming), programming experience

252-0535-00L Advanced Machine Learning

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistical knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:
- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory
- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature
Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution. PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

263-2800-00L Design of Parallel and High-Performance Computing W 9 credits 2V+2U+4A T. Hoefler

Abstract

Advanced topics in parallel and high-performance computing.

Objective

Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

Content

We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

Prerequisites / notice

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

272-0400-00L Mentored Work Specialised Courses in the Respective Subject with Educational Focus Computer Sc A W+ 2 credits 4A D. Komm, J. Hromkovic, G. Serafini

Abstract

In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

Objective

The aim is for the students
- to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.
- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.
- To try out different options for specialist further training in their profession.

Content

Thematische Schwerpunkte:

Lernformen:

Literature

Die Literatur ist themenspezifisch. Sie muss je nach Situation selber beschafft werden oder wird zur Verfügung gestellt.

Prerequisites / notice

Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.

Computer Science TC - Key for Type

O Compulsory E- Recommended, not eligible for credits
W+ Eligible for credits and recommended Z Courses outside the curriculum
W Eligible for credits Dr Suitable for doctorate

Key for Hours

V lecture P practical/laboratory course
G lecture with exercise A independent project
U exercise D diploma thesis
S seminar R revision course / private study
K colloquium

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.

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Educational Science

Course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>871-0238-01L</td>
<td>Support and Diagnosis of Knowledge Acquisition Processes (EW3)</td>
<td>W</td>
<td>3 credits</td>
<td>3S</td>
<td>C. M. Thurn, S. Daguati</td>
</tr>
</tbody>
</table>

Prerequisites: successful participation in 871-0240-00L "Human Learning (EW1)"

Abstract
In this seminar students learn advanced techniques to support and to diagnose knowledge acquisition processes in school.

Objective
The main goals are:
1. You have a deep understanding about the cognitive mechanisms of knowledge acquisition.
2. You have a basic understanding about psychological test theory and can appropriately administer tests.
3. You know various techniques of formative assessment and can apply these to uncover students' misconceptions.

Competencies
- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies, Decision-making, Media and Digital Technologies
- Social Competencies: Communication, Cooperation and Teamwork, Leadership and Responsibility, Sensitivity to Diversity
- Personal Competencies: Creative Thinking, Critical Thinking

871-0242-06L | Cognitively Activating Instructions in MINT Subjects | W    | 2 credits | 2S    | R. Schumacher |

Abstract
This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.

Objective
- Get to know cognitively activating instructions in MINT subjects
- Get information about recent literature on learning and instruction

Prerequisites / notice
Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.

871-0242-07L | Human Intelligence | W    | 1 credit | 1S    | E. Stern |

Abstract
The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.

Objective
- Understanding of research methods used in the empirical human sciences
- Getting to know intelligence tests
- Understanding findings relevant for education

see Educational Science Teaching Diploma

Subject Didactics in Computer Science

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>272-0101-00L</td>
<td>Subject Didactics of Computer Science I</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>D. Komm, J. Hromkovic, G. Serafini</td>
</tr>
</tbody>
</table>

Abstract
The unit "Subject Didactics of Computer Science I" addresses key contributions of computer science to general education. The course deals with the thoughtful choice of educational contents for computer science classes, which takes into account its comprehensibility for different age groups as well as didactic approaches suitable for a successful knowledge transfer.
### Objective

The general objective of the course consists in highlighting the tight connection between the mathematical and algorithmic way of thinking and the approaches adopted by engineering disciplines, and in reflecting on teaching approaches for sustainable computer science teaching activities.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support. They encourage the autonomy of the learners, manage to work with diverse target groups and to establish a positive learning environment.

The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.

### Content

The course "Subject Didactics of Computer Science I" addresses key contributions of computer science to general education. The chosen topics support the young learners in developing a unique and indispensable way of thinking, in enhancing their understanding of our world as well as in achieving university education entrance qualifications.

The main topics of the course unit "Subject Didactics of Computer Science I" are the didactics of finite state automata, of formal languages and of the introduction to programming. The unit focuses on contents of computer science that contribute to general education. This involves the understanding of fundamental scientific concepts such as algorithm, complexity, determinism, computation, automata, verification, testing and programming language as well as the way to embed them into a scientifically sound and didactically sustainable computer science course.

In a semester exercise, the students develop and document an adaptive teaching unit for computer science. They learn to employ the didactics methods and techniques that are introduced at the beginning of the semester.

### Lecture notes

Unterlagen und Folien werden zur Verfügung gestellt.

J. Hromkovic et al.: Lehrwerksreihe "Grundlagen der Informatik für Schweizer Maturitätsschulen"
Lehrwerksreihe "Einfach Informatik"

https://einfachinformatik.inf.ethz.ch/


### Literature

Lehrdiplom-Studierende müssen diese Lerneinheit zusammen mit dem Einführungspraktikum Informatik - 272-0201-00L - belegen.

### Prerequisites / notice

272-0103-00L Mentored Work Subject Didactics Computer Science O 2 credits 4A D. Komm, J. Hromkovic, G. Serafini

### Abstract

In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.
Objective

- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

Content

Thematic Schwerpunkte

Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.

Lernformen


Literatur

Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.

Prerequisites / notice

Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.

272-0104-00L  Mentored Work Subject Didactics Computer Science  O  2 credits  4A  D. Komm, J. Hromkovic, G. Serafini

Abstract

In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

Objective

The objective is for the students:
- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

Content

Thematic Schwerpunkte

Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.

Lernformen


Literatur

Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.

Prerequisites / notice

Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.

Professional Training

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

Number  Title  Type  ECTS  Hours  Lecturers

272-0201-00L  Introductory Practical in Computer Science  O  3 credits  6P  D. Komm, G. Serafini

Abstract

During the introductory teaching practice, the students sit in on five lessons given by the teacher responsible for their teaching practice, and teach five lessons themselves. The students are given observation and reflection assignments by the teacher responsible for their teaching practice.

Objective

At the start of their training, students acquire initial experience with the observation of teaching, the establishment of concepts for teaching and the implementation of teaching. This early confrontation with the complexity of everything that teaching involves helps students decide whether they wish to and, indeed, ought to, continue with the training. It forms a basis for the subsequent pedagogical and subject-didactics training.

Content

Den Studierenden bietet das Einführungspraktikum einen Einblick in den Berufsalltag einer Lehrperson.


Literatur

Wird von der Praktikumlernperson bestimmt.

272-0202-00L  Professional Exercises  O  2 credits  4U  D. Komm, G. Serafini

Abstract

In the course Professional Exercises the students achieve additional school-relevant experiences. The students carry out individually specified, practice related projects, in which they support, document or reflect on learning processes.

Objective

Achievement of additional school-relevant experiences. The students carry out individually specified, practice related projects, in which they support, document or reflect on learning processes.

Content

The course Professional Exercises offers the opportunity for additional school-relevant activities. The students are supported by the lecturers or by experienced teachers. They assist teachers at school, they create training systems and tests, correct the written homework of pupils and evaluate the progress of a class. The students create explanations and detailed solutions to exercises with respect to the actual knowledge of the pupils. A written assignment states the exact scope of the activity.

272-0203-00L  Teaching Internship in Computer Science  O  8 credits  17P  D. Komm, G. Serafini

Abstract

The teaching practice takes in 50 lessons: 30 are taught by the students, and the students sit in on 20 lessons. The teaching practice lasts 4-6 weeks. It gives students the opportunity to implement the contents of their specialist-subject, educational science and subject-didactics training in the classroom. Students also conduct work assignments in parallel to their teaching practice.
Das Aufbaupraktikum richtet sich an Studierende, die bereits das Didaktik-Zertifikat in ihrem Fach erworben haben und nun eine Dokument: Schriftliche Vorbereitung für Prüfungslektionen.

- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.

- They are able to assess the significance of tuition topics in their subject from different angles (including interdisciplinary angles) and impart these to their pupils.

- They acquire the skills of the teaching trade.

- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.

- They learn to assess pupils' work.

- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.


### 272-0204-00L Teaching Internship in Computer Science II

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>272-0204-00L</td>
<td>Teaching Internship for students upgrading TC to Teaching Diploma</td>
<td>W</td>
<td>4</td>
<td>9P</td>
<td>D. Komm, G. Serafini</td>
</tr>
</tbody>
</table>

#### Abstract
This is a supplement to the Teaching Internship required to obtain a Teaching Diploma in the corresponding subject. It is aimed at enlarging the already acquired teaching experience. Students observe 10 lessons and teach 15 lessons independently.

#### Objective

- Die Studierenden können die Bedeutung von Unterrichtsthemen in ihrem Fach unter verschiedenen Blickwinkeln einschätzen. Sie kennen und beherrschen das unterrichtliche Handwerk. Sie können ein gegebenes Unterrichtsthema für eine Gruppe von Lernenden fachlich und didaktisch korrekt strukturieren und in eine adäquate Lernumgebung umsetzen. Es gelingt ihnen, die Balance zwischen Anleitung und Offenheit zu finden, sodass die Lernenden sowohl über den nötigen Freiraum wie über ausreichend Orientierung verfügen, um aktiv und effektiv flexibel nutzbares (Fach-)Wissen zu erwerben.

#### Content


### 272-0205-01L Examination Lesson I in Computer Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>272-0205-01L</td>
<td>Examination Lesson I in Computer Science &quot;(272-0205-02L)&quot; is compulsory.</td>
<td>O</td>
<td>1</td>
<td>2P</td>
<td>D. Komm, G. Serafini</td>
</tr>
</tbody>
</table>

#### Abstract
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

#### Objective

- On the basis of a specific topic, the candidate shows that they are in a position
  - to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle
  - to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

#### Content

Die Studierenden erfahren das Lektionsthema in der Regel eine Woche vor dem Prüfungstermin. Von der zuständigen Lehrperson erhalten sie Informationen über den Wissensstand der zu unterrichtenden Klasse und können sie vor dem Prüfungstermin besuchen.

Sie erstellen eine Vorbereitung gemäss Anleitung und reichen sie bis am Vortag um 12 Uhr den beiden Prüfungssexperten ein.

Die gehaltene Lektion wird kriteriumsbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/ der Kandidatin über die gehaltene Lektion im Rahmen eines kurzen Kolloquiums.

#### Lecture notes
Dokument: Schriftliche Vorbereitung für Prüfungslektionen.

#### Prerequisites / notice
Nach Abschluss der übrigen Ausbildung.

### 272-0205-02L Examination Lesson II in Computer Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>272-0205-02L</td>
<td>Examination Lesson II in Computer Science &quot;(272-0205-01L)&quot; is compulsory.</td>
<td>O</td>
<td>1</td>
<td>2P</td>
<td>D. Komm, G. Serafini</td>
</tr>
</tbody>
</table>

#### Abstract
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

#### Objective

- On the basis of a specific topic, the candidate shows that they are in a position
  - to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle
  - to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

#### Content

Die Studierenden erfahren das Lektionsthema in der Regel eine Woche vor dem Prüfungstermin. Von der zuständigen Lehrperson erhalten sie Informationen über den Wissensstand der zu unterrichtenden Klasse und können sie vor dem Prüfungstermin besuchen.

Sie erstellen eine Vorbereitung gemäss Anleitung und reichen sie bis am Vortag um 12 Uhr den beiden Prüfungssexperten ein.

Die gehaltene Lektion wird kriteriumsbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/ der Kandidatin über die gehaltene Lektion im Rahmen eines kurzen Kolloquiums.

#### Lecture notes
Dokument: Schriftliche Vorbereitung für Prüfungslektionen.

#### Prerequisites / notice
Nach Abschluss der übrigen Ausbildung.


<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>252-0237-00L</td>
<td>Concepts of Object-Oriented Programming</td>
<td>W</td>
<td>8</td>
<td>3V+2U+2A</td>
<td>P. Müller</td>
</tr>
</tbody>
</table>

#### Abstract
Course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object and class initialization, program correctness, reflection

#### Objective

After this course, students will:

- Have a deep understanding of advanced concepts of object-oriented programming and their support through various language features.
- Be able to understand language concepts on a semantic level and be able to compare and evaluate language designs.
- Be able to learn new languages more rapidly.
- Be aware of many subtle problems of object-oriented programming and know how to avoid them.

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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1399 of 2653
The main goal of this course is to convey a deep understanding of the key concepts of sequential object-oriented programming and their support in different programming languages. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.

The topics discussed in the course include among others:
- The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing).
- The key problems of single and multiple inheritance and how different languages address them.
- Generic type systems, in particular, Java generics, C# generics, and C++ templates.
- The situations in which object-oriented programming does not provide encapsulation, and how to avoid them.
- The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing.
- How to maintain the consistency of data structures.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

Prerequisites:
- Mastering at least one object-oriented programming language (this course will NOT provide an introduction to object-oriented programming); programming experience.

**252-0535-00L**

**Advanced Machine Learning**

**W** 10 credits 2V+2U+4A

**C. Cotrini Jimenez**

**Abstract**

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

**Content**

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- **Fundamentals:**
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- **Supervised learning:**
  - Ensembles: Bagging and Boosting
  - Max Margin methods

- **Unsupervised learning:**
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Neural networks
  - Non-parametric density estimation
  - Learning Dynamical Systems

**Lecture notes**

No lecture notes, but slides will be made available on the course webpage.

**Literature**


**Prerequisites / notice**

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

**263-2800-00L**

**Design of Parallel and High-Performance Computing**

**W** 9 credits 2V+2U+4A

**T. Hoefler**

**Abstract**

Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

**Objective**

We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

**Content**

This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

**272-0400-00L**

**Mentored Work Specialised Courses in the Respective O Subject with Educational Focus Computer Sc A**

**2 credits** 4A

**D. Komm, J. Hromkovic, G. Serafini**

**Abstract**

In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.
**Objective**
The aim is for the students
- to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.
- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.
- To try out different options for specialist further training in their profession.

**Content**

|---------------------------|--|

**Literature**

| Die Literatur ist themenspezifisch. Sie muss je nach Situation selber beschafft werden oder wird zur Verfügung gestellt. |

**Prerequisites / notice**

| Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden. |

**272-0401-00L**

| Mentored Work Specialised Courses in the Respective O | 2 credits | 4A | D. Komm, J. Hromkovic, G. Serafini |
|--------------------------------------------------------------------------------------------------------------------------|

**Abstract**

In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

**Objective**

<table>
<thead>
<tr>
<th>The aim is for the students</th>
<th>- to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.</th>
</tr>
</thead>
<tbody>
<tr>
<td>- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.</td>
<td></td>
</tr>
<tr>
<td>- To try out different options for specialist further training in their profession.</td>
<td></td>
</tr>
</tbody>
</table>

**Content**

|---------------------------|--|

**Literature**

| Die Literatur ist themenspezifisch. Sie muss je nach Situation selber beschafft werden oder wird zur Verfügung gestellt. |

**Prerequisites / notice**

| Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden. |

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**Compulsory Elective Courses**

*Further course offerings from the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".*

*see Compulsory Elective Courses Teaching Diploma*

**Computer Science Teaching Diploma - Key for Type**

<table>
<thead>
<tr>
<th>Q</th>
<th>Compulsory</th>
</tr>
</thead>
<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</table>

**Key for Hours**

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**

*European Credit Transfer and Accumulation System*

*Special students and auditors need special permission from the lecturers.*

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Autumn Semester 2024
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Computer Science Master

Major in Data Management Systems

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10</td>
<td>3V+2U+4A</td>
<td>C. Cotrini Jimenez</td>
</tr>
</tbody>
</table>

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:
- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory
- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature

Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

263-3010-00L Big Data W 10 credits 3V+2U+4A G. Fourny

Abstract
The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations.

Objective
Do you want to be able to query your own data productively and efficiently in your future semester projects, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This courses teaches you how to do so as well as the dos and don'ts. "Big Data" refers to the case when the amount of data is very large (100 GB and more), or when the data is not completely structured (or messy). The Big Data revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it are needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small. The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each one of your projects efficiently and consistently.
Content

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage (S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Large scale analytics and machine learning are outside of the scope of this course.

Course textbook: https://ghislainfourny.github.io/big-data-textbook/

Literature

Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

Prerequisites / notice

The lecture is hybrid, meaning you can attend with us in the lecture hall, or on Zoom, or watch the recordings on YouTube later. Exercise sessions are in presence.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departments interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2023

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

263-3845-00L Data Management Systems W 8 credits 3V+1U+3A G. Alonso

Abstract

The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.

Objective

The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in-depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.

Content

The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understanding these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

Literature

The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.
Advanced topics in parallel and high-performance computing.

In this course, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: common software faults (e.g., buffer overflows, etc.), bug-detection, writing secure software (design, architecture, QA, testing), compiler-supported security (e.g., control-flow integrity), and language-supported security (e.g., memory safety).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

Prerequisites / notice
The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

ECTS
9 credits

Hours
2V+2U+2A

Lecturers
S. Capkun, S. Shinde

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Deep Learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/amli/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://ml2.inf.ethz.ch/courses/stt/

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18

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Core Courses

Number
Title
Type
ECTS
Hours
Lecturers

252-1414-00L
System Security
W
7 credits
T. Hofmann

263-2800-00L
Design of Parallel and High-Performance Computing
W
9 credits
T. Hoefler

263-3210-00L
Deep Learning
W
8 credits
T. Hofmann

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Major in Machine Intelligence

Core Courses
### Advanced Machine Learning

**252-0535-00L**

**W 10 credits 3V+2U+4A**

**C. Cotrini Jimenez**

**Abstract**

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real-world data.

**Content**

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

**Lecture notes**

No lecture notes, but slides will be made available on the course webpage.

**Literature**


**Prerequisites / notice**

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

---

### Deep Learning

**263-3210-00L**

**W 8 credits 3V+2U+2A**

**T. Hofmann**

**Abstract**

Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

**Prerequisites / notice**

This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:

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    https://ml2.inf.ethz.ch/courses/aml/
  - Computational Intelligence Lab
    http://da.inf.ethz.ch/teaching/2019/CIL/
  - Introduction to Machine Learning
    https://las.inf.ethz.ch/teaching/introml-S19
  - Statistical Learning Theory
    http://ml2.inf.ethz.ch/courses/stl/
  - Computational Statistics
    https://stat.ethz.ch/lectures/ss19/comp-stats.php
  - Probabilistic Artificial Intelligence
    https://las.inf.ethz.ch/teaching/pai-f18

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### Probabilistic Artificial Intelligence

**263-5210-00L**

**W 8 credits 3V+2U+2A**

**A. Krause**

**Abstract**

This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.
Objective
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice
Solid basic knowledge in statistics, algorithms and programming.
The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management assessed

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered

Personal Competencies
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics fostered

Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>252-3005-00L</td>
<td>Natural Language Processing</td>
<td>W</td>
<td>7</td>
<td>3V+3U+1A</td>
<td>R. Cotterell</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.</td>
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<tr>
<td>Content</td>
<td>This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.</td>
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</tr>
<tr>
<td>Literature</td>
<td>Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.</td>
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</tbody>
</table>

| 263-2400-00L | Reliable and Trustworthy Artificial Intelligence | W | 6 | 2V+2U+1A | M. Vechev |
| Abstract     | Creating reliable, secure, robust, and fair machine learning models is a core challenge in artificial intelligence and one of fundamental importance. The goal of the course is to teach both the mathematical foundations of this new and emerging area as well as to introduce students to the latest and most exciting research in the space. |
| Objective    | Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of engineering and research problems. To facilitate deeper understanding, the course includes a group coding project where students will build a system based on the learned material. |
| Content      | The course is split into 4 parts: |
|              | Robustness of Machine Learning |
|              | - Adversarial attacks and defenses on deep learning models, |
|              | - Automated certification of deep learning models (major trends: convex relaxations, branch-and-bound, randomized smoothing), |
|              | - Certified training of deep neural networks (combining symbolic and continuous methods). |
|              | Privacy of Machine Learning |
|              | - Threat models (e.g., stealing data, poisoning, membership inference, etc.), |
|              | - Attacking federated machine learning (across vision, natural language and tabular data), |
|              | - Differential privacy for defending machine learning, |
|              | - AI Regulations and checking model compliance. |
|              | Fairness of Machine Learning |
|              | - Introduction to fairness (motivation, definitions), |
|              | - Enforcing individual fairness (for both vision and tabular data), |
|              | - Enforcing group fairness (e.g., demographic parity, equalized odds). |
|              | Robustness, Privacy and Fairness of Foundation Models |
|              | - We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs). |
The coding project will utilize Python and PyTorch. Thus some programming experience in Python is expected. Students without prior knowledge of PyTorch are expected to acquire it early in the course by solving exercise sheets.

Subject-specific Competencies

Concepts and Theories  
Concepts and Theories
Techniques and Technologies  
Techniques and Technologies

Method-specific Competencies

Analytical Competencies  
Analytical Competencies
Problem-solving  
Problem-solving

Personal Competencies

Creative Thinking  
Creative Thinking
Critical Thinking  
Critical Thinking

263-5005-00L  
Artificial Intelligence in Education  

<table>
<thead>
<tr>
<th>Objective</th>
<th>The course will be centered around exploring methodological and system-focused perspectives on designing AI systems for education and analyzing educational data using AI methods. Students will be expected to a) engage in presentations and active in-class and asynchronous discussion, and b) work on problem-sets exemplifying the use of educational data mining techniques.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>The course will start with an introduction to data mining techniques (e.g., prediction, structured discovery, visualization, and relationship mining) relevant to analyzing educational data. We will then continue with topics on personalization in AI in educational technologies (e.g., learner modeling and knowledge tracing, self-improving AIED systems) while showcasing exemplary applications in areas such as content curation and dialog-based tutoring. Finally, we will cover ethical challenges associated with using AI in student-facing settings. Face-to-face meetings will be held every fortnight, although students will be expected to work individually on weekly tasks (e.g., discussing relevant literature, working on problems, preparing seminar presentations).</td>
</tr>
</tbody>
</table>

Lecture notes  
Lecture slides will be made available at the course Web site.

Literature  
No textbook is required, but there will be regularly assigned readings from research literature, linked to the course website.

Prerequisites / notice  
There are no prerequisites for this course. However, it will help if the student has taken an undergraduate or graduate level class in statistics, data science or machine learning. This class is appropriate for advanced undergraduates and master students in Computer Science as well as PhD students in other departments.

263-5056-00L  
Applications of Deep Learning on Graphs  

<table>
<thead>
<tr>
<th>Objective</th>
<th>Many established deep learning methods require dense input data with a well-defined structure (e.g., an image, a sequence of words). However, many practical applications deal with sparsely connected and complex data structures, such as molecules, knowledge graphs, and social networks. Graph Neural Networks (GNNs) and generalization learning on graphs have recently experienced a surge in popularity because it addresses the challenge to effectively learn representations over said structures. In this course, we aim to understand the fundamental principles of deep (representation) learning on graphs, the similarities and differences to other concepts in deep learning, as well as the unique challenges from a practical point of view. Finally, we provide an overview of recent applications of graph neural networks.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>1) problem-solving on graphs (node-, edge-, graph-level objectives), structural priors (inductive biases) of graph data, applications for graph learning. 2) Graph Neural Networks: convolutional, attentional, message passing; overview on the zoo of published operators. Relations to Transformers and DeepSets. 3) Expressivity of GNNs. 4) Scalability of Graph Neural Networks: Subsampling, Clustering (Pooling). 5) Augmentations and self-supervised learning on Graphs Application: Drug Discovery, Knowledge graphs, Temporal GNNs, Geometric GNNs, Deep Generative Models for Graphs.</td>
</tr>
</tbody>
</table>

Prerequisites / notice  
263-3210-00 Deep Learning or 263-0008-00 Computational Intelligence Lab; 252-0220-00 Introduction to Machine Learning; Statistics/Probability; Programming in Python; Unix Command Line.

263-5300-00L  
Guarantees for Machine Learning  

<table>
<thead>
<tr>
<th>Objective</th>
<th>This course is aimed at advanced master and doctorate students who want to conduct independent research on theory for modern machine learning (ML). It teaches standard methods in statistical learning theory commonly used to prove theoretical guarantees for ML algorithms. The knowledge is then applied in independent project work to understand and follow-up on recent theoretical ML results.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>By the end of the semester students should be able to: - understand a good fraction of theory papers published in the typical ML venues. For this purpose, students will learn common mathematical techniques from statistical learning in the first part of the course and apply this knowledge in the project work - critically examine recently published work in terms of relevance and find impactful (novel) research problems. This will be an integral part of the project work and involves experimental as well as theoretical questions - outline a possible approach to prove a conjectured theorem by e.g. reducing to more solvable subproblems. This will be practiced in in-person exercises, homeworks and potentially in the final project - effectively communicate and present the problem motivation, new insights and results to a technical audience. This will be primarily learned via the final presentation and report as well as during peer-grading of peer talks.</td>
</tr>
</tbody>
</table>

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Students should have a very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as “Introduction to Machine Learning,” “Regression” / “Statistical Modelling”. In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Methods-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Creative Thinking</td>
</tr>
<tr>
<td>assessed</td>
<td>assessed</td>
<td>assessed</td>
<td>assessed</td>
</tr>
</tbody>
</table>

**263-5351-00L Machine Learning for Genomics**

**Abstract**
The course reviews solutions provided by machine learning to the most challenging questions in human genomics.

**Objective**
Over the last few years, the parallel development of machine learning methods and molecular profiling technologies for human cells, such as sequencing, created an extremely powerful tool to get insights into the cellular mechanisms in healthy and diseased contexts. In this course, we will discuss the state-of-the-art machine learning methodology solving or attempting to solve common problems in human genomics. At the end of the course, you will be familiar with (1) classical and advanced machine learning architectures used in genomics, (2) bioinformatics analysis of human genomic and transcriptomic data, and (3) data types used in this field.

**Content**
- Short introduction to major concepts of molecular biology: DNA, genes, genome, central dogma, transcription factors, epigenetic code, DNA methylation, signaling pathways
- Prediction of transcription factor binding sites, open chromatin, histone marks, promoters, nucleosome positioning (convolutional neural networks, position weight matrices)
- Prediction of variant effects and gene expression (hidden Markov models, topic models)
- Deconvolution of mixed signal (NMF, ICA)
- DNA, RNA and protein folding (RNN, LSTM, transformers)
- Data imputation for single-cell RNA-seq data, clustering and annotation (diffusion and methods on graphs)
- Batch correction (autoencoders, optimal transport)
- Survival analysis (Cox proportional hazard model, regularization penalties, multi-omics, multi-tasking)

**Prerequisites / notice**
Introduction to Machine Learning, Statistics/Probability, Programming in Python, Unix Command Line

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Methods-specific Competencies</th>
<th>Social Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
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<tr>
<td>assessed</td>
<td>assessed</td>
<td>assessed</td>
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</tbody>
</table>

**263-5902-00L Computer Vision**

**Abstract**
The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

**Objective**
The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

**Content**
Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

**Prerequisites / notice**
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

**Major in Secure and Reliable Systems**

**Core Courses**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0237-00L</td>
<td>Concepts of Object-Oriented Programming</td>
<td>W</td>
<td>8 credits</td>
<td>3V+2U+2A</td>
<td>P. Müller</td>
</tr>
</tbody>
</table>

**Abstract**
Course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object and class initialization, program correctness, reflection

**Objective**
After this course, students will:
- Have a deep understanding of advanced concepts of object-oriented programming and their support through various language features.
- Be able to understand language concepts on a semantic level and be able to compare and evaluate language designs.
- Be able to learn new languages more rapidly.
- Be aware of many subtle problems of object-oriented programming and know how to avoid them.

**Content**
The main goal of this course is to convey a deep understanding of the key concepts of sequential object-oriented programming and their support in different programming languages. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.

The topics discussed in the course include among others:
- The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing)
- The key problems of single and multiple inheritance and how different languages address them
- Generic type systems, in particular, Java generics, C# generics, and C++ templates
- The situations in which object-oriented programming does not provide encapsulation, and how to avoid them
- The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing
- How to maintain the consistency of data structures

**Literature**
Will be announced in the lecture.

**Prerequisites / notice**
Prerequisites:
- Mastering at least one object-oriented programming language (this course will NOT provide an introduction to object-oriented programming); programming experience
Abstract
Subject of the class are engineering techniques for developing secure systems. We examine concepts, methods and tools, applied within
the different activities of the SW development process to improve security of the system. Topics: security requirements & risk analysis,
system modeling & model-based development methods, implementation-level security, and evaluation criteria for secure systems.

Objective
Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering
addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality
software.
Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and
availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools
that can be applied within the different activities of the software development process, in order to improve the security of the resulting
systems.

Topics covered include

- security requirements & risk analysis,
- system modeling and model-based development methods,
- implementation-level security, and
- evaluation criteria for the development of secure systems
Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software. Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include:
- Security requirements & risk analysis,
- System modeling and model-based development methods,
- Implementation-level security, and
- Evaluation criteria for the development of secure systems

Modules taught:

1. Introduction
   - Introduction of Infsec group and speakers
   - Security meets SW engineering: an introduction
   - The activities of SW engineering, and where security fits in
   - Overview of this class

2. Requirements Engineering: Security Requirements and some Analysis
   - Overview: functional and non-functional requirements
   - Use cases, misuse cases, sequence diagrams
   - Safety and security

3. Modeling in the design activities
   - Structure, behavior, and data flow
   - Class diagrams, statecharts

4. Model-driven security for access control (Part I)
   - SecureUML as a language for access control
   - Combining Design Modeling Languages with SecureUML
   - Semantics, i.e., what does it all mean,
   - Generation
   - Examples and experience

5. Model-driven security (Part II)
   - Continuation of above topics

6. Security patterns (design and implementation)

7. Implementation-level security
   - Buffer overflows
   - Input checking
   - Injection attacks

8. Code scanning
   - Static code analysis basics
   - Theoretical and practical challenges
   - Analysis algorithms
   - Common bug pattern search and specification
   - Dataflow analysis

9. Testing
   - Overview and basics
   - Model-based testing
   - Testing security properties

10. Risk analysis and management
    - "Risk": assets, threats, vulnerabilities, risk
    - Risk assessment: quantitative and qualitative
    - Safeguards
    - Generic risk analysis procedure
    - The OCTAVE approach
    - Example of qualitative risk assessment

11. Threat modeling
    - Overview
    - Safety engineering basics: FMEA and FTA
    - Security impact analysis in the design phase
    - Modeling security threats: attack trees
    - Examples and experience

12. Evaluation criteria
    - NIST special papers
    - ISO/IEC 27000
    - Common criteria
    - BSI baseline protection

13. Guest lecture
    - TBA

Literature
- Further relevant books and journal/conference articles will be announced in the lecture.

Prerequisites / notice
Prerequisite: Class on Information Security

252-1414-00L System Security W 7 credits 2V+2U+2A S. Capkun, S. Shinde

Abstract
The first part of the course covers general security concepts and hardware-based support for security. The second part, the focus is on system design and methodologies for building secure systems.

In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

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The first part of the lecture covers hardware-based security concepts. Topics include the concept of physical and software-based side channel attacks on hardware resources, architectural support for security (e.g., memory management and permissions, disk encryption), and trusted execution environments (Intel SGX, ARM TrustZone, AMD SEV, and RISC-V Keystone).

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: common software faults (e.g., buffer overflows, etc.), bug-detection, writing secure software (design, architecture, QA, testing), compiler-supported security (e.g., control-flow integrity), and language-supported security (e.g., memory safety).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Decision-making</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Problem-solving</td>
<td>fostered</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>fostered</td>
</tr>
</tbody>
</table>

### 263-2800-00L Design of Parallel and High-Performance Computing

**Abstract**

Advanced topics in parallel and high-performance computing.

**Objective**

Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become familiar with important technical concepts and with concurrency folklore.

**Content**

We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

**Prerequisites / notice**

This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

### 263-4640-00L Network Security

**Abstract**

Some of today’s most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems. This course provides an in-depth study of network attack techniques and methods to defend against them.

**Objective**

- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

**Content**

The course will cover topics spanning four broad themes with a focus on the first two themes:

1. network defense mechanisms such as public-key infrastructures, TLS, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. analysis and inference topics such as traffic monitoring and network forensics; and
4. new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

**Prerequisites / notice**

This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Customer Orientation</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Leadership and Responsibility</td>
<td>fostered</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
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<td></td>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Negotiation</td>
<td>fostered</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
</tr>
</tbody>
</table>

### 263-4658-00L Privacy Enhancing Technologies

**Abstract**

This course will cover topics spanning four broad themes with a focus on the first two themes:

1. network defense mechanisms such as public-key infrastructures, TLS, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. analysis and inference topics such as traffic monitoring and network forensics; and
4. new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

**Prerequisites / notice**

This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

**Competencies**

| Social Competencies | Communication | fostered |
|                     | Cooperation and Teamwork | fostered |
|                     | Customer Orientation | fostered |
|                     | Leadership and Responsibility | fostered |
|                     | Self-presentation and Social Influence | fostered |
|                     | Sensitivity to Diversity | fostered |
|                     | Negotiation | fostered |
| Personal Competencies | Adaptability and Flexibility | fostered |
|                       | Creative Thinking | assessed |
|                       | Critical Thinking | assessed |
|                       | Integrity and Work Ethics | fostered |
|                       | Self-awareness and Self-reflection | fostered |
|                       | Self-direction and Self-management | assessed |
Abstract
Privacy is a fundamental human right! And yet, technological advances (in particular in computer science) can often undermine privacy. In this class we will see how to formalize various notions of privacy and how to build systems that preserve privacy, by combining techniques from cryptography and statistics. The later parts of the course will focus on applications to machine learning.

Objective
By the end of the course, students will be able to:
- Reason about privacy concerns and the appropriate formalizations
- Combine tools from cryptography and statistics to build privacy mechanisms
- Assess, evaluate and prove privacy protection of a mechanism.

Content
The first half of the class will cover topics from cryptography such as secure multiparty computation, zero-knowledge proofs, PIR, ORAM, anonymous communication, etc. The second half will cover statistical notions of privacy, in particular differential privacy, and selected topics in machine learning privacy.

Lecture notes
Lecture notes will be posted on Moodle.

Literature
Boneh & Shoup - A Graduate Course in Applied Cryptography
References to relevant research papers will be provided

Prerequisites / notice
Basic knowledge in cryptography, probability and machine learning is recommended but not required.

Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0579-00L</td>
<td>Hardware Security</td>
<td>W</td>
<td>8</td>
<td>2V+2U+2A</td>
<td>K. Razavi</td>
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<tr>
<td>Abstract</td>
<td>This course covers the security of commodity computer hardware (e.g., CPU, DRAM, etc.) with a special focus on cutting-edge hands-on research. The aim of the course is familiarizing the students with hardware security and more specifically microarchitectural and circuit-level attacks and defenses through lectures and implementing some of these advanced attacks.</td>
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<td>Objective</td>
<td>By the end of the course, the students will be familiar with the state of the art in commodity computer hardware attacks and defenses. More specifically, the students will learn about:</td>
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<td>- security problems of commodity hardware that we use everyday and how you can defend against them.</td>
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<td>- relevant computer architecture and operating system aspects of these issues.</td>
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<td>- hands-on techniques for performing hardware attacks.</td>
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<tr>
<td>Literature</td>
<td>Slides, relevant literature and manuals will be made available during the course.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Experience with Linux, low-level systems programming and computer architecture.</td>
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<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
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<td>Concepts and Theories</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Project Management</td>
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| Social Competencies | Cooperation and Teamwork | | | | |
| Personal Competencies | Adaptability and Flexibility | | | | |
|                      | Creative Thinking             | | | | |
|                      | Critical Thinking             | | | | |
|                      | Integrity and Work Ethics     | | | | |
|                      | Self-direction and Self-management | | | | |

| Competencies | Subject-specific Competencies | | | | |
|--------------|-------------------------------|------|------|-----------------|
|              | Concepts and Theories          |      |      | assessed   |                 |
|              | Techniques and Technologies   |      |      | assessed   |                 |
| Method-specific Competencies | Analytical Competencies | | | | |
|              | Decision-making               |      |      | assessed   |                 |
|              | Media and Digital Technologies |      |      | fostered   |                 |
|              | Problem-solving               |      |      | assessed   |                 |

| Social Competencies | Cooperation and Teamwork | | | | |
| Personal Competencies | Critical Thinking | | | | |

252-1411-00L Security of Wireless Networks | W | 6 credits | 2V+1U+2A | S. Capkun, K. Kostiainen |
| Abstract | This course discusses physical layer aspects of wireless communication and a wide range of security-related topics in the domain of wireless technologies. It mainly targets computer science students. Though useful, a background in signal processing or physical layer concepts is not required. A basic understanding of security (e.g. as taught in 252-0211.00L Information Security) is recommended. |
| Objective | After this course, students should be able to describe and classify security goals of and attacks on various wireless networks and technologies, with an emphasis on physical layer aspects. |
| Content | - Introduction to wireless communication |
|          | - Physical layer security schemes |
|          | - Spreading techniques and their application in jamming-resilient communication and Global Navigation Satellite Systems (GNSSs) |
|          | - Secure ranging with Ultra-Wide Band (UWB) |
|          | - Security aspects of cellular networks, WiFi, and Bluetooth Low Energy (BLE) |

| Competencies | Subject-specific Competencies | | | | |
|--------------|-------------------------------|------|------|-----------------|
|              | Concepts and Theories          |      |      | assessed   |                 |
|              | Techniques and Technologies   |      |      | assessed   |                 |
| Method-specific Competencies | Analytical Competencies | | | | |
|              | Decision-making               |      |      | assessed   |                 |
|              | Media and Digital Technologies |      |      | fostered   |                 |
|              | Problem-solving               |      |      | assessed   |                 |

| Social Competencies | Cooperation and Teamwork | | | | |

263-2400-00L Reliable and Trustworthy Artificial Intelligence | W | 6 credits | 2V+2U+1A | M. Vechev |
| Abstract | Creating reliable, secure, robust, and fair machine learning models is a core challenge in artificial intelligence and one of fundamental importance. The goal of the course is to teach both the mathematical foundations of this new and emerging area as well as to introduce students to the latest and most exciting research in the space. |
| Objective | Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of engineering and research problems. To facilitate deeper understanding, the course includes a group coding project where students will build a system based on the learned material. |

Lecture notes will be posted on Moodle.

References to relevant research papers will be provided.
The course is split into 4 parts:

**Robustness of Machine Learning**

- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

**Privacy of Machine Learning**

- Threat models (e.g., stealing data, poisoning, membership inference, etc.).
- Attacking federated machine learning (across vision, natural language and tabular data).
- Differential privacy for defending machine learning.
- AI Regulations and checking model compliance.

**Fairness of Machine Learning**

- Introduction to fairness (motivation, definitions).
- Enforcing individual fairness (for both vision and tabular data).
- Enforcing group fairness (e.g., demographic parity, equalized odds).

Robustness, Privacy, and Fairness of Foundation Models

We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).


### Prerequisites / notice

While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in "Intro to ML" classes at most institutions (e.g., "Introduction to Machine Learning" at ETH).

### Competencies

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<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
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<td>Subject-specific Competencies</td>
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<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>Assessed</td>
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<tr>
<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>Assessed</td>
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### Content

The coding project will utilize Python and PyTorch. Thus some programming experience in Python is expected. Students without prior knowledge of PyTorch are expected to acquire it early in the course by solving exercise sheets.

#### 263-2520-00L

**Formal Foundations of Programming Languages**

- W 7 credits

**Objective**

Students will learn how to develop machine-checked proofs, how to rigorously define the semantics of a programming language and its type system, and how to analyze and formally establish the guarantees of well-typed programs.

**Content**

- The theory track (2V) will introduce operational semantics, type systems, and type soundness proofs, starting with the simply-typed lambda calculus and then continuing with increasingly expressive languages.
- The Coq track (2G) will begin with an introduction to machine-checked proofs and the Coq proof assistant. Afterwards we will mechanize the theory developed in the first track. This is the hands-on part of the course; students will carry out these proofs in Coq themselves with instructions from the lecturer.

#### Lecture notes

Will be made available on the course website.

#### Literature

Will be announced in the lecture.

**Prerequisites / notice**

A basic familiarity with propositional and first-order logic will be assumed. Courses with an emphasis on formal reasoning about programs (such as Formal Methods and Functional Programming) are advantageous background, but are not a requirement.

**Competencies**

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<td>Personal Competencies</td>
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#### 263-4657-00L

**Advanced Encryption Schemes**

Does not take place this semester.

**Abstract**

Public-Key Encryption has had a significant impact by enabling remote parties to communicate securely via an insecure channel. Latest schemes go further by providing a fine-grained access control to the encrypted data.

**Objective**

The student is comfortable with formal security definitions and proof techniques used to analyze the security of the latest encryption schemes with advanced features. This prepares the student to start reading research papers on the field.

**Content**

We will start by presenting the notion of Public-Key Encryption with its various security guarantees and some constructions. Then we will look into encryption schemes with fine-grained access control to the encrypted data, such as identity-based encryption or attribute-based encryption and present different methodology to prove their security.

**Literature**

Links to relevant research papers will be given in the course materials.

**Prerequisites / notice**

It is recommended for students to have prior exposure to cryptography, e.g. the D-INFK course "Digital Signatures" or "Applied Cryptography".

**263-4665-00L**

**Zero-Knowledge Proofs**

- W 5 credits

**Abstract**

Zero-knowledge proofs are protocols which allow a prover to convince a verifier that a statement is true without leaking any information beyond that fact. This course is a detailed introduction to zero-knowledge proof protocols.
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics

C. Cotrini Jimenez

The course notes will be written in English.

Prerequisites / notice

Students should have taken a first course in Cryptography (as taught in the Information Security course at Bachelor's level). Experience

with algebra (groups and finite fields) and probability is highly recommended.

Competencies

Subject-specific Competencies

Concepts and Theories

Methods and Techniques

Analytical Competencies

Problem-solving

Personal Competencies

Creative Thinking

Critical Thinking

Objective

-To understand what it means for a zero-knowledge proof to be secure
-To construct and analyse various types of zero-knowledge proofs
-To understand some applications of zero-knowledge proofs

Content

The course will discuss interactive zero-knowledge proofs based on various cryptographic assumptions, and their applications in cryptography and the real world. The course may also describe some more advanced constructions of non-interactive proofs.

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

ECTS

3V+2U+2A

The goal is to make students familiar with fundamental concepts, techniques, and results in combinatorial and computational geometry, so

as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains.

In particular, we want to prepare students for conducting independent research, for instance, within the scope of a thesis project.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

Number

252-0535-00L

Title

Advanced Machine Learning

Type

W

ECTS

10 credits

Hours

3V+2U+4A

Lecturers

C. Cotrini Jimenez

Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:

What is data?

Bayesian Learning

Computational learning theory

Supervised learning:

Ensembles: Bagging and Boosting

Max Margin methods

Neural networks

Unsupervised learning:

Dimensionality reduction techniques

Clustering

Mixture Models

Non-parametric density estimation

Learning Dynamical Systems

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

Number

252-1425-00L

Title

Geometry: Combinatorics and Algorithms

Type

W

ECTS

8 credits

Hours

3V+2U+2A

Lecturers

B. Gärtner, M. Hoffmann, P. Schnider

Abstract

Geometric structures are useful in many areas, and there is a need to understand their structural properties, and to work with them algorithmically. The lecture addresses theoretical foundations concerning geometric structures. Central objects of interest are triangulations. We study combinatorial (Does a certain object exist?) and algorithmic questions (Can we find a certain object efficiently?)

Objective

The goal is to make students familiar with fundamental concepts, techniques and results in combinatorial and computational geometry, so as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains.

In particular, we want to prepare students for conducting independent research, for instance, within the scope of a thesis project.

Content

Planar and geometric graphs, embeddings and their representation (Whitney's Theorem, canonical orderings, DCFL), polygon triangulations and the art gallery theorem, convexity in Rd, planar convex hull algorithms (Jarvis Wrap, Graham Scan, Chan's Algorithm), point set triangulations, Delaunay triangulations (Lawson flips, lifting map, randomized incremental construction), Voronoi diagrams, the Crossing Lemma and incidence bounds, line arrangements (duality, Zone Theorem, ham-sandwich cuts), 3-SUM hardness, counting planar triangulations.

Lecture notes

Yes

 Autumn Semester 2024

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This seminar complements the course "Introduction to Topological Data Analysis". Students get to apply what they learned in the introductory course to concrete projects in the area of topological data analysis. These projects can be of theoretical nature, e.g., the design and analysis of a new algorithm, or applied, such as using methods from topological data analysis on concrete data sets. Successful participation in the course "Introduction to Topological Data Analysis" or equivalent background in topological data analysis is required.

The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

### Elective Courses

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
<th>Literature</th>
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<tr>
<td>227-0417-00L</td>
<td>Information Theory I</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>A. Lapidoth</td>
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<tr>
<td>263-4511-00L</td>
<td>Projects in Topological Data Analysis</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>P. Schnider</td>
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<tr>
<td>263-4513-00L</td>
<td>Structural Graph Theory</td>
<td>W</td>
<td>5</td>
<td>2V+2A</td>
<td>R. M. Steiner</td>
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### Literature

- J. Lengler, B. Häupler, M. Probst

### Prerequisites / notice

- Prerequisites: The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH.
- Outlook: In the following spring semester there is a seminar "Geometry: Combinatorics and Algorithms" that builds on this course. There are ample possibilities for Semester-, Bachelor- and Master Thesis projects in the area.

### Competencies

- Subject-specific Competencies
  - Concepts and Theories: fostered
  - Techniques and Technologies: fostered
- Method-specific Competencies
  - Analytical Competencies: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: assessed
- Social Competencies
  - Communication: assessed
  - Cooperation and Teamwork: assessed

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**Advanced Algorithms**

This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms, sketching and streaming algorithms, and online algorithms.

**Projects in Topological Data Analysis**

This course familiarizes the students with some of the main tools and techniques in modern subareas of algorithm design.

**Structural Graph Theory**

This course covers the basics of Information Theory including Shannon's source coding and channel coding theorems.
This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning. The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the projects work and involve experimental as well as theoretical questions.

**Content**

This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning algorithms. It touches on the following topics:

- concentration bounds
- uniform convergence and empirical process theory
- regularization for non-parametric statistics (e.g. in RKHS, neural networks)
- high-dimensional learning
- computational and statistical learnability (information-theoretic, PAC, SQ)
- overparameterized models, implicit bias and regularization

The project work focuses on current theoretical ML research that aims to understand modern phenomena in machine learning, including but not limited to:

- how overparameterized models generalize (statistically) and converge (computationally)
- generalization of robust learning (adversarial or distribution-shift robustness)
- private and fair learning

**Prerequisites / notice**

Students should have a very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as "Introduction to Machine Learning", "Regression"/ "Statistical Modelling". In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

**Competencies**

Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

- Problem-solving
- Communication
- Cooperation and Teamwork
- Creative Thinking
- Critical Thinking

**Objective**

- understand a good fraction of theory papers published in the typical ML venues. For this purpose, students will learn common mathematical techniques from statistical learning in the first part of the course and apply this knowledge in the project work.
- critically examine recently published work in terms of relevance and find impactful (novel) research problems. This will be an integral part of the project work and involves experimental as well as theoretical questions.
- outline a possible approach to prove a conjectured theorem by e.g. reducing to more solvable subproblems. This will be practiced in personal exercises, homeworks and potentially in the final project
- effectively communicate and present the problem motivation, new insights and results to a technical audience. This will be primarily learned via the final presentation and report as well as during peer-grading of peer talks.

**Literature**

- Graph Coloring and the Probabilistic Method, by M. Molloy and B. Reed, Springer, 2002.
Combining various classical mathematical optimization techniques for linear and combinatorial optimization problems, we aim to develop a good understanding of important problem classes in the field. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered will include (but are not limited to):

- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757. Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

**401-3901-00L Linear & Combinatorial Optimization**

**Content**

- Key topics include:
  - Linear programming and polyhedra;
  - Flows and cuts;
  - Combinatorial optimization problems and polyhedral techniques;
  - Equivalence between optimization and separation.

**Objective**

- The goal of this course is to provide a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

**Prerequisites / notice**

- Students are expected to have a mathematical background and should be able to write rigorous proofs.

**Competencies**

- Subject-specific Competencies: Concepts and Theories - assessed, Techniques and Technologies - fostered
- Method-specific Competencies: Analytical Competencies - assessed, Decision-making - assessed, Media and Digital Technologies - fostered, Problem-solving - assessed
- Social Competencies: Communication - assessed, Cooperation and Teamwork - fostered, Sensitivity to Diversity - fostered
- Personal Competencies: Adaptability and Flexibility - fostered, Creative Thinking - assessed, Critical Thinking - assessed, Integrity and Work Ethics - fostered, Self-awareness and Self-reflection - fostered, Self-direction and Self-management - fostered

**Literature**


**402-0448-01L Quantum Information Processing I: Concepts**

*This course part QIP I together with the experimental part 402-0448-02L QIP II (both offered in the autumn semester) combine to the core course in experimental physics “Quantum Information Processing” (totally 10 ECTS credits). This applies to the Master's degree programme in Physics.*

**Abstract**

The course covers the key concepts and formalism of quantum information processing. Topics include quantum algorithms, quantum error correction, quantum cryptography, and quantum metrology, with an emphasis on the power of quantum information processing beyond that of classical information processing. The formalism of quantum states, measurements, and channels is developed in detail.

**Objective**

- By the end of the course students are expected to explain the basic mathematical formalism of quantum mechanics and apply it to quantum information processing problems. They are able to adapt and apply these concepts and methods to analyze and discuss quantum algorithms and other quantum information-processing protocols.

**Content**

- The topics covered in the course will include quantum circuits, qubit decomposition and universal sets of gates, efficiency of quantum circuits, quantum algorithms (Shor, Grover, Deutsch-Josza,..), stabilizer-based quantum error correction, fault-tolerant designs, the BB84 quantum key distribution protocol, and simple methods of quantum metrology.

**Lecture notes**

Will be provided.

**Literature**

- Quantum Computation and Quantum Information
- Michael Nielsen and Isaac Chuang
- Cambridge University Press

**Prerequisites / notice**

- A good understanding of finite dimensional linear algebra is recommended.
## Core Courses

### 252-0543-01L Computer Graphics

**Abstract**
This course covers fundamental and advanced concepts of modern computer graphics. Students will learn the fundamentals of digital scene representations, advanced physically-based light transport algorithms for generating photorealistic images from these scene representations, and inverse rendering methods for recovering digital scene representations from captured images.

**Objective**
At the end of the course, the students will be able to build a rendering system based on path-tracing algorithms. The students will learn the principles of physically-based rendering and computer graphics. In addition, the course is intended to stimulate the student's curiosity to explore the field of computer graphics in subsequent classes or on their own.

**Content**
We will begin with an introduction to light emission and radiometric quantities, followed by an exploration of geometry representations and texture mapping. Next, we will mathematically formulate the physics of light transport and appearance modeling. Subsequently, we will introduce relevant concepts from Monte Carlo integration and develop path-tracing algorithms to solve these equations by simulating light transport for direct and global illumination due to hard surfaces and participating media, such as fog, smoke, and translucent objects. Moreover, we will present techniques for significantly improving path-tracing efficiency, including importance sampling, multiple importance sampling, stratified sampling, denoising, and acceleration data structures. The course lectures will conclude with an overview of image-based capture and rendering methods. Topics covered will include geometry reconstruction, material acquisition, differentiable rendering, and image-based rendering.

**Lecture notes**
no

**Literature**
Books:
- Physically Based Rendering: From Theory to Implementation
- High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting
- Multiple view geometry in Computer Vision

**Prerequisites**
Prerequisites:
- Fundamentals of calculus and linear algebra, basic concepts of algorithms and data structures, programming skills in C++, and the Visual Computing course are recommended.

**Competencies**
- Subject-specific Competencies: Concepts and Theories, Techniques and Technologies, Analytical Competencies, Decision-making, Media and Digital Technologies, Project Management, Communication, Cooperation and Teamwork, Leadership and Responsibility, Creative Thinking, Critical Thinking, Integrity and Work Ethics, Self-direction and Self-management

**ECTS**
8 credits

**Hours**
3V+2U+2A

**Lecturers**
M. Gross, M. Papas

### 263-5902-00L Computer Vision

**Abstract**
The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

**Objective**
The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

**Content**
Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

**Prerequisites**
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

**ECTS**
8 credits

**Hours**
3V+1U+3A

**Lecturers**
M. Pollefeys, S. Tang, F. Yu

## Elective Courses

### 227-0560-00L Computer Vision and Artificial Intelligence for Autonomous Cars

**Abstract**
This course introduces the core computer vision techniques and algorithms that autonomous cars use to perceive the semantics and geometry of their driving environment, localize themselves in it, and predict its dynamic evolution. Emphasis is placed on techniques tailored for real-world settings, such as multi-modal fusion, domain-adaptive and outlier-aware architectures, and multi-agent methods.
Objective

Students will learn about the fundamentals of autonomous cars and of the computer vision models and methods these cars use to analyze their environment and navigate themselves in it. Students will be presented with state-of-the-art representations and algorithms for semantic, geometric and temporal visual reasoning in automated driving and will gain hands-on experience in developing computer vision algorithms and architectures for solving such tasks.

After completing this course, students will be able to:
1. understand the operating principles of visual sensors in autonomous cars
2. differentiate between the core architectural paradigms and components of modern visual perception models and describe their logic and the role of their parameters
3. systematically categorize the main visual tasks related to automated driving and understand the primary representations and algorithms which are used for solving them
4. critically analyze and evaluate current research in the area of computer vision for autonomous cars
5. practically reproduce state-of-the-art computer vision methods in automated driving
6. independently develop new models for visual perception

Content

The content of the lectures consists in the following topics:

1. Fundamentals
   (a) Fundamentals of autonomous cars and their visual sensors
   (b) Fundamental computer vision architectures and algorithms for autonomous cars

2. Semantic perception
   (a) Semantic segmentation
   (b) Object detection
   (c) Instance segmentation and panoptic segmentation

3. Geometric perception and localization
   (a) Depth estimation
   (b) 3D reconstruction
   (c) Visual localization
   (d) Unimodal visual/lidar 3D object detection

4. Robust perception: multi-modal, multi-domain and multi-agent methods
   (a) Multi-modal 2D and 3D object detection
   (b) Visual grounding and verbo-visual fusion
   (c) Domain-adaptive and outlier-aware semantic perception
   (d) Vehicle-to-vehicle communication for perception

5. Temporal perception
   (a) Multiple object tracking
   (b) Motion prediction

The practical projects involve implementing complex computer vision architectures and algorithms and applying them to real-world, multi-modal driving datasets. In particular, students will develop models and algorithms for:

1. Semantic segmentation and depth estimation
2. Sensor calibration for multi-modal 3D driving datasets
3. 3D object detection using lidars

Lecture notes

Lecture slides are provided in PDF format.

Prerequisites / notice

Students are expected to have a solid basic knowledge of linear algebra, multivariate calculus, and probability theory, and a basic background in computer vision and machine learning. All practical projects will require solid background in programming and will be based on Python and libraries of it such as PyTorch.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies

Communication fostered
Cooperation and Teamwork fostered

Personal Competencies

Creative Thinking assessed
Critical Thinking assessed

252-0546-00L

Physically-Based Simulation in Computer Graphics

W 5 credits 2V+1U+1A S. Coros, B. Thomaszewski

Abstract

This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Objective

This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Content

The lecture covers topics in physically-based modeling, such as particle systems, mass-spring models, finite difference and finite element methods. These approaches are used to represent and simulate deformable objects or fluids with applications in animated movies, 3D games and medical systems. Furthermore, the lecture covers topics such as rigid body dynamics, collision detection, and character animation.

Prerequisites / notice

Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++. Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

263-5905-00L

Mixed Reality

W 5 credits 3G+1A Z. Bauer, C. Holz, M. Pollefeys

Abstract

The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human machine interaction, as well as gaming technology.

Objective

After attending this course, students will:

1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.
The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including: Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introduction to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course are student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/graphics/HMI research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

### Seminar

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<td>W</td>
<td>2</td>
<td>2S</td>
<td>S. Sadosadati, Y. Liang, O. Mutlu</td>
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**Abstract**

In this seminar course, we will cover fundamental and cutting-edge research papers in computer architecture. The course will consist of multiple components that are aimed at improving students’ technical skills in computer architecture, critical thinking and analysis on computer architecture concepts, as well as technical presentation of concepts and papers in both spoken and written forms.

**Objective**

The main objective is to learn how to rigorously analyze and present papers and ideas on computer architecture. We will have rigorous presentation and discussion of selected papers during lectures and a written report delivered by each student at the end of the semester. This course is for those interested in computer architecture. Registered students are expected to attend every lecture, participate in the discussion, and create a synthesis report at the end of the course.

**Content**

Topics will center around computer architecture. We will, for example, discuss papers on hardware security; new execution paradigms like processing in memory; architectural acceleration mechanisms for key applications like machine learning, graph processing and bioinformatics; memory systems; interconnects; various fundamental and emerging paradigms in computer architecture; hardware/software co-design and cooperation; fault tolerance; energy efficiency; heterogeneous and parallel systems; technology scaling; new execution models, etc.

See [https://safari.ethz.ch/architecture_seminar](https://safari.ethz.ch/architecture_seminar) for past examples.

**Lecture notes**

All the materials will be posted on the course website: [https://safari.ethz.ch/architecture_seminar/](https://safari.ethz.ch/architecture_seminar/)

Links to past course materials, including the synthesis report assignment, can be found in this page: [https://safari.ethz.ch/architecture_seminar/](https://safari.ethz.ch/architecture_seminar/)

**Literature**

Key papers and articles, on both fundamentals and cutting-edge topics in computer architecture will be provided and discussed. These will be posted on the course website.

See [https://safari.ethz.ch/architecture_seminar/](https://safari.ethz.ch/architecture_seminar/)

**Prerequisites / notice**

Digital Design and Computer Architecture OR Digital Circuits / Computer Engineering

Students should (1) have done very well in Digital Design and Computer Architecture, Digital Circuits or a similar course and (2) show a genuine interest in Computer Architecture.

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<td>W</td>
<td>4</td>
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<td>M. Brandis</td>
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</table>

**Abstract**

The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

**Objective**

Participants will learn how to analyze and solve IT problems in a systematic way, present findings to decision bodies, and defend their conclusions.

**Content**

Participants understand the different viewpoints for IT-decisions in practice, including technical and business aspects, can effectively analyze IT questions from the different viewpoints and facilitate decision making.

**Prerequisites / notice**

Successful completion of Lecture "Information Technology in Practice".

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Problem-solving
  - Project Management
- Social Competencies
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Negotiation
- Personal Competencies
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

**Prerequisites / notice**

- Good programming skills (C# / C++ / Java etc.)
- Computer graphics/vision experience: Students should have taken, at a minimum, Visual Computing. Higher level courses are recommended, such as Introduction to Computer Graphics, 3D Vision, Computer Vision.
The seminar covers various topics in information security: security protocols (models, specification & verification), trust management, access control, non-interference, side-channel attacks, identity-based cryptography, host-based attack detection, anomaly detection in backbone networks, key-management for sensor networks.

Objective
The main goals of the seminar are the independent study of scientific literature and assessment of its contributions as well as learning and practicing presentation techniques.

Content
The seminar covers various topics in information security, including network security, cryptography and security protocols. The participants are expected to read a scientific paper and present it in a 35-40 min talk. At the beginning of the semester a short introduction to presentation techniques will be given.

Selected Topics
- security protocols: models, specification & verification
- trust management, access control and non-interference
- side-channel attacks
- identity-based cryptography
- host-based attack detection
- anomaly detection in backbone networks
- key-management for sensor networks

Literature
The reading list will be published on the course web site.

252-5051-00L Advanced Topics in Machine Learning

The seminar covers advanced topics in computer vision, such as 3D reconstruction, image understanding, object detection, people tracking, motion prediction, and other related topics. Each time the course is offered, a collection of research papers is selected and each student presents one paper to the class and leads a discussion about the paper and related topics.

Abstract
In this seminar, recent papers of the pattern recognition and machine learning literature are presented and discussed. Possible topics cover statistical models in computer vision, graphical models and machine learning.

Objective
The seminar "Advanced Topics in Machine Learning" familiarizes students with recent developments in pattern recognition and machine learning. Original articles have to be presented and critically reviewed. The participants will learn how to structure a scientific presentation in English which covers the key ideas of a scientific paper. An important goal of the seminar presentation is to summarize the essential ideas of the paper in sufficient depth while omitting details which are not essential for the understanding of the work. The presentation style will play an important role and should reach the level of professional scientific presentations.

Content
The seminar will cover a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from computer vision or bioinformatics - two fields, which relies more and more on machine learning methodology and statistical models.

Literature
The papers will be presented in the first session of the seminar.

263-2100-00L Research Topics in Software Engineering

The seminar covers a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from computer vision or bioinformatics - two fields, which relies more and more on machine learning methodology and statistical models.

Abstract
This seminar covers advanced topics in computer vision, such as 3D reconstruction, image understanding, object detection, people tracking, motion prediction, and other related topics. Each time the course is offered, a collection of research papers is selected covering topics such as 3D reconstruction, image understanding, object detection, people tracking, motion prediction and others. Each student presents one paper to the class and leads a discussion about the paper and related topics.

Objective
The goal is to get an in-depth understanding of actual problems and research topics in the field of computer vision as well as improve presentations and critical analysis skills.

Content
This seminar covers advanced topics in computer vision by reading and presenting classic and state-of-the-art papers. Each time the course is offered, a collection of research papers are selected covering topics such as 3D reconstruction, image understanding, object detection, people tracking, motion prediction and others. Each student presents one paper to the class and leads a discussion about the paper and related topics.

All students read the papers and participate in the discussion.

Literature
Individual research papers are selected each term.

252-5701-00L Seminar in Advanced Topics in Vision

The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
This seminar covers advanced topics in computer vision, such as 3D reconstruction, image understanding, object detection, people tracking, motion prediction, and other related topics. Each time the course is offered, a collection of research papers is selected covering topics such as 3D reconstruction, image understanding, object detection, people tracking, motion prediction and others. Each student presents one paper to the class and leads a discussion about the paper and related topics.

Objective
The goal is to get an in-depth understanding of actual problems and research topics in the field of computer vision as well as improve presentations and critical analysis skills.

Content
This seminar covers advanced topics in computer vision by reading and presenting classic and state-of-the-art papers. Each time the course is offered, a collection of research papers are selected covering topics such as 3D reconstruction, image understanding, object detection, people tracking, motion prediction and others. Each student presents one paper to the class and leads a discussion about the paper and related topics.

All students read the papers and participate in the discussion.

Literature
Individual research papers are selected each term.

263-3504-00L Hardware Acceleration for Data Processing

The seminar covers advanced topics in computer vision, such as 3D reconstruction, image understanding, object detection, people tracking, motion prediction, and other related topics. Each time the course is offered, a collection of research papers are selected covering topics such as 3D reconstruction, image understanding, object detection, people tracking, motion prediction and others. Each student presents one paper to the class and leads a discussion about the paper and related topics.

Abstract
This seminar covers various topics in information security, including network security, cryptography and security protocols. The participants are expected to read a scientific paper and present it in a 35-40 min talk. At the beginning of the semester a short introduction to presentation techniques will be given.

Objective
The main goals of the seminar are the independent study of scientific literature and assessment of its contributions as well as learning and practicing presentation techniques.

Content
The seminar covers various topics in information security, including network security, cryptography and security protocols. The participants are expected to read a scientific paper and present it in a 35-40 min talk. At the beginning of the semester a short introduction to presentation techniques will be given.

Selected Topics
- security protocols: models, specification & verification
- trust management, access control and non-interference
- side-channel attacks
- identity-based cryptography
- host-based attack detection
- anomaly detection in backbone networks
- key-management for sensor networks

Literature
The reading list will be published on the course web site.
The goal of this course is for students to gain a comprehensive understanding of state-of-the-art HCI research on user-centered design. This is a research seminar course where we meet weekly for two-hour discussions on selected papers.

263-3713-00L Advanced Topics in Human-Centric Computer Vision

Objective
The learning objective is to analyze selected research papers published at top computer vision and machine learning venues. A key focus will be on identifying and discussing open problems and novel solutions in this space. The seminar will achieve this via several components: reading papers, technical presentations, writing analysis and critique summaries, class discussions, and exploration of potential research topics.

Content
The goal of the seminar is not only to familiarize students with exciting new research topics, but also to teach basic scientific writing and oral presentation skills. The seminar will have a different structure from regular seminars to encourage more discussion and a deeper learning experience.

We will treat papers as case studies and discuss them in-depth in the seminar. Once per semester, every student will have to take one of the following roles:

Presenter: Give a presentation about the paper that you read in depth.
Reviewer: Perform a critical review of the paper.
All other students: read the paper and submit questions they have about the paper before the presentation.

Prerequisites / notice
Participation will be limited subject to available topics. Furthermore, students will have to submit a motivation paragraph. Participants will be selected based on this paragraph.

Competencies
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<th>Competency Type</th>
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<td>Personal Competencies</td>
<td>Analytical Competencies</td>
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263-4410-00L Seminar on Advanced Graph Algorithms and Optimization

Objective
This seminar aims to familiarize students with current research topics in fast graph algorithms and optimization.

Content
We will study recent papers that made significant contributions in the areas in fast graph algorithms and optimization.

Prerequisites / notice
As prerequisite we require that you passed the course "Advanced Graph Algorithms and Optimization". In exceptional cases, students who passed one of the courses "Randomized Algorithms and Probabilistic Methods", "Optimization for Data Science", or "Advanced Algorithms" may also participate, at the discretion of the lecturer.

Competencies
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<td>Personal Competencies</td>
<td>Analytical Competencies</td>
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263-4902-00L Seminar on User-Centered Programming Interfaces

Abstract
This course introduces students to research topics around the principles and practices of designing user-centered programming interfaces. We will explore and discuss research topics on understanding programmers from specialized domains, interactive programming paradigms, collaborative interfaces, learning-oriented interfaces, and AI's impact on future programming interfaces.

Objective
The goal of this course is for students to gain a comprehensive understanding of state-of-the-art HCI research on user-centered programming interfaces. Additionally, students will develop skills in reading, presenting, summarizing, and critiquing research papers.

Content
This is a research seminar course where we meet weekly for two-hour discussions on selected papers. Students are expected to lead a presentation on the assigned topic and actively participate in the discussions.

Prerequisites / notice
As prerequisite students are expected to lead a presentation on the assigned topic and actively participate in the discussions.

Competencies
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<td>Personal Competencies</td>
<td>Analytical Competencies</td>
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263-5057-00L From Publication to the Doctor’s Office

Abstract
The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Objective
The goal of the seminar is not only to familiarize students with exciting new research topics, but also to teach basic scientific writing and oral presentation skills. The seminar will have a different structure from regular seminars to encourage more discussion and a deeper learning experience.

We will treat papers as case studies and discuss them in-depth in the seminar. Once per semester, every student will have to take one of the following roles:

Presenter: Give a presentation about the paper that you read in depth.
Reviewer: Perform a critical review of the paper.
All other students: read the paper and submit questions they have about the paper before the presentation.

Prerequisites / notice
Participation will be limited subject to available topics. Furthermore, students will have to submit a motivation paragraph. Participants will be selected based on this paragraph.

Competencies
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Abstract

This seminar course is designed to provide students with an opportunity to review and critically evaluate recent publications in medical field focusing on examples when CS method or bioinformatics/statistical technique has lead to an instrumentation, technique or drug approved for clinical practice use.

Objective

Throughout the course, students will read and analyze recent publications that demonstrate successful applications and sometimes failures in medicine. Promising research applications will also be discussed. The publications will cover a wide range of topics, including discovery, image analysis, prognostic models, and learning healthcare.

Content

The course will be structured as half lecture content and half seminar content. Lectures will review state of the medical practice prior to the discovery, obstacles in moving the field forward, and the need for improvement. Lecture will be followed by the seminar part where students will take turns presenting the assigned publications and leading the discussions. Students' presentations will focus on the main findings, and specific steps taken to translate the finding into clinical practice.

Publications will include examples of:
- specific CS/bioinformatics/statistics applications that has been brought to „bedside“ – has been approved by European Medicines Agency / Food and Drug Administration (USA) for clinical use or are widely used in medical research;
- examples of failures of how a discovery did not translate into an endproduct and why;
- current active research areas.

Covered topics will include some of the following:
- Drug discovery: Computer-aided drug discovery has become an integral part of the drug development process, enabling researchers to design and screen large libraries of molecules in silico (i.e., using computer simulations) before synthesizing and testing them in the lab. This has led to the discovery of new drug candidates for a wide range of diseases, including cancer, Alzheimer's disease, and HIV/AIDS.
- Genomics: Advances in computational genomics have enabled researchers to analyze and interpret large-scale genomic data, including DNA sequencing data, to identify disease-causing mutations, genetic risk factors, and drug targets. Examples of the development of personalized medicine, where treatments are tailored to an individual's genetic makeup. Examples when drug target identified by genetics has led to approved treatment.
- Imaging: Computer vision and image processing techniques have revolutionized medical imaging, enabling researchers to extract quantitative information from medical images that were previously inaccessible. This has led to the development of new diagnostic and prognostic tools for a wide range of diseases, including cancer, cardiovascular disease, and neurological disorders.
- Real-world data applications: emulation of clinical trials using electronic health records data.
- Large language models: Generating clinical trial protocols using large language models. Natural Language Processing for information extraction and interpretation.
- Learning healthcare systems: Advances in data analytics and information technology have enabled the development of learning healthcare systems, which use real-time data from electronic health records, medical devices, and other sources to improve patient outcomes and reduce healthcare costs. This has the potential to transform the way healthcare is delivered, making it more personalized, efficient, and effective.

In addition to the presentations, students will also be required to write critical reviews of the assigned publications throughout the course. The reviews will be evaluated based on the students' ability to identify the strengths and weaknesses of the publications and to provide insightful and constructive feedback.

Prerequisites / notice

The course is intended for advanced undergraduate and graduate students with a background in computer science, bioinformatics, or a related field and interest in applying their skills to medical research.

This course assumes a working knowledge of R/Python and intermediate statistical analysis, including linear, logistic, survival regressions or ability and interest to learn them outside of the class.

Competencies

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<th>Method-specific Competencies</th>
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263-5100-00L Topics in Medical Machine Learning

The deadline for deregistering expires at the end of the fourth week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract

This seminar discusses recent relevant contributions to the fields of medical machine learning and related areas. Each participant will hold a presentation and lead the subsequent discussion.

Objective

Preparing and holding a scientific presentation in front of peers is a central part of working in the scientific domain. In this seminar, the participants will learn how to efficiently summarize the relevant parts of a scientific publication, critically reflect its contents, and summarize it for presentation to an audience. The necessary skills to successfully present the key points of existing research work are the same as those needed to communicate own research ideas. In addition to holding a presentation, each student will both contribute to as well as lead a discussion section on the topics presented in the class.

Content

The topics covered in the seminar are related to recent computational challenges that arise in the medical field, including but not limited to clinical data analysis, interpretable machine learning, privacy considerations, statistical frameworks, etc. Both recently published works contributing novel ideas to the areas mentioned above as well as seminal contributions from the past are on the list of selected papers. Publications will include examples of:
- examples of failures of how a discovery did not translate into an endproduct and why;
- current active research areas.

263-5702-00L Seminar on Digital Humans

The deadline for deregistering expires at the end of the third week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract

This seminar covers advanced topic in digital humans with a focus on the latest research results. Topics include estimating human pose and motion from images, human motion synthesis, learning-based human avatar creation, learning neural implicit representations for humans, modeling, animations, artificial intelligence for digital characters, and others. A collection of research papers is selected.

Objective

The goal is to get an overview of actual research topics in the field of digital humans and to improve presentation and critical analysis skills.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1423 of 2653
Content

This seminar covers advanced topics in digital humans including both seminal research papers as well as the latest research results. A collection of research papers are selected covering topics such as estimating human pose and motion from images, human motion synthesis, learning-based human avatar creation, learning neural implicit representations for humans, modeling, animations, artificial intelligence for digital characters, and others. Each student presents one paper to the class and leads a discussion about the paper. All students read the papers and participate in the discussion.

Literature

Individual research papers are selected each term. See https://vlg.inf.ethz.ch/, https://igl.ethz.ch/, and http://graphics.ethz.ch/ for example papers.

Combinatorial Skills

Method-specific Competencies

Analytical Competencies

Social Competencies

Communication

Personal Competencies

Critical Thinking

Practical Work

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<tr>
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<td>8</td>
<td>7P</td>
<td>D. Basin</td>
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</table>

Abstract

Hands-on course on applied aspects of information security. Applied information security, operating system security, OS hardening, computer forensics, web application security, project work, design, implementation, and configuration of security mechanisms, risk analysis, system review.

Objective

The Applied Security Laboratory addresses four major topics: operating system security (hardening, vulnerability scanning, access control, logging), application security with an emphasis on web applications (web server setup, common web exploits, authentication, session handling, code security), computer forensics, and risk analysis and risk management.

Content

This course emphasizes applied aspects of Information Security. The students will study a number of topics in a hands-on fashion and carry out experiments in order to better understand the need for secure implementation and configuration of IT systems and to assess the effectiveness and impact of security measures. This part is based on a book and virtual machines that include example applications, questions, and answers.

The students will also complete an independent project; based on a set of functional requirements, they will design and implement a prototypical IT system. In addition, they will conduct a thorough security analysis and devise appropriate security measures for their systems. Finally, they will carry out a technical and conceptual review of another system. All project work will be performed in teams and must be properly documented.

Lecture notes

The course is based on the book "Applied Information Security - A Hands-on Approach". More information:

http://www.infsec.ethz.ch/appliedlabbook

Literature

Recommended reading includes:

* Various: OWASP Guide to Building Secure Web Applications, available online
* O'Reilly, Loukides: Unix Power Tools, O'Reilly & Associates.
* Frisch: Essential System Administration, O'Reilly & Associates.
* NIST: Risk Management Guide for Information Technology Systems, available online as PDF
* BSI: IT-Grundschutzhandbuch, available online

Prerequisites

* The lab allows flexible working since there are only few mandatory meetings during the semester.
* The lab covers a variety of different techniques. Thus, participating students should have a solid foundation in the following areas: information security, operating system administration (especially Unix/Linux), and networking. Students are also expected to have a basic understanding of HTML, PHP, JavaScript, and MySQL because several examples are implemented in these languages.
* Students must be prepared to spend more than three hours per week to complete the lab assignments and the project. This applies particularly to students who do not meet the recommended requirements given above. Successful participants of the course receive 8 credits as compensation for their effort.
* All participants must sign the lab's charter and usage policy during the introduction lecture.

Minors

Minors in Computer Graphics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0543-01L</td>
<td>Computer Graphics</td>
<td>W</td>
<td>8</td>
<td>3V+2U+2A</td>
<td>M. Gross, M. Papas</td>
</tr>
</tbody>
</table>

Abstract

This course covers fundamental and advanced concepts of modern computer graphics. Students will learn the fundamentals of digital scene representations, advanced physically-based light transport algorithms for generating photorealistic images from these scene representations, and inverse rendering methods for recovering digital scene representations from captured images.

Objective

At the end of the course, the students will be able to build a rendering system based on path-tracing algorithms. The students will learn the principles of physically-based rendering and computer graphics. In addition, the course is intended to stimulate the student's curiosity to explore the field of computer graphics in subsequent classes or on their own.

Content

We will begin with an introduction to light emission and radiometric quantities, followed by an exploration of geometry representations and texture mapping. Next, we will mathematically formulate the physics of light transport and appearance modeling. Subsequently, we will introduce relevant concepts from Monte Carlo integration and develop path-tracing algorithms to solve these equations by simulating light transport for direct and global illumination due to hard surfaces and participating media, such as fog, smoke, and translucent objects. Moreover, we will present techniques for significantly improving path-tracing efficiency, including importance sampling, multiple importance sampling, stratified sampling, denoising, and acceleration data structures. The course lectures will conclude with an overview of image-based capture and rendering methods. Topics covered will include geometry reconstruction, material acquisition, differentiable rendering, and image-based rendering.

Lecture notes

No
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Literature
Books:
- Physically Based Rendering: From Theory to Implementation
- High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting
- Multiple view geometry in Computer Vision

Prerequisites / notice
Prerequisites:
- Fundamentals of calculus and linear algebra, basic concepts of algorithms and data structures, programming skills in C++, and the Visual Computing course are recommended.
- The programming assignments will be in C++. This will not be taught in the class.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management
Social Competencies
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-direction and Self-management

252-0546-00L Physically-Based Simulation in Computer Graphics W 5 credits 2V+1U+1A S. Coros, B. Thomaszewski

Abstract
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Objective
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Content
The lecture covers topics in physically-based modeling, such as particle systems, mass-spring models, finite difference and finite element methods. These approaches are used to represent and simulate deformable objects or fluids with applications in animated movies, 3D games and medical systems. Furthermore, the lecture covers topics such as rigid body dynamics, collision detection, and character animation.

Prerequisites / notice
Prerequisites:
- Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++. Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

263-5905-00L Mixed Reality W 5 credits 3G+1A Z. Bauer, C. Holz, M. Pollefeys

Abstract
The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human machine interaction, as well as gaming technology.

Objective
After attending this course, students will:
1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.

Content
The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including: Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introduction to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course is student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/plots/graphics/HMI research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

Prerequisites / notice
Prerequisites include:
- Good programming skills (C# / C++ / Java etc.)
- Computer graphics/vision experience: Students should have taken, at a minimum, Visual Computing. Higher level courses are recommended, such as Introduction to Computer Graphics, 3D Vision, Computer Vision.

Minor in Computer Vision

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0560-00L</td>
<td>Computer Vision and Artificial Intelligence for Autonomous Cars Up until FS2022 offered as Deep Learning for Autonomous Driving</td>
<td>W</td>
<td>6</td>
<td>3V+2P</td>
<td>C. Sakardis</td>
</tr>
</tbody>
</table>

Abstract
This course introduces the core computer vision techniques and algorithms that autonomous cars use to perceive the semantics and geometry of their driving environment, localize themselves in it, and predict its dynamic evolution. Emphasis is placed on techniques tailored for real-world settings, such as multi-modal fusion, domain-adaptive and outlier-aware architectures, and multi-agent methods.

Objective
Students will learn about the fundamentals of autonomous cars and of the computer vision models and methods these cars use to analyze their environment and navigate themselves in it. Students will be presented with state-of-the-art representations and algorithms for semantic, geometric and temporal visual reasoning in automated driving and will gain hands-on experience in developing computer vision algorithms and architectures for solving such tasks.

After completing this course, students will be able to:
1. understand the operating principles of visual sensors in autonomous cars
2. differentiate between the core architectural paradigms and components of modern visual perception models and describe their logic and the role of their parameters
3. systematically categorize the main visual tasks related to automated driving and understand the primary representations and algorithms which are used for solving them
4. critically analyze and evaluate current research in the area of computer vision for autonomous cars
5. practically reproduce state-of-the-art computer vision methods in automated driving
6. independently develop new models for visual perception
Content

The content of the lectures consists in the following topics:

1. Fundamentals
   (a) Fundamentals of autonomous cars and their visual sensors
   (b) Fundamental computer vision architectures and algorithms for autonomous cars

2. Semantic perception
   (a) Semantic segmentation
   (b) Object detection
   (c) Instance segmentation and panoptic segmentation

3. Geometric perception and localization
   (a) Depth estimation
   (b) 3D reconstruction
   (c) Visual localization
   (d) Unimodal visual/lidar 3D object detection

4. Robust perception: multi-modal, multi-domain and multi-agent methods
   (a) Multi-modal 2D and 3D object detection
   (b) Visual grounding and verbo-visual fusion
   (c) Domain-adaptive and outlier-aware semantic perception
   (d) Vehicle-to-vehicle communication for perception

5. Temporal perception
   (a) Multiple object tracking
   (b) Motion prediction

The practical projects involve implementing complex computer vision architectures and algorithms and applying them to real-world, multi-modal driving datasets. In particular, students will develop models and algorithms for:

1. Semantic segmentation and depth estimation
2. Sensor calibration for multi-modal 3D driving datasets
3. 3D object detection using lidars

Lecture notes
Lecture slides are provided in PDF format.

Prerequisites / notice
Students are expected to have a solid basic knowledge of linear algebra, multivariate calculus, and probability theory, and a basic background in computer vision and machine learning. All practical projects will require solid background in programming and will be based on Python and libraries of it such as PyTorch.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

263-3210-00L Deep Learning W 8 credits 3V+2U+2A T. Hofmann

Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

  Advanced Machine Learning
  https://ml2.inf.ethz.ch/courses/aml/

  Computational Intelligence Lab
  http://da.inf.ethz.ch/teaching/2019/CIL/

  Introduction to Machine Learning
  https://las.inf.ethz.ch/teaching/introml-S19

  Statistical Learning Theory
  http://ml2.inf.ethz.ch/courses/stt/

  Computational Statistics
  https://stat.ethz.ch/lectures/ss19/comp-stats.php

  Probabilistic Artificial Intelligence
  https://las.inf.ethz.ch/teaching/pai-f18

263-5902-00L Computer Vision W 8 credits 3V+1U+3A M. Pollefeys, S. Tang, F. Yu

Abstract
The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.
Objective

The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition.

Prerequisites / notice

It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

263-5905-00L Mixed Reality

Title

The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human machine interaction, as well as gaming technology.

Objective

After attending this course, students will:
1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.

Content

The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including: Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introduction to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course are student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/graphics/HMI research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

Prerequisites / notice

Prerequisites include:
- Good programming skills (C# / C++ / Java etc.)
- Computer graphics/vision experience: Students should have taken, at a minimum, Visual Computing. Higher level courses are recommended, such as Introduction to Computer Graphics, 3D Vision, Computer Vision.

Minor in Data Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10 credits</td>
<td>3V+2U+4A</td>
<td>C. Cotrini Jimenez</td>
</tr>
</tbody>
</table>

Objective

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Content

Topics covered in the lecture include:
- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory
- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Literature

No lecture notes, but slides will be made available on the course webpage.


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

263-2800-00L Design of Parallel and High-Performance Computing

Objective

Advanced topics in parallel and high-performance computing.

Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of cache and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

<table>
<thead>
<tr>
<th>263-3010-00L</th>
<th>Big Data</th>
<th>W 10 credits 3V+2U+4A</th>
<th>G. Fourny</th>
</tr>
</thead>
</table>
**Abstract**  | The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations."

"Big Data" refers to the case when the amount of data is very large (100 GB and more), or when the data is not completely structured (or messy). The Big Data revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it are needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each one of your projects efficiently and consistently.

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage(S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems ( ?, * , + )
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Large scale analytics and machine learning are outside of the scope of this course.

Course textbook: https://ghislainfourny.github.io/big-data-textbook/

Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

The lecture is hybrid, meaning you can attend with us in the lecture hall, or on Zoom, or watch the recordings on YouTube later. Exercise sessions are in presence.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departments interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2023

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations. In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This course will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/pai-f18/

Statistical Learning Theory
http://m2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/ss19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18/

The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

This is the course where you get credit points by building some of the most advanced exploits on the planet! The luckiest team will collect a Best Demo Award at the end of the course.

- security problems of commodity hardware that we use everyday and how you can defend against them.
- relevant computer architecture and operating system aspects of these issues.
- hands-on techniques for performing hardware attacks.

This is the course where you get credit points by building some of the most advanced exploits on the planet! The luckiest team will collect a Best Demo Award at the end of the course.

Slides, relevant literature and manuals will be made available during the course.
Prerequisites / notice

Experience with Linux, low-level systems programming and computer architecture.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>fostered</td>
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<td></td>
<td>Media and Digital Technologies</td>
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<td></td>
<td>Problem-solving</td>
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<td></td>
<td>Project Management</td>
<td>fostered</td>
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<tr>
<td>Social Competencies</td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Creative Thinking</td>
<td>fostered</td>
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<td>Critical Thinking</td>
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<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
</tr>
</tbody>
</table>

252-0463-00L Security Engineering W 7 credits 2V+2U+2A D. Basin, S. Krstic

Abstract

Subject of the class are engineering techniques for developing secure systems. We examine concepts, methods and tools, applied within the different activities of the SW development process to improve security of the system. Topics: security requirements & risk analysis, system modeling & model-based development methods, implementation-level security, and evaluation criteria for secure systems.

Objective

Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software.

Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems.
Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software. Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include:

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems

Modules taught:

1. Introduction
   - Introduction of Infsec group and speakers
   - Security meets SW engineering: an introduction
   - The activities of SW engineering, and where security fits in
   - Overview of this class
2. Requirements Engineering: Security Requirements and some Analysis
   - Overview: functional and non-functional requirements
   - Use cases, misuse cases, sequence diagrams
   - Safety and security
3. Modeling in the design activities
   - Structure, behavior, and data flow
   - Class diagrams, statecharts
4. Model-driven security for access control (Part I)
   - SecureUML as a language for access control
   - Combining Design Modeling Languages with SecureUML
   - Semantics, i.e., what does it all mean,
   - Generation
   - Examples and experience
5. Model-driven security (Part II)
   - Continuation of above topics
6. Security patterns (design and implementation)
7. Implementation-level security
   - Buffer overflows
   - Input checking
   - Injection attacks
8. Code scanning
   - Static code analysis basics
   - Theoretical and practical challenges
   - Analysis algorithms
   - Common bug pattern search and specification
   - Dataflow analysis
9. Testing
   - Overview and basics
   - Model-based testing
   - Testing security properties
10. Risk analysis and management
   - "Risk": assets, threats, vulnerabilities, risk
   - Risk assessment: quantitative and qualitative
   - Safeguards
   - Generic risk analysis procedure
   - The OCTAVE approach
   - Example of qualitative risk assessment
11. Threat modeling
    - Overview
    - Safety engineering basics: FMEA and FTA
    - Security impact analysis in the design phase
    - Modeling security threats: attack trees
    - Examples and experience
12. Evaluation criteria
    - NIST special papers
    - ISO/IEC 27000
    - Common criteria
    - BSI baseline protection
13. Guest lecture
    - TBA

Literature

- Further relevant books and journal/conference articles will be announced in the lecture.

Prerequisites / notice

Prerequisite: Class on Information Security

252-1411-00L Security of Wireless Networks

Abstract

This course discusses physical layer aspects of wireless communication and a wide range of security-related topics in the domain of wireless technologies. It mainly targets computer science students. Though useful, a background in signal processing or physical layer concepts is not required. A basic understanding of security (e.g. as taught in 252-0211.00L Information Security) is recommended.

Objective

After this course, students should be able to describe and classify security goals of and attacks on various wireless networks and technologies, with an emphasis on physical layer aspects.
Content
- Introduction to wireless communication
- Physical layer security schemes
- Spreading techniques and their application in jamming-resilient communication and Global Navigation Satellite Systems (GNSSs)
- Secure ranging with Ultra-Wide Band (UWB)
- Security aspects of cellular networks, WiFi, and Bluetooth Low Energy (BLE)

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Social Competencies
- Cooperation and Teamwork

Personal Competencies
- Critical Thinking

252-1414-00L System Security W 7 credits 2V+2U+2A S. Capkun, S. Shinde
Abstract
The first part of the course covers general security concepts and hardware-based support for security. In the second part, the focus is on system design and methodologies for building secure systems.

Objective
In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

Content
The first part of the lecture covers hardware-based security concepts. Topics include the concept of physical and software-based side channel attacks on hardware resources, architectural support for security (e.g., memory management and permissions, disk encryption), and trusted execution environments (Intel SGX, ARM TrustZone, AMD SEV, and RISC- V Keystone).

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: common software faults (e.g., buffer overflows, etc.), bug-detection, writing secure software (design, architecture, QA, testing), compiler-supported security (e.g., control-flow integrity), and language-supported security (e.g., memory safety).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Social Competencies
- Communication

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking

263-4640-00L Network Security W 8 credits 2V+2U+3A P. De Vaere, S. Frei, K. Paterson, A. Perrig
Abstract
Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems. This course provides an in-depth study of network attack techniques and methods to defend against them.

Objective
- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

Content
The course will cover topics spanning four broad themes with a focus on the first two themes:
1. network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. analysis and inference topics such as traffic monitoring and network forensics; and
4. new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

Prerequisites / notice
This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course. The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.
Public-Key Encryption has had a significant impact by enabling remote parties to communicate securely via an insecure channel. Latest schemes go further by providing a fine-grained access to the encrypted data. The student is comfortable with formal security definitions and proof techniques used to analyze the security of the latest encryption schemes with advanced features. This prepares the student to start reading research papers on the field.

Privacy is a fundamental human right! And yet, technological advances (in particular in computer science) can often undermine privacy. In this class we will see how to formalize various notions of privacy and how to build systems that preserve privacy, by combining techniques from cryptography and statistics. The later parts of the course will focus on applications to machine learning.

Zero-knowledge proofs are protocols which allow a prover to convince a verifier that a statement is true without leaking any information beyond that fact. This course is a detailed introduction to zero-knowledge proof protocols.

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.
Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real-world data.

Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- **Fundamentals:**
  - What is data?
  - Bayesian Learning
  - Computational learning theory
- **Supervised learning:**
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
- **Unsupervised learning:**
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least “Introduction to Machine Learning” or an equivalent course offered by another institution. PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
Content

The course is split into 4 parts:

**Robustness of Machine Learning**

- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

**Privacy of Machine Learning**

- Threat models (e.g., stealing data, poisoning, membership inference, etc.).
- Attacking federated machine learning (across vision, natural language and tabular data).
- Differential privacy for defending machine learning.
- AI Regulations and checking model compliance.

**Fairness of Machine Learning**

- Introduction to fairness (motivation, definitions).
- Enforcing individual fairness (for both vision and tabular data).
- Enforcing group fairness (e.g., demographic parity, equalized odds).

**Robustness, Privacy and Fairness of Foundation Models**

- We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).


**Prerequisites / notice**

While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in “Intro to ML” classes at most institutions (e.g., “Introduction to Machine Learning” at ETH).

The coding project will utilize Python and PyTorch. Thus some programming experience in Python is expected. Students without prior knowledge of PyTorch are expected to acquire it early in the course by solving exercise sheets.

Competencies

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263-3210-00L **Deep Learning**

Abstract

Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective

In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice

This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

  Advanced Machine Learning
  https://ml2.inf.ethz.ch/courses/aml/

  Computational Intelligence Lab
  http://da.inf.ethz.ch/teaching/2019/CIL/

  Introduction to Machine Learning
  https://las.inf.ethz.ch/teaching/introml-S19

  Statistical Learning Theory
  http://ml2.inf.ethz.ch/courses/slt/

  Computational Statistics
  https://stat.ethz.ch/lectures/ss19/comp-stats.php

  Probabilistic Artificial Intelligence
  https://las.inf.ethz.ch/teaching/pai-f18

263-5005-00L **Artificial Intelligence in Education**

Abstract

Artificial Intelligence (AI) methods have shown to have a profound impact in educational technologies, where the great variety of tasks and data types enable us to get benefit of AI techniques in many different ways. We will review relevant methods and applications of AI in various educational technologies, and work on problem sets and projects to solve problems in education with the help of AI.

Objective

The course will be centered around exploring methodological and system-focused perspectives on designing AI systems for education and analyzing educational data using AI methods. Students will be expected to a) engage in presentations and active in-class and asynchronous discussion, and b) work on problem-sets exemplifying the use of educational data mining techniques.
The course will start with an introduction to data mining techniques (e.g., prediction, structured discovery, visualization, and relationship mining) relevant to analyzing educational data. We will then continue with topics on personalization in AI in educational technologies (e.g., learner modeling and knowledge tracing, self-improving AIED systems) while showcasing exemplary applications in areas such as content curation and dialog-based tutoring. Finally, we will cover ethical challenges associated with using AI in student-facing settings. Face-to-face meetings will be held every fortnight, although students will be expected to work individually on weekly tasks (e.g., discussing relevant literature, working on problems, preparing seminar presentations).

Lecture slides will be made available at the course Web site.

No textbook is required, but there will be regularly assigned readings from research literature, linked to the course website.

There are no prerequisites for this class. However, it will help if the student has taken an undergraduate or graduate level class in statistics, data science or machine learning. This class is appropriate for advanced undergraduates and master students in Computer Science as well as PhD students in other departments.

**263-5056-00L Applications of Deep Learning on Graphs**

**Objective**

This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

**Content**

Many established deep learning methods require dense input data with a well-defined structure (e.g. an image, a sequence of word embeddings). However, many practical applications deal with sparsely connected and complex data structures, such as molecules, knowledge graphs or social networks. Graph Neural Networks (GNNs) and general representation learning on graphs have recently experienced a surge in popularity because it addresses the challenge to effectively learn representations over said structures. In this course, we aim to understand the fundamental principles of deep (representation) learning on graphs, the similarities and differences to other concepts in deep learning, as well as the unique challenges from a practical point of view. Finally, we provide an overview of recent applications of graph neural networks.

**Prerequisites / notice**

263-3210-00 Deep Learning or 263-0008-00 Computational Intelligence Lab;
252-0220-00 Introduction to Machine Learning; Statistics/Probability; Programming in Python; Unix Command Line.

**263-5210-00L Probabilistic Artificial Intelligence**

**Objective**

How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

**Content**

Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

**Prerequisites / notice**

Solid basic knowledge in statistics, algorithms and programming.

**Competencies**

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management
- Communication
- Cooperation and Teamwork
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

**263-5300-00L Guarantees for Machine Learning**

**Objective**

By the end of the semester students should be able to

- understand a good fraction of theory papers published in the typical ML venues. For this purpose, students will learn common mathematical techniques from statistical learning in the first part of the course and apply this knowledge in the project work
- critically examine recently published work in terms of relevance and find impactful (novel) research problems. This will be an integral part of the project work and involves experimental as well as theoretical questions
- outline a possible approach to prove a conjectured theorem by e.g. reducing to more solvable subproblems. This will be practiced in in-person exercises, homeworks and potentially in the final project
- effectively communicate and present the problem motivation, new insights and results to a technical audience. This will be primarily learned via the final presentation and report as well as during peer-grading of peer talks.
This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning algorithms. It touches on the following topics:

- concentration bounds
- uniform convergence and empirical process theory
- regularization for non-parametric statistics (e.g., in RKHS, neural networks)
- high-dimensional learning
- computational and statistical learnability (information-theoretic, PAC, SQ)
- overparameterized models, implicit bias and regularization

The project work focuses on current theoretical ML research that aims to understand modern phenomena in machine learning, including but not limited to:

- how overparameterized models generalize (statistically) and converge (computationally)
- complexity measures and approximation theoretic properties of randomly initialized and trained neural networks
- generalization of robust learning (adversarial or distribution-shift robustness)
- private and fair learning

Students should have a very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as "Introduction to Machine Learning", "Regression", "Statistical Modelling". In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

### Prerequisites / notice

The course will be composed of lectures and practical exercises (some of which including labs).

Lecture notes

Lecture notes and material will be made available before each course on the course website.

Literature

Relevant references will be made available through the course website.

Prerequisites / notice

Prerequisites: Communication Networks (227-0120-00L) or equivalents / programming skills (in any language) are expected (some of the exercises will involve coding).
After this course, students should be able to describe and classify security goals of and attacks on various wireless networks and technologies, with an emphasis on physical layer aspects.

The course will cover topics spanning four broad themes with a focus on the first two themes:

1. Network defense mechanisms such as public-key infrastructures, TLS, VPs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. Network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. Analysis and inference topics such as traffic monitoring and network forensics; and

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

### Security of Wireless Networks

**W 6 credits 2V+1U+2A S. Capkun, K. Kostiainen**

**Abstract**
This course discusses physical layer aspects of wireless communication and a wide range of security-related topics in the domain of wireless technologies. It mainly targets computer science students. Though useful, a background in signal processing or physical layer concepts is not required. A basic understanding of security (e.g. as taught in 252-0211-00L Information Security) is recommended.

**Objective**
After this course, students should be able to describe and classify security goals of and attacks on various wireless networks and technologies, with an emphasis on physical layer aspects.

**Content**
- Introduction to wireless communication
- Physical layer security schemes
- Spreading techniques and their application in jamming-resistant communication and Global Navigation Satellite Systems (GNSSs)
- Secure ranging with Ultra-Wide Band (UWB)
- Security aspects of cellular networks, WiFi, and Bluetooth Low Energy (BLE)

### Network Security

**W 8 credits 2V+2U+3A P. De Vaere, S. Frei, K. Paterson, A. Perrig**

**Abstract**
Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems. This course provides an in-depth study of network attack techniques and methods to defend against them.

**Objective**
- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

**Content**
The course will cover topics spanning four broad themes with a focus on the first two themes:

1. Network defense mechanisms such as public-key infrastructures, TLS, VPs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. Network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. Analysis and inference topics such as traffic monitoring and network forensics; and

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

**Prerequisites / notice**
This course is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course. The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.
Course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object and class initialization, program correctness, reflection.

After this course, students will:
- Have a deep understanding of advanced concepts of object-oriented programming and their support through various language features.
- Be able to understand language concepts at a semantic level and be able to compare and evaluate language designs.
- Be able to learn new languages more rapidly.
- Be aware of many subtle problems of object-oriented programming and know how to avoid them.

The main goal of this course is to convey a deep understanding of the key concepts of sequential object-oriented programming and their support in different programming languages. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.

The topics discussed in the course include among others:
- The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing)
- The key problems of single and multiple inheritance and how different languages address them.
- Generic type systems, in particular, Java generics, C# generics, and C++ templates.
- The situations in which object-oriented programming does not provide encapsulation, and how to avoid them.
- The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing.
- How to maintain the consistency of data structures.

Creating reliable, secure, robust, and fair machine learning models is a core challenge in artificial intelligence and one of fundamental importance. The goal of the course is to teach both the mathematical foundations of this new and emerging area as well as to introduce students to the latest and most exciting research in the space.

The course is split into 4 parts:
- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

Creating reliable, secure, robust, and fair machine learning models is a core challenge in artificial intelligence and one of fundamental importance. The goal of the course is to teach both the mathematical foundations of this new and emerging area as well as to introduce students to the latest and most exciting research in the space.

The course is split into 4 parts:
- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

Privacy of Machine Learning
- Threat models (e.g., stealing data, poisoning, membership inference, etc.).
- Differential privacy for defending machine learning.
- AI Regulations and checking model compliance.

Fairness of Machine Learning
- Introduction to fairness (motivation, definitions).
- Enforcing individual fairness (for both vision and tabular data).
- Enforcing group fairness (e.g., demographic parity, equalized odds).

Robustness, Privacy and Fairness of Foundation Models
- We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).


The coding project will utilize Python and PyTorch. Thus some programming experience in Python is expected. Students without prior knowledge of PyTorch are expected to acquire it early in the course by solving exercise sheets.

While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in "Intro to ML" classes at most institutions (e.g., "Introduction to Machine Learning" at ETH).
The course will proceed in two parallel tracks:

- The theory track (2V) will introduce operational semantics, type systems, and type soundness proofs, starting with the simply-typed lambda calculus and then continuing with increasingly expressive languages.

- The Coq track (2G) will begin with an introduction to machine-checked proofs and the Coq proof assistant. Afterwards we will mechanize the theory developed in the first track. This is the hands-on part of the course; students will carry out these proofs in Coq themselves with instructions from the lecturer.

Lecture notes
Will be made available on the course website.

Literature
Will be announced in the lecture.

Prerequisites / notice
A basic familiarity with propositional and first-order logic will be assumed. Courses with an emphasis on formal reasoning about programs (such as Formal Methods and Functional Programming) are advantageous background, but are not a requirement.

Competencies

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263-2800-00L Design of Parallel and High-Performance Computing

Abstract
Advanced topics in parallel and high-performance computing.

Objective
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Foster parallel thinking and foster ability to work in groups.

Content
The first half of the class will cover topics from cryptography such as secure multiparty computation, zero-knowledge proofs, PIR, ORAM. In this class we will see how to formalize various notions of privacy and how to build systems that preserve privacy, by combining techniques from cryptography and statistics.

The second part, the focus is on system design and methodologies for building secure systems. Topics include: common software faults and trusted execution environments (Intel SGX, ARM TrustZone, AMD SEV, and RISC-V). Become familiar with important technical concepts and with concurrency folklore.

The first half of the class will cover topics from cryptography such as secure multiparty computation, zero-knowledge proofs, PIR, ORAM, anonymous communication, etc. The first half of the class will cover topics from cryptography such as secure multiparty computation, zero-knowledge proofs, PIR, ORAM, anonymous communication, etc. The second half will cover statistical notions of privacy, in particular differential privacy, and selected topics in machine learning privacy.

Prerequisites / notice
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

263-4658-00L Privacy Enhancing Technologies

Abstract
Privacy is a fundamental human right! And yet, technological advances (in particular in computer science) can often undermine privacy. In this class we will see how to formalize various notions of privacy and how to build systems that preserve privacy, by combining techniques from cryptography and statistics.

Objective
By the end of the course, students will be able to:
- Reason about privacy concerns and the appropriate formalizations
- Combine tools from cryptography and statistics to build privacy mechanisms
- Assess, evaluate and prove privacy protection of a mechanism.

Content
The first half of the class will cover topics from cryptography such as secure multiparty computation, zero-knowledge proofs, PIR, ORAM, anonymous communication, etc. The first half of the class will cover topics from cryptography such as secure multiparty computation, zero-knowledge proofs, PIR, ORAM, anonymous communication, etc. The second half will cover statistical notions of privacy, in particular differential privacy, and selected topics in machine learning privacy.

Lecture notes
Lecture notes will be posted on Moodle.

Literature
Boneh & Shoup - A Graduate Course in Applied Cryptography
References to relevant research papers will be provided.

Prerequisites / notice
Basic knowledge in cryptography, probability and machine learning is recommended but not required.

Minor in Systems Software

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<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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263-2800-00L Design of Parallel and High-Performance Computing

Abstract
Advanced topics in parallel and high-performance computing.

Objective
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Foster parallel thinking and foster ability to work in groups.

Content
The first half of the class will cover topics from cryptography such as secure multiparty computation, zero-knowledge proofs, PIR, ORAM, anonymous communication, etc. The first half of the class will cover topics from cryptography such as secure multiparty computation, zero-knowledge proofs, PIR, ORAM, anonymous communication, etc. The second half will cover statistical notions of privacy, in particular differential privacy, and selected topics in machine learning privacy.

Prerequisites / notice
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

T. Hoefler

Data: 15.06.2024 12:39
Autumn Semester 2024
Page 1440 of 2653
Objective
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

Content
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

Prerequisites / notice
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

263-3845-00L Data Management Systems W 8 credits 3V+1U+3A G. Alonso

Abstract
The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.

Objective
The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.

Content
The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understanding these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

Literature
The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

Prerequisites / notice
The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Minor in Theoretical Computer Science

Number Title Type ECTS Hours Lecturers
227-0417-00L Information Theory I W 6 credits 4G A. Lapidoth

Abstract
This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

Objective
The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

Content
The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

Literature
T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

252-0535-00L Advanced Machine Learning W 10 credits 3V+2U+4A C. Cottrini Jimenez

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensible to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
What is data?
Bayesian Learning
Computational learning theory
Supervised learning:
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks
Unsupervised learning:
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation
Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution. PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

Prerequisites / notice

252-1425-00L Geometry: Combinatorics and Algorithms W 8 credits 3V+2U+2A B. Gärtner, M. Hoffmann, P. Schnider

Abstract

Geometric structures are useful in many areas, and there is a need to understand their structural properties, and to work with them algorithmically. The lecture addresses theoretical foundations concerning geometric structures. Central objects of interest are triangulations. We study combinatorial (Does a certain object exist?) and algorithmic questions (Can we find a certain object efficiently?)

Objective

The lectures build on students' fundamental concepts, techniques and results in combinatorial and computational geometry, and extend them by making them applicable to various application domains. In particular, we want to prepare students for conducting independent research, for instance, within the scope of a thesis project.

Content

Planar and geometric graphs, embeddings and their representation (Whitney's Theorem, canonical orderings, DCEL), polygon triangulations and the art gallery theorem, convexity in R^d, planar convex hull algorithms, point set triangulations, Delaunay triangulations (Lawson flips, lifting map, randomized incremental construction), Voronoi diagrams, the Crossing Lemma and incidence bounds, line arrangements (duality, Zone Theorem, ham-sandwich cuts), 3-SUM hardness, counting planar triangulations.

Lecture notes

yes

Literature


Prerequisites / notice

Fostered: The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH.

Outlook: In the following spring semester there is a seminar "Geometry: Combinatorics and Algorithms" that builds on this course. There are ample possibilities for Semester-, Bachelor- and Master Thesis projects in the area.

263-4500-00L Advanced Algorithms W 9 credits 3V+2U+3A J. Lengler, B. Häupler, M. Probst

Abstract

This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms, sketching and streaming algorithms, and online algorithms.

Objective

This course familiarizes the students with some of the main tools and techniques in modern subareas of algorithm design.

Content

The lectures will cover modern topics in algorithm design and analysis, including the following: graph sparsifications while preserving cuts or distances, various approximation algorithms techniques and concepts, metric embeddings and probabilistic tree embeddings, online algorithms, multiplicative weight updates, streaming algorithms, sketching algorithms.

Lecture notes

https://people.inf.ethz.ch/~aroeyskoe/AA23

Prerequisites / notice

This course is designed for masters and doctoral students and it is targeted those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

Competencies

Subject-specific Competencies

Concepts and Theories fostered

Method-specific Competencies

Analytical Competencies fostered

Decision-making fostered

Problem-solving fostered

263-4511-00L Projects in Topological Data Analysis W 4 credits 3G P. Schnider

Abstract

This seminar complements the course "Introduction to Topological Data Analysis". Students of the seminar will collaborate with students from international universities on concrete projects in topological data analysis, both theoretical and applied.

Objective

Each student is expected to collaborate in an international working group with students from the partner universities. Each group works on one of the projects suggested by the lecturers, and is assigned a mentor. At the end of the semester, each working group presents their findings in a written report and an oral presentation.

Content

The seminar complements the course "Introduction to Topological Data Analysis". Students get to apply what they learned in the introductory course to concrete projects in the area of topological data analysis. These projects can be of theoretical nature, e.g., the design and analysis of a new algorithm, or applied, such as using methods from topological data analysis on concrete data sets.

Prerequisites / notice

Successful participation in the course "Introduction to Topological Data Analysis" or equivalent background in topological data analysis is required.

Competencies

Subject-specific Competencies

Concepts and Theories fostered

Method-specific Competencies

Techniques and Technologies fostered

Analytical Competencies fostered

Media and Digital Technologies fostered

Problem-solving assessed

Project Management assessed

Social Competencies

Communication assessed

Cooperation and Teamwork assessed

263-4513-00L Structural Graph Theory W 5 credits 2V+2A R. M. Steiner

Abstract

Structural graph theory forms, besides extremal graph theory, one of the two main pillars of modern graph theory. While the latter is concerned with maximizing the number of edges or the density of graphs, structural graph theory focuses on understanding the structural nature of all members of a class of graphs.

Objective

This course will cover several cornerstone results of structural graph theory.

The students obtain a thorough understanding of the mathematical tools, techniques and results in structural graph theory, and understand the relations and applications which this rich theory has in other areas, such as computational complexity and logic. Additionally, they enhance their skillset for the design of efficient algorithms on structurally constrained classes of graphs.
### Analytical Competencies

This course provides a gentle introduction to the Probabilistic Method, with an emphasis on methodology. We will try to illustrate the main concepts and theories on subject-specific competency levels.

Subject-specific Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Literature</th>
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</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
<td>Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years.</td>
</tr>
</tbody>
</table>

Method-specific Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Literature</th>
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</table>

### Prerequisites / notice

The students should be familiar with the basics of the following areas: graph theory, linear programming, complexity theory and probabilistic methods. Having taken a previous course covering basic graph theory is strongly advised.

### Competencies

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies
- Problem-solving

### Guarantees for Machine Learning

**W 7 credits 3V+1U+2A F. Yang**

**Objective**

By the end of the semester students should be able to

- understand a good fraction of theory papers published in the typical ML venues. For this purpose, students will learn common mathematical techniques from statistical learning in the first part of the course and apply this knowledge in the project work
- critically examine recently published work in terms of relevance and find impactful (novel) research problems. This will be an integral part of the project work and involves experimental as well as theoretical questions
- outline a possible approach to prove a conjectured theorem by e.g. reducing to more solvable subproblems. This will be practiced in-person exercises, homeworks and potentially in the final project
- effectively communicate and present the problem motivation, new insights and results to a technical audience. This will be primarily learned via the final presentation and report as well as during peer-grading of peer talks.

**Content**

This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning algorithms. It touches on the following topics

- concentration bounds
- uniform convergence and empirical process theory
- regularization for non-parametric statistics (e.g. in RKHS, neural networks)
- high-dimensional learning
- computational and statistical learnability (information-theoretic, PAC, SQ)
- overparameterized models, implicit bias and regularization

The project work focuses on current theoretical ML research that aims to understand modern phenomena in machine learning, including but not limited to

- how overparameterized models generalize (statistically and converge (computationally)
- complexity measures and approximation theoretic properties of randomly initialized and trained neural networks
- generalization of robust learning (adversarial or distribution-shift robustness)
- private and fair learning

**Prerequisites / notice**

Students should have a very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as “Introduction to Machine Learning”, “Regression” / “Statistical Modelling”. In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

**Competencies**

<table>
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<tr>
<th>Competencies</th>
<th>Literature</th>
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<tbody>
<tr>
<td>Personal Competencies</td>
<td>- Graph Coloring and the Probabilistic Method, by M. Molloy and B. Reed, Springer, 2002.</td>
</tr>
</tbody>
</table>

### Probabilistic Methods in Combinatorics

**W 5 credits 2V+1U B. Sudakov**

**Abstract**

This course provides a gentle introduction to the Probabilistic Method, with an emphasis on methodology. We will try to illustrate the main ideas by showing the application of probabilistic reasoning to various combinatorial problems.

**Content**

The topics covered in the class will include (but are not limited to): linearity of expectation, the second moment method, the local lemma, correlation inequalities, martingales, large deviation inequalities, Janson and Talagrand inequalities and pseudo-randomness.

**Literature**

- Graph Coloring and the Probabilistic Method, by M. Molloy and B. Reed, Springer, 2002.

### Algebraic Methods in Combinatorics

**W 5 credits 2V+1U not available**

**Abstract**

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

**Objective**

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows: In order to bound the cardinality of a discrete structure $A$ one maps its elements to vectors in a linear space, and shows that the set $A$ is mapped to linearly independent vectors. It then follows that the cardinality of $A$ is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem.
- Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at [https://moodle-app2.let.ethz.ch/course/view.php?id=15757](https://moodle-app2.let.ethz.ch/course/view.php?id=15757)

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Students are expected to have a mathematical background and should be able to write rigorous proofs.

**401-3901-00L Linear & Combinatorial Optimization**

**W 10 credits 4V+2U R. Zenklusen**

**Abstract**

Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

**Objective**

The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

**Content**

Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

**Literature**


**Prerequisites / notice**

Solid background in linear algebra.

**Competencies**

**Subject-specific Competencies**

- Concepts and Theories: assessed
- Techniques and Technologies: fostered

**Method-specific Competencies**

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed

**Social Competencies**

- Communication: assessed
- Cooperation and Teamwork: fostered
- Sensitivity to Diversity: fostered

**Personal Competencies**

- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

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**402-0448-01L Quantum Information Processing I: Concepts**

This theory part QIP I together with the experimental part 402-0448-02L QIP II (both offered in the autumn semester) combine to the core course in experimental physics "Quantum Information Processing" (totally 10 ECTS credits). This applies to the Master's degree programme in Physics.

**Abstract**

The course covers the key concepts and formalism of quantum information processing. Topics include quantum algorithms, quantum error correction, quantum cryptography, and quantum metrology, with an emphasis on the power of quantum information processing beyond that of classical information processing. The formalism of quantum states, measurements, and channels is developed in detail.

**Objective**

By the end of the course students are able to explain the basic mathematical formalism of quantum mechanics and apply it to quantum information processing problems. They are able to adapt and apply these concepts and methods to analyze and discuss quantum algorithms and other quantum information-processing protocols.

**Content**

The topics covered in the course will include quantum circuits, gate decomposition and universal sets of gates, efficiency of quantum circuits, quantum algorithms (Shor, Grover, Deutsch-Josza,..), stabilizer-based quantum error correction, fault-tolerant designs, the BB84 quantum key distribution protocol, and simple methods of quantum metrology.

**Lecture notes**

Will be provided.

**Literature**

- Quantum Computation and Quantum Information
  Michael Nielsen and Isaac Chuang
  Cambridge University Press

**Prerequisites / notice**

A good understanding of finite dimensional linear algebra is recommended.
### Interfocus Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>263-0006-00L</td>
<td>Algorithms Lab</td>
<td>O</td>
<td>8</td>
<td>4P+3A</td>
<td>A. Steger</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>Students learn how to solve algorithmic problems given by a textual description (understanding problem setting, finding appropriate modeling, choosing suitable algorithms, and implementing them). Knowledge of basic algorithms and data structures is assumed; more advanced material and usage of standard libraries for combinatorial algorithms are introduced in tutorials.</td>
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<td>The objective of this course is to learn how to solve algorithmic problems given by a textual description. This includes appropriate problem modeling, choice of suitable (combinatorial) algorithms, and implementing them (using C/C++, STL, CGAL, and BGL).</td>
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| 263-0009-00L   | Information Security Lab                    | O    | 8    | 2V+1U+3P+1A | S. Shinde, K. Paterson |
|                | Abstract                                    |      |      |             |                   |
|                | This InterFocus Course will provide a broad, hands-on introduction to Information Security, introducing adversarial thinking and security by design as key approaches to building secure systems. |
|                | Objective                                   |      |      |             |                   |
|                | This course will introduce key concepts from Information Security, both from attack and defence perspectives. Students will gain an appreciation of the complexity and challenge of building secure systems. |
|                | Content                                     |      |      |             |                   |
|                | The course is organised in three-week segments. In each segment, a new concept from Information Security will be introduced. The overall scope will be broad, including cryptography, protocol design, system security, and privacy. |
|                | Lecture notes                               |      |      |             |                   |
|                | Will be made available during the semester. |
|                | Literature                                  |      |      |             |                   |
|                | Paul C. van Oorschot, Computer Security and the Internet: Tools and Jewels. |
|                | Dan Boneh and Victor Shoup, A Graduate Course in Applied Cryptography. |

### Elective Courses

Students can individually choose from the entire Master course offerings in the area of Computer Science (or a closely related field). From ETH Zurich, EPFL Lausanne, the University of Zurich and - but only with the consent of the Director of Studies - from all other Swiss universities.

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<th>Number</th>
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<tbody>
<tr>
<td>252-0293-00L</td>
<td>Wireless Networking and Mobile Computing</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>S. Mangold</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>This course gives an overview about wireless standards and summarizes the state of art for Wi-Fi 802.11, Cellular 5G, and Internet-of-Things, contact tracing with Bluetooth, audio communication, visible light communications, medical technology. The course combines lectures with a set of assignments in which students are asked to work with a JAVA simulation tool, and Arduino boards.</td>
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<td>The objective of the course is to learn about the general principles of wireless communications, including physics, frequency spectrum regulation, and standards. Further, the most up-to-date standards and protocols used for wireless LAN IEEE 802.11, Wi-Fi, Internet-of-Things, sensor networks, cellular networks, visible light communication, and cognitive radios, are analyzed and evaluated. Students develop their own add-on mobile computing algorithms to improve the behavior of the systems, using a Java-based event-driven simulator. We also hand out embedded systems that can be used for experiments for optical communication. Throughout the course, insights from telecommunications, toy industry, and medical technology industry are shared.</td>
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<td>Wireless Communication, Wi-Fi, Contact Tracing, Bluetooth, Internet-of-Things, 5G, Standards, Regulation, Algorithms, Radio Spectrum, Cognitive Radio, Mesh Networks, Optical Communication, Visible Light Communication. We will address contact tracing, radio link budget, location distance measurements, and Bluetooth in more depth. MedTech basics are also provided.</td>
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<td>Lecture notes</td>
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<td>The course material will be made available by the lecturer.</td>
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<td>Literature</td>
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<td>(1) The course webpage (look for Stefan Mangold's site)</td>
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<td>(2) The Java 802 protocol emulator “JEmula802” from <a href="https://bitbucket.org/lfield/jemula802">https://bitbucket.org/lfield/jemula802</a></td>
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</table>
Prerequisites / notice
Students should have interest in wireless communication, and should be familiar with Java programming. Experience with GNU Octave or Matlab will help too (not required).

Competencies
- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management
- Social Competencies
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
  - Negotiation
- Personal Competencies
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

Abstract
Independent project work under the supervision of a Computer Science Professor.

Objective
Only students who fulfill one of the following requirements are allowed to begin a research project:
- 1 lab (interfocus course) and 1 focus course
- 2 core focus courses
- 2 labs (interfocus courses)

A task description must be submitted to the Student Administration Office at the beginning of the work.

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Abstract
The "Training for Programming Coaches" course is designed to prepare students for the role of a teaching assistant in an introductory programming course. The focus is on developing constructive coaching skills, particularly in giving effective feedback and competently conducting project presentations.

Objective
In this course, teaching assistants (TAs) will learn...

1. Understanding the role of teaching assistants:
   - recognising the responsibilities and expectations of teaching assistants.

2. Develop communication skills:
   - Using effective communication techniques.
   - Empathic listening and appropriate response to students' questions and concerns.

3. Giving feedback:
   - Understanding the principles of effective feedback.
   - Using methods to formulate feedback that is both developmental and motivating.
   - Avoiding common mistakes and misunderstandings when giving feedback.

4. Accepting project presentations:
   - Develop criteria for evaluating and assessing project presentations.
   - Apply objective assessment techniques to ensure fairness and consistency.
   - Methods to support and develop students' presentation skills.

5. Conflict resolution:
   - recognising and addressing potential conflict situations between students and teaching assistants.
   - Developing strategies for de-escalation and conflict resolution.

6. Didactic skills:
   - Teaching basic didactic principles to support the learning process of students.
   - Designing learning experiences and using tools that promote student understanding.
   - Workshops: Praktische Übungen, Simulationen und Rollenspiele zur Anwendung der erlernten Prinzipien in realitätsnahen Szenarien.
   - Peer-Feedback: Gegenseitiges Feedback unter den Kursteilnehmenden zur Förderung eines kollaborativen Lernumfelds.
   - Praktische Übungen: Anwendung der gelernten Konzepte im Übungsalltag mit Feedbacksequenzen durch die Kursleiter.
Venture Capital is important to fund big transformational ideas and is often misunderstood by tech or research entrepreneurs. This lecture immerses participants in the role of a Venture Capitalist (VC) to learn from experienced entrepreneurs and investors. In small teams, you work on a case of a real start-up and defend the case in a simulated investment committee consisting of experienced VCs.

After attending this course, students will be able to:
- Explain the differences between VC and founder thinking
- Evaluate if a start-up is suited for venture capital (“VC readiness”)
- Evaluate founder friendliness of term sheets
- Determine funding needs & strategy for a start-up from research to first round
- Write and evaluate an investment memo

The course is practically oriented and features guest speakers from leading venture capital firms and start-ups. The course embraces a unique perspective combining technology and investor thinking. The seminar is structured around five days with the following themes.

The detailed program is listed here: https://bit.ly/techinvesting23

- The macro picture. Why does venture capital exist? What are major tech breakthrough areas and their disruptive potential? We also review the differences in the US and European perspective as well as developments towards more impact and diversity conscious funds.
- A peek into the mind of a VC. How to build a successful VC? Learn what key factors & processes required to build a successful venture capital company. This includes strategic decisions for investment thesis, structure of a fund, portfolio economics, valuation & ownership targets, cap table. In addition, we introduce the fundamentals of the investment process (including due diligence, term sheets, and deal memo) as well as portfolio management.
- The founder’s perspective. Why should you raise venture capital and how? Learn to evaluate the founder friendliness of terms, company approach, strategic decisions, negotiation and valuation.
- Fundraising types. Learn about different types of funding and their implications. This includes an overview of the Swiss ecosystem and a discussion of the different types (grants, equity, loans, SAFE, crowd, …). We also include a practical session on crypto technology for modern fund-raising using launchpads and tokenized shares.

Tying it all together. The last day is focused on simulating an investment committee meeting where the groups present their deal memos and discuss with the audience.
After attending this course, students will be able to:
- Understand the basics of patenting in the digital space relevant for a global market
- Evaluate patenting opportunities with a more differentiated view on the topic
- Effectively use patents as a cost-effective part of a technology startup’s business plan
- Conduct patent searches, freedom-to-operate analysis and infringement analyses
- Write their first software/AI-related invention disclosure suitable for patenting

The course is focused on patenting digital innovations. It is designed for students with entrepreneurial interests that like to get a hands-on perspective on the topic of intellectual property strategies and patents.

The seminar includes presentations and practical group exercises to apply the acquired knowledge in practice. Entrepreneurs and leading IP experts are joining the seminar as guest speakers for discussion of real-life examples.

Topics that will be covered include:
- Best practices that any AI/software startups should know about IP and patents
- How investors evaluate a strong IP situation of a start-up
- How to efficiently monitor competitor patent activity and obtain "FTO"
- How to create an effective patent filing strategy that grows with the business
- How to efficiently create AI patents while not getting distracted from the founder’s core business

The course also contains a group work of a “FTO battle” where two teams compete in a freedom-to-operate analysis and individual work to write their first invention disclosure related to an AI or software topic.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
<th>Credit Type</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-5058-00L</td>
<td>Technology and Entrepreneurship</td>
<td>W 3</td>
<td>6S</td>
<td>A. Ilic</td>
</tr>
<tr>
<td>263-5907-00L</td>
<td>Geometry for Computational Design and Fabrication</td>
<td>W 1</td>
<td>2G</td>
<td></td>
</tr>
<tr>
<td>227-0811-00L</td>
<td>Creative Thinking Seminar</td>
<td>W 2</td>
<td>2S</td>
<td>A. C. Notz</td>
</tr>
<tr>
<td>227-2210-00L</td>
<td>Computer Architecture</td>
<td>W 8</td>
<td>6G+1A</td>
<td>S. Sadosadati, O. Mutlu</td>
</tr>
</tbody>
</table>

- Additional material pointed out by the instructor prior to and during the course.

- Grichnik, D., Hess, M., Probst, D., Antretter, T., & Pukall, B. (2020). Startup Navigator Framework. They will learn how to structure and communicate these ideas to business angel and venture capital investors.


- The students will gain insights into the concept and mechanics of Creative Thinking. They will trace the historical roots of creativity and its contemporary significance, explore how Creative Thinking intersects with modern innovations and technologies.

- The students will develop a comprehensive understanding of Creative Thinking and its practical application, start to cultivate the ability to generate innovative solutions through creative practices and will analyze the broader implications of creativity in various contexts.

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- The main intention of the course is to present geometric concepts that turned out to simplify the solution of problems in computational design and fabrication and hold promise to provide useful methodology for future research in this area.

- Another focus is on geometric optimization problems, discussing mainly geometric ideas on initialization, regularization and the formulation of frequently appearing objective functions. A further topic is given by transformations which preserve important structures. This reaches into the sphere geometries of Möbius and Laguerre and transformations of nets. Finally, we present the basics of kinematical geometry, such as velocity fields and their use in registration algorithms, infinitesimal flexibility and the closely related static equilibrium of shells.

As a result, students develop internationally scalable and technology-driven businesses in teams. The special focus lies on the ability to successfully pitch these ventures to business angels or venture capital investors.

- Write their first software/AI-related invention disclosure suitable for patenting
- Conduct patent searches, freedom-to-operate analysis and infringement analyses
- Evaluate patenting opportunities with a more differentiated view on the topic
- Effectively use patents as a cost-effective part of a technology startup’s business plan
- How investors evaluate a strong IP situation of a start-up
- How to efficiently monitor competitor patent activity and obtain “FTO”
- How to create an effective patent filing strategy that grows with the business
- How to efficiently create AI patents while not getting distracted from the founder’s core business


- As a result, students develop internationally scalable and technology-driven businesses in teams. The special focus lies on the ability to successfully pitch these ventures to business angels or venture capital investors.

- Additional material pointed out by the instructor prior to and during the course.

- The students will gain insights into the concept and mechanics of Creative Thinking. They will trace the historical roots of creativity and its contemporary significance, explore how Creative Thinking intersects with modern innovations and technologies.

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Abstract

Computer architecture is the science & art of designing and optimizing hardware components and the hardware/software interface to create a computer that meets design goals. This course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.

Objective

We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), new paradigms like processing-in-memory, parallel computing systems (including multicore processors, coherence and consistency, GPUs), heterogeneous computing, interconnection networks, specialized systems for major data-intensive workloads (e.g. graph analytics, bioinformatics, machine learning), etc. We will focus on fundamentals as well as cutting-edge research. Significant attention will be given to real-life examples and tradeoffs, as well as critical analysis of modern computing systems.

Content

The principles presented in the lecture are reinforced in the laboratory through 1) the design and implementation of a cycle-accurate simulator, where we will explore different components of a modern computing system (e.g., pipeline, memory hierarchy, branch prediction, prefetching, caches, multithreading), and 2) the extension of state-of-the-art research simulators (e.g., Ramulator) for more in-depth understanding of specific system components (e.g., memory scheduling, prefetching).

See the course website for detailed and complete content of past incarnations of the course: https://safari.ethz.ch/architecture

Lecture notes

All the materials (including lecture slides) will be provided on the course website: https://safari.ethz.ch/architecture/

The video recordings of the lectures are expected to be made available after lectures.

Literature

We will provide required and recommended readings in every lecture. They will mainly consist of research papers presented in major Computer Architecture and related conferences and journals. See https://safari.ethz.ch/architecture for past examples.

Prerequisites / notice


Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
</tr>
<tr>
<td>Techniques and Technologies</td>
<td>Analytical Competencies</td>
<td>Leadership and Responsibility</td>
<td>Critical Thinking</td>
</tr>
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</tr>
<tr>
<td>assessed</td>
<td>Problem-solving</td>
<td></td>
<td>Self-direction and Self-management</td>
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<tr>
<td>assessed</td>
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<td>assessed</td>
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</tbody>
</table>

Science in Perspective

Note that no more than six credits can be accredited in this category.

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-INFK

Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-0800-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Only students who fulfill the following criteria are allowed to begin with their master thesis:

- a. successful completion of the bachelor programme;
- b. fulfilling any additional requirements necessary to gain admission to the master programme;
- c. "Inter focus courses" (16 credits) completed;
- d. "Focus courses" (26 credits) completed, from which at least 16 credits must come from the Major Core courses;
- e. "Practical work" at least 8 credits completed.
- f. In total, besides the master thesis, no more than 8 credits may be missing.

Abstract

The Master's thesis concludes the study programme. Thesis work should prove the students' ability to independent, structured and scientific working.

Objective

To work independently and to produce a scientifically structured work under the supervision of a Computer Science Professor.

Content

Independent project work supervised by a Computer Science professor. The duration of the MT is 28 weeks (full-time), where the 28 weeks are composed of 26 weeks of actual processing time and 2 weeks to compensate for public holidays, sick days and other short-term absences.

Prerequisites / notice

Supervisor must be a professor at D-INFK or affiliated, see https://inf.ethz.ch/people/faculty.html

Computer Science Master - Key for Type

- Z Courses outside the curriculum
- Dr Suitable for doctorate
- O Compulsory

W+ Eligible for credits and recommended
W  Eligible for credits
E- Recommended, not eligible for credits
### Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</tr>
</tbody>
</table>

**ECTS**  
European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
## Integrated Building Systems Master

### Main Courses

#### Fundamental Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1633-00L</td>
<td>Energy Conversion</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>I. Karlin, G. Sansavini, S. A. Hosseini</td>
</tr>
</tbody>
</table>

**Abstract**

This course provides the students with an introduction to thermodynamics and energy conversion. Students shall gain basic understanding of energy and energy interactions as well as their link to energy conversion technologies.

**Objective**

Thermodynamics is key to understanding and use of energy conversion processes in Nature and technology. Main objective of this course is to give a compact introduction into basics of Thermodynamics: Thermodynamic states and thermodynamic processes; Work and Heat; First and Second Laws of Thermodynamics. Students shall learn how to use energy balance equation in the analysis of power cycles and shall be able to evaluate efficiency of internal combustion engines, gas turbines and steam power plants. The course shall extensively use thermodynamic charts to building up students' intuition about opportunities and restrictions to increase useful work output of energy conversion. Thermodynamic functions such as entropy, enthalpy and free enthalpy shall be used to understand chemical and phase equilibrium. The course also gives introduction to refrigeration cycles, combustion and refrigeration. The course compactly covers the standard course of thermodynamics for engineers, with additional topics of a general physics interest (nonideal gas equation of state and Joule-Thomson effect) also included.

In the course "Energy Conversion", the competencies of process understanding and system understanding are applied and examined and the competencies process understanding and modeling are taught.

**Content**

1. Thermodynamic systems, states and state variables
2. Properties of substances: Water, air and ideal gas
3. Energy conservation in closed and open systems: work, internal energy, heat and enthalpy
4. Second law of thermodynamics and entropy
5. Energy analysis of steam power cycles
6. Energy analysis of gas power cycles
7. Refrigeration and heat pump cycles
8. Nonideal gas equation of state and Joule-Thomson effect
9. Maximal work and exergy
10. Mixtures
11. Chemical reactions and combustion systems; chemical and phase equilibrium

**Lecture notes**

Lecture slides and supplementary documentation will be available online.

**Literature**


**Prerequisites / notice**

This course is intended for students outside of D-MAVT. Students are assumed to have an adequate background in calculus, physics, and engineering mechanics.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th></th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td></td>
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<tr>
<td>Techniques and Technologies</td>
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</table>

<table>
<thead>
<tr>
<th>Method-specific Competencies</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Analytical Competencies</td>
<td></td>
<td></td>
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<tr>
<td>Decision-making</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Management</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Social Competencies                           |            |         |
| Communication                                 | fostered   |         |
| Cooperation and Teamwork                      | fostered   |         |
| Customer Orientation                          | fostered   |         |
| Leadership and Responsibility                 | assessed   |         |
| Self-presentation and Social Influence        | fostered   |         |
| Sensitivity to Diversity                      | fostered   |         |
| Negotiation                                  | fostered   |         |

| Personal Competencies                         |            |         |
| Adaptability and Flexibility                  | fostered   |         |
| Creative Thinking                             | assessed   |         |
| Critical Thinking                             | assessed   |         |
| Integrity and Work Ethics                     | assessed   |         |
| Self-awareness and Self-reflection            | fostered   |         |
| Self-direction and Self-management            | assessed   |         |

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<table>
<thead>
<tr>
<th>Number</th>
<th>Mathematics</th>
<th>W</th>
<th>4</th>
<th>3V+1U</th>
<th>C. Busch</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0203-00L</td>
<td>This course gives an introduction to the following subjects: calculus, multivariable calculus, differential equations, linear algebra (systems of linear equations, matrices, eigenvectors). Basic mathematical knowledge for engineers. Mathematics as a tool to solve engineering problems.</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Abstract**

This course gives an introduction to the following subjects: calculus, multivariable calculus, differential equations, linear algebra (systems of linear equations, matrices, eigenvectors).

**Objective**

Basic mathematical knowledge for engineers. Mathematics as a tool to solve engineering problems.

**Content**

This course gives an introduction to the following subjects: calculus, multivariable calculus, differential equations, linear algebra (systems of linear equations, matrices, eigenvectors).

**Literature**

Tom M. Apostol, Calculus, Volume 1, One-Variable Calculus with an Introduction to Linear Algebra, 2nd Edition, Wiley
Tom M. Apostol, Multi-Variable Calculus and Linear Algebra with Applications, 2nd Edition, Wiley
Ulrich L. Rohde, Introduction to differential calculus : Systematic studies with engineering applications for beginners, Wiley.
Ulrich L. Rohde, Introduction to integral calculus : Systematic studies with engineering applications for beginners, Wiley.
A list will be handed out in the lecture.
<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Creative Thinking</td>
</tr>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>Problem-solving</td>
<td>Cooperation and Teamwork</td>
<td>Critical Thinking</td>
</tr>
<tr>
<td></td>
<td>fostered</td>
<td>assessed</td>
<td>fostered</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>assessed</td>
<td>assessed</td>
<td>fostered</td>
<td>fostered</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>066-0427-00L Design and Building Process MIBS</th>
<th>W</th>
<th>2 credits</th>
<th>2V</th>
<th>A. Paulus, S. Menz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Design and Building Process MIBS is a brief manual for prospective architects and engineers covering the competences and the responsibilities of all involved parties through the design and building process. Lectures on six compact aspects gaining importance in a increasingly specialised, complex and international surrounding.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Participants will come to understand how they can best navigate the design and building process, especially in relation to understanding their profession, gaining a thorough knowledge of rules and regulations, as well as understanding how involved parties' minds work. They will also have the opportunity to investigate ways in which they can relate to, understand, and best respond to their clients' wants and needs. Finally, course participants will come to appreciate the various tools and instruments, which are available to them when implementing their projects. The course will guide the participants, bringing the individual pieces of knowledge into a superordinate relationship.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Design and Building Process MIBS is a brief manual for prospective architects and engineers covering the competences and the responsibilities of involved parties through the design and building process. Three compact chapters regarding the established building culture are gaining importance in an increasingly specialised, complex and international surrounding. Lectures on the topics of competence, organisation, agility, monitoring, interest, and the environment will guide the participants, bringing the individual pieces of knowledge into a superordinate relationship. The course introduces the key figures, depicts the criteria of the project and highlights the proved services of the consultants. In addition to discussing the basics, the terminologies and the tendencies, the lecture units will refer to the studios as well as the practice. Teaching-based workshops will compliment and deepen the understanding of the three selected aspects of profession, methodology, and environment. The course is presented as a moderated seminar to allow students the opportunity for individual input: active collaboration between the students and their tutor therefore required.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Literature</td>
<td><a href="https://map.arch.ethz.ch">https://map.arch.ethz.ch</a></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Conceptual Knowledge</th>
<th>Design and Building Process MIBS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>assessed</td>
<td>W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>103-0317-00L Spatial Planning and Development</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>D. Kaufmann, A. Kuitenbrouwer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The course deals with theoretical, methodological and practical foundations around the understanding and production of urban space. It discusses theoretical planning frameworks, and tasks of spatial planning at various scales, addresses current and future challenges of spatial development and reviews approaches for a sustainable development in Switzerland and beyond.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>The overall aim of the course is to raise students’ awareness and curiosity about the aspects that guide and shape our environment. Through lectures, readings, discussions, and exercises, the course seeks to achieve this goal by accumulating crucial notions from both theoretical and practice-based examples, and applying such knowledge into tasks of spatial planning. At the end of this course, students should feel empowered to critically engage with the teaching topic from a variety of approaches. By taking up the lecture, the students should be able to analyse, interpret and reflect complex cross-scale tasks of spatial development and transformation, and to use their theoretical, methodical and professional knowledge to tackle them. You as students will...</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>... assess present and future core challenges of spatial planning and development.</td>
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<tr>
<td></td>
<td>... discuss the role of spatial planning and development in shaping our living environment.</td>
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</tr>
<tr>
<td></td>
<td>... differentiate the levels, scales and tasks of spatial planning instruments and processes.</td>
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<tr>
<td></td>
<td>... reflect on theoretical concepts and practical examples of decision-making of spatial tasks.</td>
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<tr>
<td></td>
<td>... identify and apply spatially relevant principles and systems for action-oriented planning and decision-making.</td>
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<tr>
<td></td>
<td>... acquire theoretical, methodological, practical know-how to examine, clarify, and solve tasks on spatial development</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1452 of 2653
Spatial development as a discipline deals with the development, (trans)formation, and arrangement of our urban environment. We simultaneously perceive and contribute to its transformation, making space the result of manifold intended and unintended changes. To mediate between different demands, interests and interventions of multiple actors, a forward-looking, evidence-based, and action-oriented planning is necessary. As guidance for future action, (spatial) planning has to be committed to the sustainable handling as well as just allocation of resources, in particular of the non-replicable resource land.

The course focuses on both theoretical concepts and practice-oriented approaches to gain knowledge and be equipped to address current issues in spatial planning and development. This is mirrored in the course’s structure made of both of lectures and exercises.

The lecture series introduces necessary key concepts and covers the following main topics:
- Drivers of spatial development, inward development, core tasks and current challenges for (spatial) planners.
- Interplay of formal and informal planning instruments across scales and actors.
- Differentiation urban typologies, their characteristics and challenges
- Types of spatial analysis and key figures
- Planning approaches and the (political) steering of spatial development.
- Types of processes and participation in spatial development.
- Approaches for planning complex urban situations
- Concepts for sustainable development

The exercises provide a framework for practical application of the learned theoretical concepts of spatial planning to real-life situations.

### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0527-10L</td>
<td>Materials and Constructions</td>
<td>O</td>
<td>4</td>
<td>2G</td>
<td>G. Habert, M. Posani</td>
</tr>
</tbody>
</table>

**Abstract**

Building materials with a special focus on regenerative materials: earth, bio-based and reuse.
Looking at material sourcing, properties and performance, as well as how they are integrated in the buildings (building envelope and detailing).
Choice of material is done out of sustainability concern.
Comfort, moisture transfer and building physics with hygroscopic materials.

**Objective**

Special focus on regenerative materials: earth, bio-based and reuse
The students will acquire knowledge in the following fields:
Fundamentals of material performance
Introduction to durability problems of building facades
Materials for the building envelope:
- Overview of structural materials and systems: concrete, steel, stone, earth, wood and bamboo
- Insulating materials (bio-based vs conventional)
Assessment of materials and components behaviour and performance
Degradation risks connected to insulation and post-insulation
Aspects of sustainability and durability
Special focus on comfort, moisture transfer and building physics with hygroscopic materials will be done.

**Content**

Introduction
Sustainable cement and concrete
Earth construction
Stone
Steel
Bamboo
Timber construction
Building physic and conventional insulation
Bio-based insulation and degradation risks with insulation
Hygrothermal properties of building materials and dynamic numerical simulations
Efficiency and sustainability of modern window glazing

Course will have general lectures
+ hands on lab @home experiments
+ group project for implementation of regenerative materials.

**Competencies**

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<tr>
<th>Subject-specific Competencies</th>
<th>Techniques and Technologies</th>
<th>assessed</th>
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<td>Method-specific Competencies</td>
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<td>Social Competencies</td>
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<td>Self-awareness and Self-reflection</td>
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</table>
Building Physics: Theory and Applications

Abstract
Principles of heat and mass transport, hygro-thermal performance, durability of the building envelope and interaction with indoor and outdoor climates, applications.

Objective
The students will acquire in the following fields:
- Indoor and outdoor climate and driving forces.
- Hygrothermal properties of building materials.
- Building envelope solutions and their construction.
- Hygrothermal performance and durability.

Content
Principles of heat and mass transport, hygro-thermal performance, durability of the building envelope and interaction with indoor and outdoor climates, applications.

Prerequisites / notice
Enrolment after agreement with the lecturer only.

Lecture notes
Handouts, supporting material and exercises are provided online via Moodle.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
Social Competencies
- Communication
- Leadership and Responsibility
- Sensitivity to Diversity
Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Technology and Innovation Management

Abstract
This course focuses on the sources of innovation (with a specific focus on digital technologies), the tools and techniques that organizations deploy to innovate routinely, and the strategic implications of technical change at different levels of analysis: individuals, firms and whole ecosystems.

Objective
This course intends to enable all students to:
- Acquire and understand the basic jargon, concepts and methods necessary to discuss, in a precise and concise manner, innovation processes and their outcomes at different levels of analysis.
- Analyze the differences between individual and organizational decision processes and their innovative outcomes.
- Evaluate critically the potential of different (digital) technologies to impact business organizations.

Content
Organizations and people are faced with a fundamental decision: they have to allocate resources between well-known tasks that reliably generate positive results; or explore new ways of doing things, new technologies, products and services. The latter is a high risk choice. Its rewards can be high, but the chances of success are small. How do firms organize to take these decisions? What kind of management skills are necessary to take them? What kind of tools and methods are deployed to sustain managerial decision-making in highly volatile environments? These are the central questions on which this course focuses, relying on a combination of lectures, case-based discussion, and guest speakers.

Lecture notes
Slides will be available on the Moodle page.

Literature
Readings will be available on the Moodle page.

Prerequisites / notice
The course content and methods are designed for students with some background in management and/or economics.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
Social Competencies
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- Critical Thinking
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- Self-awareness and Self-reflection
- Self-direction and Self-management

Principles of Microeconomics

Abstract
The course introduces basic principles, problems and approaches of microeconomics. This provides the students with reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution.

Objective
The learning objectives of the course are:
1. Students must be able to discuss basic principles, problems and approaches in microeconomics.
2. Students can analyse and explain simple economic principles in a market using supply and demand graphs.
3. Students can contrast different market structures and describe firm and consumer behaviour.
4. Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole.
5. Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics.
6. Students can apply simple mathematical concepts on economic problems.
The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture "Principles of Microeconomics" is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.

Topics covered by the course are:

- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade

For students taking only the course 'Principles of Microeconomics' there is a shorter version of the same book: N. Gregory Mankiw and Mark P. Taylor (2023), "Microeconomics", 6th edition, South-Western Cengage Learning.

Complementary:

GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.
The course will follow two main objectives and a third optional objective, depending on the design projects the students choose. At the end of the course, the students will:
1. Know the methodology of LCA
2. Be able to apply LCA in the design process to assess and improve the environmental performance of their projects
3. Be able to use the parametric LCA tool and link it to additional performance assessment tools for a holistic optimisation

Part I: Exercises with lectures on demand
The first six individual courses will follow the "lectures on demand" approach. Small "hands-on" exercises focusing on one specific aspect will be given out and the necessary background knowledge will be provided in the form of short input lectures when questions arise. The following topics will be discussed during the first part:
1) LCA basic introduction
2) System boundaries, functional unit, end of life
3) Carbon budget and LCA benchmarks
4) BIM-LCA, available calculation tools and databases
5) Integrated analysis of environmental and cost assessment
6) Bio-based carbon storage

Part II: Project-based learning
In the second part, the students will work on their individual project in groups of three. For the design task, the students will bring their own project and work on improving it. The projects can be chosen depending on the students background and range from buildings to infrastructure projects. Intermediate presentations will ensure the continuous work and make sure all groups are on the same level and learn from each other. During this part, the following hands-on tutorials will be given:
1) Introduction to Rhinoceros 6 and 7
2) Introduction to grasshopper
3) Integrated assessment tools (ladybug tools)
4) Introduction to in-house grasshopper plugin for LCA analysis

Lecture notes
As the course follows a lecture on demand approach, the lecture slides will be provided after each course.

Literature
A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.

Prerequisites / notice
The students are expected to work out of class as well. The course time will be used by the teachers to answer project-specific questions.

The lecture series will be conducted in English and is aimed at students of master's programs, particularly in civil engineering and MIBS. No lecture will be given during Seminar week.

101-0608-00L Design-Integrated Life Cycle Assessment W 4 credits 2G G. Habert, A. Rodionova

Abstract
Currently, Life Cycle Assessment (LCA) is applied as an ex-post design evaluation of buildings, but rarely used to improve the building during the design process.

The aim of this course is to apply LCA during the design of buildings by means of a digital, parametric tool. The necessary fundamentals of the LCA method will be taught following a lecture on demands approach.

Objective
The course will follow two main objectives and a third optional objective, depending on the design projects the students' choose. At the end of the course, the students will:
1. Know the methodology of LCA
2. Be able to apply LCA in the design process to assess and improve the environmental performance of their projects
3. Be able to use the parametric LCA tool and link it to additional performance assessment tools for a holistic optimisation

Content
The course will be structured into two parts, each making up about half of the semester.

Part I: Exercises with lectures on demand
The first six individual courses will follow the "lectures on demand" approach. Small "hands-on" exercises focusing on one specific aspect will be given out and the necessary background knowledge will be provided in the form of short input lectures when questions arise. The following topics will be discussed during the first part:
1) LCA basic introduction
2) System boundaries, functional unit, end of life
3) Carbon budget and LCA benchmarks
4) BIM-LCA, available calculation tools and databases
5) Integrated analysis of environmental and cost assessment
6) Bio-based carbon storage

Part II: Project-based learning
In the second part, the students will work on their individual project in groups of three. For the design task, the students will bring their own project and work on improving it. The projects can be chosen depending on the students background and range from buildings to infrastructure projects. Intermediate presentations will ensure the continuous work and make sure all groups are on the same level and learn from each other. During this part, the following hands-on tutorials will be given:
1) Introduction to Rhinoceros 6 and 7
2) Introduction to grasshopper
3) Integrated assessment tools (ladybug tools)
4) Introduction to in-house grasshopper plugin for LCA analysis

Lecture notes
As the course follows a lecture on demand approach, the lecture slides will be provided after each course.

Literature
A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.

Prerequisites / notice
The students are expected to work out of class as well. The course time will be used by the teachers to answer project-specific questions.

The lecture series will be conducted in English and is aimed at students of master's programs, particularly in civil engineering and MIBS. No lecture will be given during Seminar week.

151-0209-00L Renewable Energy Technologies W 4 credits 3G A. Bardow, E. Casati

Abstract
The first part of the course covers the engineering aspects of the prominent renewable energy technologies: solar (PV and thermal), wind, hydro, geothermal and bioenergy. We further discuss energy storage, renewable transport and renewable heating & cooling. Finally, we introduce the key concepts of the economics of renewable energy and its integration in the energy system.

Objective
Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization.

Lecture notes
Lecture Notes containing copies of the presented slides.

Prerequisites / notice
Prerequisite: strong background on the fundamentals of engineering thermodynamics, equivalent to the material taught in the courses Thermodynamics I, II, and III of D-MAVT.

Competencies

Subject-specific Competencies
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

101-0123-00L Structural Design W 3 credits 2G J. Paoli, F. Bertagna

Abstract
The goal of the course is to introduce students to Structural Design. The course fosters the development of a design thinking that emerges from the coexistence of a number of design parameters and performance criteria related to force flow, construction technologies, material use, and spatial qualities.
Objective
After a successful completion of the course, students will be able to:

1. Critically evaluate structural design concepts based on their impact and implications beyond the sole structural performance
2. Identify the most relevant design parameters and performance criteria for a given design task and select adequate tools to effectively integrate them as part of the design process
3. To develop structural systems in compliance with structural, spatial, and environmental design aspects simultaneously

Content
The goal of the course is to introduce students to Structural Design. The course fosters the development of a design thinking that emerges from the coexistence of a number of design parameters and performance criteria related to force flow, construction technologies, material use, and spatial qualities. Students will learn about diverse tools that allow for controlling such a complex blend of parameters and criteria at the interface between different disciplines such as structural engineering and architecture. These tools will include physical models, graphical methods, and digital tools. After a series of lectures and workshops, students will work on a design exercise that represents the core of the entire course. The design exercise is an opportunity to deal with an open-ended task that does not admit a univocal answer. In fact, besides structural performance, design options will be discussed and evaluated through a set of criteria including spatial qualities, constructability, and environmental footprint.

Competencies

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Lecturer: D. J. Norris

ECTS: 4

151-0909-00L Chemistry

Abstract
This is a general chemistry course aimed at first-year bachelor students in the Department of Mechanical and Process Engineering.

Objective
The aims of the course are:
1) To provide a thorough understanding of the basic principles of chemistry and its application.
2) To develop an understanding of the atomic and molecular nature of matter and of the chemical reactions that describe its transformations, and
3) To emphasize areas considered most relevant in an engineering context.

Content
Electronic structure of atoms, chemical bonding, molecular geometry and bonding theories, intermolecular forces, gases, thermodynamics, chemical thermodynamics, chemical kinetics, equilibria, liquids and solutions, acids and bases, redox- and electrochemistry.

Lecture notes
The instructor’s lecture notes will be available prior to every lecture and can be downloaded from Moodle.

Literature

ECTS: 4

151-0245-00L Energy Systems Analysis: an Introduction and Overview with Applications

Abstract
Introductory (advanced Bachelor or beginner Master level) course on Energy Systems Analysis, providing an overview of the field and methods. After an introduction to systems thinking and characterisation of technologies, three main blocks cover with Lifecycle Assessment (LCA, 3 units), bottom-up linear optimisation models (5 units) and Multi-Criteria Decision Analysis (MCDA, 3 units).

Objective
- Analyse energy technologies with respect to different criteria/characteristics
- Discuss and debate the pros and cons of different ESA models/approaches (for specific applications)
- Explain the system-level interdependencies/interconnections within the energy system
- Evaluate the effect of uncertainties and “the human dimension” on ESA and scenarios

Content
The course provides an introduction and overview to the most well-established models and methods of energy systems analysis, in each case introducing students to the theory and assumptions of the method, strengths and weaknesses of the specific approach, and case studies for exemplary energy technologies and systems. The students are taught to understand and will be able to apply the basic principles of these methods in the context of targeted assignments relating to real-world energy systems.

Lecture notes
No but slides are provided before the lectures and videos recorded.

Literature
Will be provided during the course.

Prerequisites / notice
No specific prerequisites, some background in energy-related topics in the Bachelor would be beneficial.

Competencies

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Lecturer: R. McKenna, P. Burgherr, E. Panos, R. Sacchi

ECTS: 4

401-0647-00L Introduction to Mathematical Optimization

Abstract
Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering.

Objective
The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.
Topics covered in this course include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.

Information about relevant literature will be given in the lecture.

This course is meant for students who did not already attend the course “Mathematical Optimization”, which is a more advance lecture covering similar topics. Compared to “Mathematical Optimization”, this course has a stronger focus on modeling and applications.

<table>
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<tr>
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<th>Course Title</th>
<th>Credits</th>
<th>Prerequisites</th>
<th>Literature</th>
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<tbody>
<tr>
<td>227-0477-00L</td>
<td>Acoustics I</td>
<td>W 3 credits 2G</td>
<td>R. Pieren</td>
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<tr>
<td></td>
<td>Abstract</td>
<td>Introduction to the fundamentals of acoustics in the field of sound field calculations, measurement of acoustical events, outdoor sound propagation and room acoustics of large and small enclosures.</td>
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<td>Objective</td>
<td>Understanding of the basic acoustical concepts and methods. Ability to understand the technical and scientific literature. Confidence in the use of measuring instruments.</td>
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<td>Content</td>
<td>Fundamentals of acoustics, calculation of sound fields, measurement and analysis of acoustical events, anatomy and properties of the ear, outdoor sound propagation, absorption and transmission of sound, room acoustics of large and small enclosures, noise and noise control.</td>
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<td>Lecture notes</td>
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<td>Self-direction and Self-management fostered</td>
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<tr>
<td>101-0577-00L</td>
<td>An Introduction to Sustainable Development in the Built Environment</td>
<td>W 3 credits 2G</td>
<td>G. Habert, E. Z. Escamilla</td>
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<tr>
<td></td>
<td>Abstract</td>
<td>In 2015, the UN Conference in Paris shaped future world objectives to tackle climate change. This decarbonization strategy is additional to Sustainable Development goals formulated the same year by the UN general assembly.</td>
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<td>Objective</td>
<td>At the end of the semester, the students have an understanding of the term of sustainable development, its history, the current political and scientific discourses and its relevance for our built environment.</td>
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<td>Content</td>
<td>The course aims to promote an integral view and understanding of sustainability and describing different spheres (social/cultural, ecological, economical, and institutional) that influence our built environment. Students will acquire critical knowledge and understand the role of involved stakeholders, their motivations and constraints, learn how to evaluate challenges, identify deficits and define strategies to promote a more sustainable construction. After the course students should be able to define the relevance of specific local, regional or territorial aspects to achieve coherent and applicable solutions toward sustainable development. The course offers an environmental, socio-economic and socio-technical perspective focussing on buildings, cities and their transition to resilience with sustainable development. Students will learn on theory and application of current scientific pathways towards sustainable development.</td>
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<td>Methods</td>
<td>- Overview on the history and emergence of sustainable development</td>
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<td>- Overview on the current understanding and definition of sustainable development and beyond</td>
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<td>Lecture notes</td>
<td>All relevant information will be online available before the lectures. For each lecture slides of the lecture will be provided.</td>
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<td>Literature</td>
<td>A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.</td>
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**Transport Planning Methods**

**W 6 credits 4G E. Heinen**

**Abstract**
The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/policy by means of cost-benefit analysis.

**Objective**
- Knowledge and understanding of statistical methods and algorithms commonly used in transport planning
- Comprehend the reasoning and capabilities of transport models
- Ability to independently develop a transport model able to solve/answer planning problem
- Getting familiar with cost-benefit analysis as a decision-making supporting tool

**Content**
The course provides the necessary knowledge to develop models supporting the solution of given planning problems and also introduces cost-benefit analysis as a decision-making tool. Examples of such planning problems are the estimation of traffic volumes, prediction of estimated utilization of new public transport lines, and evaluation of effects (e.g. change in emissions of a city) triggered by building new infrastructure and changes to operational regulations.

To cope with that, the problem is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/policy by means of cost-benefit analysis. Interim lab sessions take place regularly to guide and support students with the applied part of the course.

**Lecture notes**
Moodle platform (enrollment needed)

**Literature**

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**Corporate Sustainability**

**W 3 credits 2G V. Hoffmann, C. Bening-Bach, B. Girod, L. Miehé**

**Abstract**
The lecture explores current challenges of corporate sustainability and prepares students to become champions for sustainable business practices. The module combines asynchronous videos, live sessions, with a group work phase between weeks 5-10 of semester during which students deep-dive into one of 10 sustainability challenges.

**Objective**
Students
- assess the limits and the potential of corporate sustainability for sustainable development
- develop competencies that are useful in the context of corporate sustainability and beyond (analytical competency, critical thinking, problem solving)
- recognize and realize opportunities through team work for corporate sustainability in a business environment
- present strategic recommendations in teams

**Content**
Corporate Sustainability is the flagship course of the Group for Sustainability and Technology at D- MTEC. In this course, students learn about key concepts in corporate sustainability and develop skills to implement them in the real world. The course prepares students for making well-informed sustainability decisions in their future careers.

The course uses constructive alignment to bring the various innovative teaching and learning elements (e.g., case-based experiential learning, reflective thinking and blended learning with videos and quizzes) into a coherent transformational journey. Students can now flexibly, efficiently, and effectively acquire the conceptual foundations that are essential for a substantial understanding of corporate sustainability.

http://www.sustec.ethz.ch/teaching/lectures/corporate-sustainability.html

**Lecture notes**
Presentation slides will be made available on Moodle after lectures.

**Literature**


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**Introduction to Computational Physics**

**W 8 credits 2V+2U A. Adelmann**

**Abstract**
This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

**Objective**
Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

**Content**
Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

**Lecture notes**
Lecture notes and slides are available online and will be distributed if desired.

**Literature**
Lecture notes and slides are available online and will be distributed if desired.
Analytical Competencies

fostered

Method-specific Competencies

Structural Reliability and Risk Analysis

Structural reliability aims at quantifying the probability of failure of systems due to uncertainties in their design, manufacturing and environmental conditions. Risk analysis combines this information with the consequences of failure in view of optimal decision making. The course presents the underlying probabilistic modelling and computational methods for reliability and risk assessment.

Objective

The goal of this course is to provide the students with a thorough understanding of the key concepts behind structural reliability and risk analysis. Aft After this course the students will have refreshed their knowledge of probability theory and statistics to model uncertainties in view of engineering applications. They will be able to analyze the reliability of a structure and to use risk assessment methods for decision making under uncertain conditions. They will be aware of the state-of-the-art computational methods and software in this field.

Content

Engineers are confronted everyday to decision making under limited amount of information and uncertain conditions. When designing new structures and systems, the design codes such as SIA or Euro- codes usually provide a framework that guarantees safety and reliability. However the level of safety is not quantified explicitly, which does not allow the analyst to properly choose between design variants and evaluate a total cost in case of failure. In contrast, the framework of risk analysis allows one to incorporate the uncertainty in decision making.

The first part of the course is a reminder on probability theory that is used as a main tool for reliability and risk analysis. Classical concepts such as random variables and vectors, dependence and correlation are recalled. Basic statistical inference methods used for building a probabilistic model from the available data, e.g. the maximum likelihood method, are presented.

The second part is related to structural reliability analysis, i.e. methods that allow one to compute probabilities of failure of a given system with respect to prescribed criteria. The framework of reliability analysis is first set up. Reliability indices are introduced together with the first order-second moment method (FOSM) and the first order reliability method (FORM). Methods based on Monte Carlo simulation are then reviewed and illustrated through various examples. By-products of reliability analysis such as sensitivity measures and partial safety coefficients are derived and their links to structural design codes is shown. The reliability of structural systems is also introduced as well as the methods used to reassess existing structures based on new information.

The third part of the course addresses risk assessment methods. Techniques for the identification of hazard scenarios and their representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. Elements of Bayesian decision making, i.e. pre-, post and pre-post risk assessment methods are presented.

The course also includes a tutorial using the UQLab software dedicated to real-world structural reliability analysis.

Lecture notes

Slides of the lectures are available online every week. A printed version of the full set of slides is proposed to the students at the beginning of the semester.

Literature


Prerequisites

Basic course on probability theory and statistics

A. Miftakhova

assessed

3 credits

S. Marelli

assessed

Structural Reliability and Risk Analysis

W

3 credits

S. Marelli

701-1346-00L

Climate Change Mitigation: Carbon Dioxide Removal

Future climate change can only kept within reasonable bounds when CO2 emissions are drastically reduced. In this course, we will discuss a portfolio of options involving the alteration of natural carbon sinks and carbon sequestration. The course includes introductory lectures, presentations from guest speakers from industry and the public sector, and final presentations by the students.

Objective

The goal of this course is to investigate, as a group, a particular set of carbon mitigation/sequestration options and to evaluate their potential, their cost, and their consequences.

Content

From the large number of carbon sequestration/mitigation options, a few options will be selected and then investigated in detail by the students. The results of this research will then be presented to the other students, the involved faculty, and discussed in detail by the whole group.

Lecture notes

None

Literature

Will be identified based on the chosen topic.

Exam: No final exam. Pass/No-Pass is assigned based on the quality of the presentation and ensuing discussion.

A. Minabutdinov

S. Marelli, R. Schöbi, B. Sudret, UQLab user manual - Structural reliability (rare events estimation), Report UQLab-V0.92-107.

Basic course on probability theory and statistics

Concepts and Theories

fostered

Techniques and Technologies

fostered

Analytical Competencies

fostered

Decision-making

fostered

Project Management

fostered

Social Competencies

Communication

fostered

Cooperation and Teamwork

fostered

Self-presentation and Social Influence

fostered

Sensitivity to Diversity

fostered

Personal Competencies

Negotiation

fostered

Creative Thinking

fostered

Critical Thinking

fostered

Integrity and Work Ethics

fostered

Resource and Environmental Economics

Relationship between economy and environment, market failures, external effects and public goods, contingent valuation, internalisation of externalities, economics of non-renewable resources, economics of renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.

Method-specific Competencies

Techniques and Technologies

fostered

Analytical Competencies

fostered

Decision-making

fostered

Project Management

fostered

Communication

fostered

Cooperation and Teamwork

fostered

Self-presentation and Social Influence

fostered

Sensitivity to Diversity

fostered

Creative Thinking

fostered

Critical Thinking

fostered

Integrity and Work Ethics

fostered

A. Miftakhova, A. Minabutdinov

A. Minabutdinov

assessed

3 credits

Autumn Semester 2024
A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.


Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.
Objective

The students learn to...
- choose and apply appropriate tools from computer science,
- process and analyze real-world data from their subject of study,
- handle the complexity of real-world data,
- query databases and understand and evaluate the corresponding database model,
- encode a problem into a program, test the program, and correct errors,
- implement models from the natural sciences as a simulation.

Content

1. Modeling and simulations
2. Data management with lists and tables
3. Data management with a relational database
4. Introduction to programming with Python 1 (variables & data types)
5. Introduction to programming with Python 2 (control structures & logic)
6. Introduction to programming with Python 3 (sequential data structures)

Lecture notes

All materials for the lecture are available at www.evim.ethz.ch

Literature


Prerequisites / notice

This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies

- Communication
- Cooperation and Teamwork

Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

Project Management for Construction Projects

Abstract

This course is designed to lay down the foundation of the different concepts, techniques, and tools for successful project management of construction projects.

Objective

The goal is that at the end of this course students should have a good understanding of the different project management knowledge areas, the phases required for successful project management, and the role of a project manager. To demonstrate this, students will work in groups in different case studies to apply the concepts, tools and techniques presented in the class.

Two 3 to 4 hours sessions towards the end of the lecture series will introduce a practical project to allow the teams to demonstrate the tools and techniques learned during the semester.

The course will have a final quiz that will be graded.

The course will be supported by several external lecturers from the construction industry and demonstrations of real-life case studies.

Content

The main content of the course is summarized in the following topics:

- Introduction, project and organization structures
- Project scheduling
- Resource management
- Risk management
- Project estimating and budgeting
- Project financing and Public-Private Partnerships (PPP)
- Construction Process management and controlling
- Sustainability management
- Reporting and Communication
- Interpersonal skills and leadership in Construction projects
- Advanced Topics in Construction Project management (BIM / 5D planning, KI)
- Project Evaluation and Closure

Lecture notes

The slides for the class will be available for download from Moodle at least one day before each class. Copies of all necessary documents will be distributed at appropriate times.

Literature

Relevant readings will be recommended throughout the course (and made available to the students via Moodle).

Prerequisites / notice

The students will be randomly assigned to teams. Students will be graded as a team based on the final Project proposal with the in-class oral presentation as well as a final exam (50% exam and 50% project). Homework will not be graded but your final report and presentation will consist mostly of your homework assignments consolidated and put in a report and presentation format.
### Competencies

**Subject-specific Competencies**
- Concepts and Theories fostered
- Techniques and Technologies fostered

**Method-specific Competencies**
- Analytical Competencies fostered
- Decision-making assessed
- Problem-solving assessed
- Project Management assessed

**Social Competencies**
- Communication assessed
- Cooperation and Teamwork assessed
- Customer Orientation assessed
- Leadership and Responsibility assessed
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation assessed

**Personal Competencies**
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

### 376-1177-00L Human Factors I

**Abstract**
Strategies of human-system-interaction, individual needs, physical & mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people's health, well-being, and satisfaction as well as the overall system performance.

**Objective**
The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications. Students are expected to learn about how to enable an efficient and qualitatively high standing interaction between human and the environment, considering costs, benefits, health, and safety as well. Thus, an ergonomic design and evaluation process of products, tasks, and environments may be promoted in different disciplines. The goal is achieved in addressing a broad variety of topics and embedding the discussion in macroscopic factors such as the behavior of consumers and objectives of economy.

**Content**
- Physiological, physical, and cognitive factors in sensation, perception, and action
- Body spaces and functional anthropometry, Digital Human Models
- Experimental techniques in assessing human performance, well-being, and comfort
- Usability engineering in system designs, product development, and innovation
- Human information processing and biological cybernetics
- Interaction among consumers, environments, behavior, and tasks

**Literature**
- Gavriel Salvendy, Handbook of Human Factors and Ergonomics, 4th edition (2012), is available on NEBIS as electronic version and for free to ETH students
- Further textbooks are introduced in the lecture
- Brouchures, checklists, key articles etc. are uploaded in ILIAS

### 103-0569-00L European Aspects of Spatial Development

**Abstract**
Following the insight into historical perspective and contemporary models of governance and planning, the course focuses on the international dimension of spatial planning in Europe. This includes a discussion of how European spatial policy is made and by whom, how planners can participate in such process and how they can address transnational challenges of spatial development cooperatively.

**Objective**
Keeping the general aim of exploring the European dimension of spatial planning in mind, the specific course learning objectives are as follows:
- to interpret the history of spatial planning at the transnational scale
- to understand and explain the content of the European spatial policy agenda
- to describe and analyse the role of territorial cooperation in making European spatial development patterns and planning procedures
- to discuss the changing role of planners and evaluate the ways to their engagement in European spatial policy-making

**Content**
- European spatial policy agenda: introduction and basic directives
- governance models
- planning models; collaborative planning model (main concepts & critics)
- post-positivist approach to spatial planning
- transnational spatial planning in Europe; questioning the European spatial planning; spatial development trends in Europe
- EU as a political system: EU institutions & non-EU actors
- planning families in Europe; the European spatial planning agenda
- spatial planning strategies and programmes on territorial cooperation
- the notion of planning culture and planning system; planning cultures in Europe
- basic characteristics of planning systems in Europe
- the relevance of European transnational cooperation for spatial planning
- European transnational initiatives

**Lecture notes**
The documents for the lecture will be provided at the moodle.
Obligatory literature:

Recommended literature:

Planning models:

EU as a political context:

Territorial cooperation in Europe:

Planning families and cultures:

Planning systems in Europe:

Prerequisites / notice
- Only for master students, otherwise a special permission by the lecturer is required.

Competencies

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<th>Competency Type</th>
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851-0252-08L Evidence-Based Design: Methods and Tools for Evaluating Architectural Design

Abstract
Students are taught a variety of analytic techniques that can be used to evaluate architectural design. The concept of evidence-based design is introduced, and complemented with theoretical background on space syntax and spatial cognition. This is a project-oriented course, students implement a range of methods on a sample project. The course is tailored for architecture design students.

Objective
The course aims to teach students how to evaluate a design project from the perspective of the end user. The concept of evidence-based design is introduced through a series of case studies. Students are given a theoretical background in space syntax and spatial cognition, with a view to applying this knowledge during the design process. The course covers a range of methods including visibility analysis, network analysis, conducting real-world observations, and virtual reality for architectural design. Students apply these methods to a case study of their choice, which can be at building or urban scale. For students taking a B-ARCH or M-ARCH degree, this can be a completed or ongoing design studio project. The course gives students the chance to implement the methods iteratively and explore how best to address the needs of the eventual end-user during the design process.

The course is tailored for students studying for B-ARCH and M-ARCH degrees. As an alternative to obtaining D-GESS credit, architecture students can obtain course credit in "Vertiefungsfach" or "Wahlfach".

252-0834-00L Information Systems for Engineers

Abstract
We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).
Objective

Do you want to be able to query your own data productively and efficiently in your future semester projects, bachelor's thesis, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This courses teaches you how to do so as well as the dos and don'ts.

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook

Literature

- Lecture material (slides).
  (It is not required to buy the book, as the library has it)

Prerequisites / notice

For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logic
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

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### 052-0707-00L Urban Design III

**W 2 credits 2V**

H. Klumpner.
F. T. Salva Rocha Franco

#### Abstract
Students are introduced to a narrative of 'Urban Stories' through a series of three tools driven by social, governance, and environmental transformations in today's urbanization processes. Each lecture explores one city's spatial and organizational ingenuity born out of a particular place's realities, allowing students to transfer these inventions into a catalog of conceptual tools.

#### Objective
- How can students of architecture become active agents of change? What does it take to go beyond a building's scale, making design-relevant decisions to the city rather than a single client? How can we design in cities with a lack of land, tax base, risk, and resilience, understanding that Zurich is the exception and these other cities are the rule? How can we discover, set rather than follow trends and understand existing urban phenomena activating them in a design process? The lecture series produces a growing catalog of operational urban tools across the globe, considering Governance, Social, and Environmental realities. Instead of limited binary comparing of cities, we are building a catalog of change, analyzing what design solutions cities have been developing informally incrementally over time, why, and how. We look at the people, institutions, culture behind the design and make concepts behind these tools visible. Students get first-hand information from cities where the chair as a Team has researched, worked, or constructed projects over the last year, allowing competent, practical insight about the people and topics that make these places unique. Students will be able to use and expand an alternative repertoire of experiences and evidence-based design tools, go to the conceptual core of them, and understand how and to what extent they can be relevant in other places. Urban Stories is the basic practice of architecture and urban design. It introduces a repertoire of urban design instruments to the students to use, test, and start their designs.

#### Content
Urban form cannot be reduced to physical space. Cities result from social construction, under the influence of technologies, ecology, culture, the impact of experts, and accidents. Urban un-concluded processes respond to political interests, economic pressure, cultural inclinations, along with the imagination of architects and urbanists and the informal powers at work in complex adaptive systems. Current urban phenomena are the result of urban evolution. The facts stored in urban environments include contributions from its entire lifecycle, visible in the physical environment, and non-physical aspects. This imaginary city exists along with its potentials and problems and with the conflicts that have evolved. Knowledge and understanding, along with a critical observation of the actions and policies, are necessary to understand the diversity and instability present in the contemporary city and understand how urban form evolved to its current state.

How did cities develop into the cities we live in now? Urban plans, instruments, visions, political decisions, economic reasonings, cultural inputs, and social organization have been used to operate in urban settlements in specific moments of change. We have chosen cities that exemplify how these instruments have been implemented and how they have shaped urban environments. We transcribe these instruments into urban operational tools that we have recognized and collected within existing tested cases in contemporary cities across the globe.

This lecture series will introduce urban knowledge and the way it has introduced urban models and operational modes within different concrete realities, therefore shaping cities. The lecture series translates urban knowledge into operational tools, extracted from cities where they have been tested and become exemplary samples, most relevant for understanding how the urban landscape has taken shape. The tools are clustered in twelve thematic clusters and three tool scales for better comparability and cross-reflection.

The Tool case studies are compiled into a global urbanization toolbox, which we use as typological models to read the city and critically reflect upon it. The presented contents are meant to serve as inspiration for positioning in future professional life and provide instruments for future design decisions.

In an interview with a local designer, we measure our insights against the most pressing design topics in cities today, including inclusion, affordable housing, provision of public spaces, and infrastructure for all.

#### Lecture notes
The learning material, available via https://moodle-app2.let.ethz.ch/ is comprised of:
- Toolbox 'Reader' with an introduction to the lecture course and tool summaries
- Weekly exercise tasks
- Infographics with basic information of each city
- Quiz question for each tool
- Additional reading material
- Interviews with experts
- Archive of lecture recordings

#### Literature
- Reading material will be provided throughout the semester.

### 151-3209-00L Engineering Design Optimization

**W 4 credits 4G**

K. Shea. T. Stankovic

#### Abstract
The course covers fundamentals of computational optimization methods in the context of engineering design. It develops skills to formally state and model engineering design tasks as optimization problems and select appropriate methods to solve them.

#### Objective
- The lecture and exercises teach the fundamentals of optimization methods in the context of engineering design. After taking the course students will be able to express engineering design problems as formal optimization problems. Students will also be able to select and apply a suitable optimization method given the nature of the optimization model. They will understand the links between optimization and engineering design in order to design more efficient and performance optimized technical products. The exercises are MATLAB based.

#### Content

#### Lecture notes
available on Moodle

### 101-0139-00L Scientific Machine and Deep Learning for Design and Construction

**W 3 credits 4G**

B. Bickel, A. Müller, M. Piovarci

#### Abstract
This course will present methods of scientific machine and deep learning (ML/ DL) for applications in design and construction. After providing proper background on ML and the scientific ML (SciML) track, several applications of SciML together with their computational implementation during the design and construction process of the built environment are examined.
This course aims to provide a graduate-level introduction to machine learning, with a particular focus on scientific machine learning for applications in the design and construction phases of projects from architecture and civil engineering.

Upon completion of the course, the students will be able to:
1. Understand main ML background theory and methods.
2. Assess a problem and apply ML and DL in a computational framework accordingly.
3. Incorporate scientific domain knowledge in the SciML process.
4. Define, plan, conduct and present a SciML project.

The course will include theory and algorithms for SciML, programming assignments, as well as a final project assessment.

The topics to be covered are:
2. Incorporation of Domain Knowledge into ML and DL.
4. ML training, validation and testing pipelines for academic and research projects.

A comprehensive series of computer/lab exercises and in-class demonstrations will take place, providing a "hands-on" feel for the course topics.

The course script is composed by lecture slides, which are available online and will be continuously updated throughout the duration of the course.

Suggested Reading:
The course includes theory and algorithms for SciML, programming assignments, and a final project assessment.

Prerequisites / notice
Familiarity with Python is advised.

Literature
Suggested Reading:
Marc Peter Deisenroth, A Ailod Faisal, and Cheng Soon Ong Mathematics for Machine Learning
S. Guido, A. Muller: Introduction to machine learning with python. O'Reilly Media, 2016
O. Martin: Bayesian analysis with python. Packt Publishing Ltd, 2016

102-0327-01L Implementation of Environmental and Other Sustainability Goals
Master students in Environmental Engineering choosing module Ecological Systems Design are not allowed to enrol 102-0327-01 Advanced Environmental Assessments (2KP) as already included in 102-0307-01 Advanced Environmental, Social and Economic Assessments (5KP).

Objective
This course teaches approaches and methods to identify, assess and manage environmental (mainly) and societal (to some extent) aspects in organisations. The course contains an introduction to the global ISO 14001 standard on environmental management, into the concept of ecobalance of organisations, and supply chain management, and a general view on how such approaches fit into a management system.

Students will learn to:
- describe the concept of ecobalance of organisations, and supply chain management, and a general view on how such approaches fit into a management system.
- Sustainability problems of the current economic system and measuring units;
- describe the management system of an organisation and how to develop a sustainability orientation
- discuss approaches to measure environmental performance of an organisation, including ‘organisational LCA’ (Ecobalance)
- explain the pros and cons of single score environmental assessment methods
- apply life cycle costing
- interpret stakeholder relations of an organisation
- (if time allows) describe sustainable supply chain management and stakeholder management
- Sustainability problems of the current economic system and its measuring units;
- The structure of a management system, and elements to integrate environmental management (ISO 14001) and social management (SA8000), especially into strategy development, planning, controlling and communication;
- Sustainability Opportunities and Innovation for companies
- The concept of ‘continuous Improvement’, and its application to environmental management
- Life Cycle Costing, as part of Life Cycle Management
- environmental performance measurement of an organisation, including ‘organisational LCA’ (Ecobalance), incl. practical examples of companies.
- single score environmental assessment methods, with a focus on the ‘ecopoints’ method
- stakeholder management and sustainability oriented communication
- an intro into sustainability issues of supply chain management

Content
Students will get small homework exercises to apply the course topics and methods issues.

Lecture notes
Documents will be available on Ilias

Literature
Will be made available.

Prerequisites / notice
This course is meant for any interested student.

(Students of ESD Ecological Systems Design should choose the combined "AESEA" course (102-0307-01), which is specifically offered and mandatory for their module and includes this course.

Basic knowledge of environmental assessment tools is a prerequisite for this class. Students who have not yet had classwork in this topic will profit more from this course after reading an appropriate textbook before or at the beginning of this course, e.g. Jolliett, O et al. (2016). Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5.2).
This course provides an in-depth analysis of both the theoretical underpinnings to different approaches to climate policy at the international and national levels, and how these different approaches have played out in practice. Students will learn how legislative frameworks have developed over the last 25 years, and also be able to appraise those frameworks critically. The goal is to give students a glimpse into the enormous complexity of this policy area, an understanding of some of the many debates that are currently raging (of which the debate about whether climate change is actually real is probably the least complicated or interesting). We want to give students the ability to evaluate policy arguments made by politicians, experts, and academics with a critical eye, informed by a knowledge of history, an understanding of the theoretical underpinnings, and the results of empirical testing of different strategies. A student taking this course ought to be able to step into an NGO or government agency involved in climate policy analysis or political advocacy, and immediately be able to make an informed and creative contribution. Moreover, by experiencing the depth of this policy area, students should be able to appreciate the complexity inherent in all policy areas.

Climate change is one of the defining challenges of our time, touching all aspects of the environment and of society. There is broad recognition (although with some dissent) that governments ought to do something about it; making sure that emissions of greenhouse gases (GHGs) stop within the next 20 to 30 years; helping people to adapt to the consequences of the climate change to which we have already committed ourselves; and, most controversially, perhaps taking measures to actively remove GHG’s from the atmosphere, or to alter the radiation balance of the Earth through solar engineering.

It’s a complicated set of problems, especially the first of these, known as mitigation. Fundamentally this is because it means doing something that humanity has never really tried before at a planetary scale: deliberately altering the ways the we produce, convert, and consume energy, which is at the heart of modern society. Modern society – the entire anthropocene – grew up on fossil fuels, and the huge benefits they offered in terms of energy that was inexpensive, easy to transport and store, and very dense in terms of its energy content per unit mass or volume. How to manage a society of over 7 billion people, at anything like today’s living standards, without the benefits of that energy, is a question for which there is no easy answer, There are also other challenges outside of energy. How do we build houses, office buildings, and infrastructure networks without cement, a substance that releases large amounts of CO2 as it hardens? How do we reverse the pace of deforestation, particularly in developing countries? How do we eliminate the GHG emissions from agriculture: the methane from cows’ bellies and rice paddies, together with the chemicals that enter the atmosphere from the application of fertilizer?

These are all tough questions at a technical level, but even tougher when you consider that governments typically need to employ indirect methods to get these things to happen. Arguably a government could simply pass a law that forbids people from using fossil fuels. But politically this is simply unrealistic, at least while so many people depend on fossil fuels in their daily lives. What is to be done? For this, one needs to turn to various ideas about how government can and should influence society. On the one hand are ideas suggesting that government ought to play a very limited role, relative to private actors, and should step in only to correct “market failures,” with interventions designed specifically around that failure. On the other hand are ideas suggesting that government (meaning all of us, working together through a democratic process) is the appropriate decision-making body for core decisions on where society can and should go. These issues come to the fore in climate policy discussions and debates.

There will be reading assignments for select classes. All of these will be posted in PDF format on a course Moodle. In addition, there will be one books and one report to be read over the course of the semester. They are:

Ministry of the Future, by Kim Stanley Robinson

Ten Principles for Policy Making in the Energy Transition, by Laura Diaz Anadon et al.

Autumn Semester 2024
This lecture series aims to introduce students to specific contemporary urban (design) conditions. The lecture series examines historical, social and political frameworks of urban issues, and explores and scrutinise possible design methodologies facing these issues. Throughout this course, the lectures will explore perspectives upon the urban condition from a historical, political and social perspective, as well as reflections from philosophy, and urban geography. It will couple this with experiences and manifestoes developed within architectural practices (including practices of landscape architecture and urban design). It urges how design and design research can contribute to the understanding of and intervening in the urban territory, to establish a more just urban condition.

<table>
<thead>
<tr>
<th>Content</th>
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</thead>
<tbody>
<tr>
<td>1. Thermodynamic systems, states and state variables</td>
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<tr>
<td>2. Properties of substances: Water, air and ideal gas</td>
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<tr>
<td>3. Energy conservation in closed and open systems: work, internal energy, heat and enthalpy</td>
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<tr>
<td>4. Second law of thermodynamics and entropy</td>
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<tr>
<td>5. Energy analysis of steam power cycles</td>
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<td>6. Energy analysis of gas power cycles</td>
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<td>7. Refrigeration and heat pump cycles</td>
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<td>8. Nonideal gas equation of state and Joule-Thomson effect</td>
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<td>9. Maximal work and exergy</td>
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<td>10. Mixtures</td>
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<tr>
<td>11. Chemical reactions and combustion systems; chemical and phase equilibrium</td>
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</tbody>
</table>

**Lecture notes**
Lecture slides and supplementary documentation will be available online.

**Literature**

**Prerequisites / notice**
This course is intended for students outside of D-MAVT.

This course week is obligatory for students of all semesters. There are many and varied study contents. Students are assumed to have an adequate background in calculus, physics, and engineering mechanics.

**Competencies**

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<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td></td>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
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<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
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<td>fostered</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>Leadership and Responsibility</td>
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<td></td>
<td>Problem-solving</td>
<td>Self-presentation and Social Influence</td>
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<td>Problem-solving</td>
<td>Sensitivity to Diversity</td>
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<td>Project Management</td>
<td>Negotiation</td>
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<td>fostered</td>
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**052-1205-24L Seminar Week Autumn Semester 2024**
W 2 credits 3A Lecturers

**Abstract**
The seminar week is obligatory for students of all semesters. There are many and varied study contents.

**Objective**
The students will be enabled to discuss narrowly formulated factual questions in small groups and in direct contact with the professors.

**063-0805-24L History and Theory in Architecture IX: Theories of Urban Design**
W 1 credit 1V T. Avermaete

**Abstract**
This course offers a survey of several theories of urban design through a series of thematic lectures. The aim of the lectures is to address these theme's from a historical and a designerly perspective.

**Objective**
This lecture series aims to introduce students to specific contemporary urban (design) conditions. The lecture series examines historical, social and political frameworks of urban issues, and explores and scrutinise possible design methodologies facing these issues.

**Content**

Cities are the most common human habitat today. It is, moreover, expected that within the next few decades two-thirds of the world's population will live in urban areas. This 'fact' nevertheless is rather empty, hollow. The terms used, 'urban' and 'city', after all, do not refer to a single condition. 'Urban' might refer to the core of New York (Manhattan), as well as to its suburbs. Likewise, when using the term 'city', we might indicate a variety of settlements, like Johannesburg, São Paulo, Tokyo, Laos, Cairo, Kiev, Paris, London, Dubai, as well as Zurich, Bern, and Zug. In short, the urban condition thus varies from sprawling suburbs to historic inner cities, from super-luxury villa district to the unbearable circumstances of the unhoused surviving in the streets, and from cities in the West to cities in the so-called Global South. It is, nevertheless, valuable to examine the 'urban' condition today, as it is in the urban territory – in all its diversity – that the societal, political, and environmental challenges of our time become prominent and urgent, and that most often shape the condition wherein architects, landscape architects, and urban designers have to operate. From climate change to segregation, and from the housing crisis to pandemics, all these become visible and tangible within cities, challenging its inhabitants.

In this course, which is offered by the Chair of the History and Theory of Urban Design (Avermaete) as part of the History and Theory of Architecture IX lecture series, students will be introduced to a variety of themes that are at stake in today's urban condition. Getting to understand these circumstances is a prerequisite for any architectural engagement with the city. The starting point of this lecture series is the claim that the built environment conditions its use, and thus forms the condition of human, societal, and political life.

Throughout this course, the lectures will explore perspectives upon the urban condition from a historical, political and social perspective, as well as reflections from philosophy, and urban geography. It will couple this with experiences and manifestoes developed within architectural practices (including practices of landscape architecture and urban design). It urges how design and design research can contribute to the understanding of and intervening in the urban territory, to establish a more just urban condition.
A. Schüller

Can architecture, urban design and planning contribute to housing reconstruction after conflicts and natural disasters? Answers to this question will be provided by researchers and socially engaged architects from Europe, Asia and Latin America through the presentation of concrete case studies and projects.

• General introduction: reconstruction approaches after conflicts and natural disasters
• Housing culture and post-tsunami reconstruction in Tamil Nadu, India
• Patterns of adaptation to culturally inadequate post-disaster housing
• Reconstruction challenges in rural and urban settings
• Housing reconstruction in rural and urban Nepal after the 2015 earthquake
• Rebuilding communities and schools in Haiti
• Learnings from postwar reconstruction in Kosovo
• Bottom-up housing initiatives in ongoing conflicts: the case of Ukraine
• Humanitarian planning: tackling emergency shelter needs.
• Housing initiatives in temporary camps

Lecture notes
A course overview including lecture summaries is made available to inscribed students prior the start of the semester.

Literature
A bibliography will be made available to inscribed students prior the start of the semester.

Project Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>066-0425-00L</td>
<td>Integrated Design MIBS</td>
<td>O</td>
<td>6</td>
<td>3V+3U</td>
<td>A. Schüller, M. Meshkin Kiya, Z. Shi</td>
</tr>
</tbody>
</table>

Abstract

During the integrated design studio students work on a selected integrated architectural / urban design project, considering both energy- and climate systems (HVAC) as well architectural and urban design in a specific site context. The objective is to follow an integrated design process to achieve synergistic solutions.
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>066-0431-00L</td>
<td>Semester Project MIBS</td>
<td>O</td>
<td>6 credits</td>
<td>13A</td>
<td>Supervisors</td>
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</tbody>
</table>

**Abstract**
The semester project focuses on solving specific research questions in the field of integrated building systems.

**Objective**
The semester project is designed to train students in solving specific research questions in the field of integrated building systems. The goal is to apply acquired knowledge which is gained throughout the first year of the master's program. The semester project is advised by a professor who is affiliated with one of the partner departments of the Master program "Integrated building systems".

**Content**
The semester project is designed to train students in solving specific research questions in the field of integrated building systems. The goal is to apply acquired knowledge which is gained throughout the first year of the master's program. The semester project is advised by a professor who is affiliated with one of the partner departments of the Master program "Integrated building systems".

### Science in Perspective

- **see Science in Perspective: Language Courses ETH/UZH**
- **see Science in Perspective: Type A: Enhancement of Reflection Capability**

**Recommended Science in Perspective (Type B) for D-ARCH**

### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>066-0434-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>40D</td>
<td>Professors</td>
</tr>
</tbody>
</table>

**Abstract**
A 6-months Master thesis completes the Master's program of Integrated Building Systems. With the thesis project students are expected to demonstrate their ability to independent and structured scientific thinking.

**Objective**
A 6-months Master thesis completes the Master's program of Integrated Building Systems. With the thesis project students are expected to demonstrate their ability to independent and structured scientific thinking.

**Content**
A 6-months Master thesis completes the Master's program of Integrated Building Systems. With the thesis project students are expected to demonstrate their ability to independent and structured scientific thinking. The thesis can be performed either at ETH Zurich, an industrial enterprise, or in a research institution, but has to be advised by one or more professors affiliated with the Master program "Integrated building systems". The responsible supervisor defines the topic in consultation with the student, together with the scope of work, criteria of assessment, and dates of beginning and delivery of the work.

**Integrated Building Systems Master - Key for Type**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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</tbody>
</table>

**Key for Hours**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

**ECTS**
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Interdisciplinary Sciences Bachelor

### Physical-Chemical Direction

#### 1. Semester (Physical-Chemical Direction)

##### Compulsory Subjects First Year Examinations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-1261-07L</td>
<td>Analysis I: One Variable</td>
<td>O</td>
<td>10</td>
<td>6V+3U</td>
<td>L. Kobel-Keller</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>Introduction to the differential and integral calculus in one real variable: fundamentals of mathematical thinking, numbers, sequences, basic point set topology, continuity, differentiable functions, ordinary differential equations, Riemann integration.</td>
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<td><strong>Objective</strong></td>
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<td>The ability to work with the basics of calculus in a mathematically rigorous way.</td>
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<td><strong>Literature</strong></td>
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<tr>
<td></td>
<td>H. Amann, J. Escher: Analysis I</td>
<td></td>
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<tr>
<td></td>
<td>J. Appell: Analysis in Beispielen und Gegenbeispielen</td>
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<td></td>
<td>R. Courant: Vorlesungen über Differential- und Integralrechnung</td>
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<td></td>
<td>O. Forster: Analysis I</td>
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<td></td>
<td>H. Heuser: Lehrbuch der Analysis</td>
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<td></td>
<td>K. Königsberger: Analysis 1</td>
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<td>W. Walter: Analysis 1</td>
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<td>V. Zorich: Mathematical Analysis I (englisch)</td>
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<td></td>
<td>A. Beutelspacher: &quot;Das ist o.B.d.A. trivial&quot;</td>
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<tr>
<td></td>
<td>H. Schichl, R. Steinbauer: Einführung in das mathematische Arbeiten</td>
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<tr>
<td>401-1151-00L</td>
<td>Linear Algebra I</td>
<td>O</td>
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<td><strong>Abstract</strong></td>
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<td><strong>Objective</strong></td>
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<td>- Mastering basic concepts of Linear Algebra</td>
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<td>- Introduction to mathematical methods</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<td>- Basics</td>
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<td>- Vectorspaces and linear maps</td>
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<td>- Systems of linear equations and matrices</td>
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<td>- Determinants</td>
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<td>- Endomorphisms and eigenvalues</td>
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<tr>
<td></td>
<td><strong>Lecture notes</strong></td>
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<tr>
<td></td>
<td>We will provide German lecture notes and an English translation at latest at the start of the semester.</td>
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<tr>
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<td><strong>Literature</strong></td>
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<td>Lecture notes in German and an English translation will be published on the website of the course, at latest at the start of the semester. Besides this we also recommend:</td>
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<td>In addition we recommend this general introduction into studying mathematics:</td>
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<tr>
<td>402-1701-00L</td>
<td>Physics I</td>
<td>O</td>
<td>7</td>
<td>4V+2U</td>
<td>K. Ensslin</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>This course gives a first introduction to Physics with an emphasis on classical mechanics.</td>
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<tr>
<td></td>
<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>Acquire knowledge of the basic principles regarding the physics of classical mechanics. Skills in solving physics problems.</td>
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<tr>
<td>529-0011-01L</td>
<td>General Chemistry (Physical Chemistry) I</td>
<td>O</td>
<td>3</td>
<td>2V+1U</td>
<td>H. J. Wörner</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>The lecture provides an introduction to some of the physical fundamentals of chemistry, in particular radioactivity, quantum mechanics, the structure of matter and an atom, the periodic table of elements, and chemical bonding.</td>
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</tbody>
</table>
Objective

After the lecture, students will be able to,
- to calculate physical quantities and their units which are important for chemistry,
- name some properties of chemically relevant particles and propose experimental methods to determine these properties,
- name applications and hazards of radioactivity,
- categorize radioactive decay processes and mathematically represent the time course of simple decay reactions and qualitatively predict and represent them,
- describe wave and particle properties of electromagnetic radiation and matter and propose experimental methods for their detection,
- to explain the basics of quantum mechanics (meaning of the wave function, Heisenberg's uncertainty principle, operators, commutators) and to perform simple calculations with them,
- analyze and calculate absorption and emission spectra of single-electron atoms,
- to set up the Schrödinger equation for a molecular multi-particle system,
- independently solve the Schrödinger equation for the molecular systems of particles in a box and harmonic oscillator in one dimension and generalize to higher dimensional non-interacting problems,
- model molecular vibrations of diatomic molecules using the harmonic and anharmonic oscillator model,
- explain the concept of an orbital and represent mathematically and pictorially the qualitative form of the orbitals of the hydrogen atom,
- explain the structure of the periodic table of elements with the help of the orbital concept,
- recognize and use similarities in the electronic structure of atoms to predict chemically relevant properties, and
- establish term symbols for atomic ground states.

Translated with www.DeepL.com/Translator (free version)

Content

Atomic structure and structure of matter: atomic theory, elementary particles, atomic nuclei, radioactivity, nuclear reactions. Atomic orbitals and energy levels: ionization energies, atomic spectroscopy, term values and symbols. Quantum mechanical atom model: wave-particle duality, the uncertainty principle, Schrödinger’s equation, the hydrogen atom, construction of the periodic table of the elements. Chemical bonding: ionic bonding, covalent bonding, molecular orbitals.

Lecture notes

See homepage of the lecture.

Literature

See homepage of the lecture.

Prerequisites / notice

Voraussetzungen: Maturastoff. Insbesondere Integral- und Differentialrechnung.

Competencies

Subject-specific Competencies | Concepts and Theories | ECTS | Hours | Lecturers
--- | --- | --- | --- | ---
Primarily 529-0011-04L Practical Course General Chemistry | | 8 credits | 12P | M. Bezdek, D. Dirin, T. Segawa, A. Yakimov

Information about the practical course will be given on the first day.

Abstract

The general chemistry practical course aims at preparing the students for the work in modern chemistry laboratory. The students are trained to behave safely in the laboratory and use chemicals, chemistry glassware, and related equipment to perform and analyze the equilibrium in basic chemical reactions.

Objective

The students are expected to gain practical experience with as well as establish understanding of the following concepts and phenomena:

- Safe behavior and safety regulations in chemistry laboratory;
- Best practices in common techniques (purification, recrystallization, distillation, etc.);
- Analysis of measured values (measuring error, average value, error analysis);
- Acid-base-equilibria (strengths of acids and bases, pH- and pKa-values, titrations, buffer systems);
- Precipitation equilibria (gravimetry, potentiometry, conductivity measurements);
- Oxidation state and redox reactions (redox-titrations, galvanic elements);
- Metal complexes (syntheses of complexes, ligand exchange reactions, complexometric titration)
- Qualitative analysis (cation and anion separation, determination of cations and anions).

Content

In the general chemistry practical course students are introduced to the work in chemistry laboratory. During the course they become familiar with common chemistry glassware and related equipment as well as learn basic experimental procedures, such as distillation, recrystallization, purification, digestion etc. Upon the measurements of pH, conductivity, and potential in the course of reactions, students establish the understanding of the chemical equilibrium concept.

Students work with various classes of inorganic compounds and types of chemical reactions, e.g. acid-base, redox, precipitation. They also obtain first experience with the synthesis of metal complexes as well as learn basics of qualitative analysis of an unknown substance.

Literature

Moodle Lernplattform

Prerequisites / notice

Compulsory: online enrolment latest one week after start of the semester

By enrolling in the laboratory course, students confirm to study all safety information thoroughly and to follow instructions.

Competencies

Subject-specific Competencies | Concepts and Theories | ECTS | Hours | Lecturers
--- | --- | --- | --- | ---
Primarily | | | | 

Method-specific Competencies

Analytical Competencies | Decision-making | Problem-solving | 
--- | --- | --- | 

Social Competencies

Communication | Cooperation and Teamwork | 
--- | --- | 

Personal Competencies

Adaptability and Flexibility | Critical Thinking | Integrity and Work Ethics | Self-awareness and Self-reflection | Self-direction and Self-management | 
--- | --- | --- | --- | --- |
## 3. Semester (Physical-Chemical Direction)
### Examination Block

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0422-00L</td>
<td>Physical Chemistry II: Chemical Reaction Kinetics</td>
<td>O</td>
<td>4 credits</td>
<td>3V+1U</td>
<td>R. Signorell</td>
</tr>
<tr>
<td></td>
<td>Introduction to Chemical Reaction Kinetics</td>
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<td></td>
<td>Will be provided</td>
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<tr>
<td>402-2883-00L</td>
<td>Physics III</td>
<td>O</td>
<td>7 credits</td>
<td>4V+2U</td>
<td>S. Johnson</td>
</tr>
<tr>
<td></td>
<td>Introductory course on quantum and atomic physics including optics and statistical physics. A basic introduction to quantum and atomic physics, including basics of optics and equilibrium statistical physics. The course will focus on the relation of these topics to experimental methods and observations.</td>
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</table>
Einführung in die Quantenphysik: Planck'sche Strahlung (Wärmestrahlung), Photonen, Photoelektrischer Effekt, Thomson und Rutherford Streuung, Compton Streuung, Meherelektronenatome, Röntgenspektren, Auswahlregeln, Absorption und Emission von Strahlung, Molekülorbitale und Kovalente Bindung


Lecture notes
Im Rahmen der Veranstaltung werden die Folien in elektronischer Form zur Verfügung gestellt. Ergänzendes Buch wird als Pflichtlektüre empfohlen. Es wird kein Skript in der Vorlesung verteilt.
Wir werden die Quantenmechanik anhand der Schrödinger-Gleichung mit den klassischen elektro-magnetischen Wellen vergleichen. Zu den klassischen Wellen werden Ergänzungsunterlagen verteilt.

Literature
M. Alonso, E. J. Finn
Quantenphysik und Statistische Physik
R. Oldenbourg Verlag, München
5. Auflage
ISBN 978-3-486-71340-4

Competencies
Subject-specific Competencies
Concepts and Theories
assessed
Techniques and Technologies
assessed

Method-specific Competencies
Analytical Competencies
assessed
Decision-making
fostered

Personal Competencies
Creative Thinking
fostered
Critical Thinking
fostered

The Bachelor's programme in Interdisciplinary Sciences allows students to choose from any subject taught at a Bachelor level at ETH Zurich.

In consultation with the Director of Studies of Interdisciplinary Sciences, every student must establish his/her own individual study programme at the beginning of the 2nd year. See the Programme Regulations 2018 for further details.

Number Title Type ECTS Hours Lecturers
252-0847-00L Computer Science W 5 credits 2V+2U M. Fischer, F. Friedrich Wicker

Abstract
The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.

Objective
Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens "behind the scenes" when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.

Content
The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.

Lecture notes
Lecture slides and all other material will be made available for download on the course web page.

Literature
Bjarne Stroustrup: Einführung in die Programmierung mit C++, Pearson Studium, 2010
Andrew Koenig and Barbara E. Moo: Accelerated C++, Addison-Wesley, 2000

Competencies
Subject-specific Competencies
Concepts and Theories
assessed
Techniques and Technologies
assessed

Method-specific Competencies
Analytical Competencies
assessed
Decision-making
fostered

Personal Competencies
Creative Thinking
fostered
Critical Thinking
fostered

401-2303-00L Complex Analysis W 6 credits 3V+2U Ö. Imamoglu

Abstract
Complex functions of one variable, Cauchy-Riemann equations, Cauchy theorem and integral formula, singularities, residue theorem, index of closed curves, analytic continuation, special functions, conformal mappings, Riemann mapping theorem.

Objective
Working knowledge of functions of one complex variables; in particular applications of the residue theorem.
Literature

Th. Gamelin: Complex Analysis. Springer 2001
D. Salamon: "Funktionentheorie". Birkhauser, 2011. (In German)
K.Jaenich: Funktionentheorie. Springer Verlag
R.Remmert: Funktionentheorie I. Springer Verlag
E.Hille: Analytic Function Theory. AMS Chelsea Publications

401-2333-00L Mathematical Methods of Physics I W 6 credits 3V+2U P. Hintz
Abstract

402-0205-00L Quantum Mechanics I W 8 credits 3V+2U M. Krstic Marinkovic
Abstract
Applications: simple potentials in wave mechanics, scattering and resonance, harmonic oscillator, hydrogen atom, and perturbation theory.

Objectives
Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems.

Content
The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradoxon and Bell's inequality); Perturbation theory.

Literature
G. Baym, Lectures on Quantum Mechanics
E. Merzbacher, Quantum Mechanics
L.I. Schiff, Quantum Mechanics
R. Feynman and A.R. Hibbs, Quantum Mechanics and Path Integrals
J.J. Sakurai: Modern Quantum Mechanics
A. Messiah: Quantum Mechanics I
S. Weinberg: Lectures on Quantum Mechanics

402-0255-00L Introduction to Solid State Physics W 8 credits 3V+2U A. Zheludev
Abstract
The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, electronic properties of insulators, metals, semiconductors, transport properties, and magnetism.

Objective
Introduction to Solid State Physics.

Content
The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, thermal properties of insulators; metals (classical and quantum mechanical description of electronic states, thermal and transport properties of metals); semiconductors (bandstructure and n/p-type doping); magnetism.

Lecture notes
The script will be available on moodle.

Literature
C. Kittel, Festkörperphysik
Ashcroft & Mermin, Festkörperphysik
402-0263-00L  
**Astrophysics I**  
*Physics BSc students with programme regulations 2016 need to register for "402-0263-10L Astrophysics".*  
*W 8 credits 3V+2U  A. Refregier*

**Abstract**
This introductory course will develop basic concepts in astrophysics as applied to the understanding of the physics of planets, stars, galaxies, and the Universe.

**Objective**
The course provides an overview of fundamental concepts and physical processes in astrophysics with the dual goals of: i) illustrating physical principles through a variety of astrophysical applications; and ii) providing an overview of research topics in astrophysics.

**Literature**
Astrophysics for physicist, Arnab Ray Choudhuri

**Competencies**
- Subject-specific Competencies: Concepts and Theories assessed
- Method-specific Competencies: Analytical Competencies assessed

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402-0595-00L  
**Semiconductor Nanostructures**  
*W 6 credits 2V+1U  T. M. Ihn*

**Abstract**
The course covers the foundations of semiconductor nanostructures, e.g., materials, band structures, bandgap engineering and doping, field-effect transistors. The physics of the quantum Hall effect and of common nanostructures based on two-dimensional electron gases will be discussed, i.e., quantum point contacts, Aharonov-Bohm rings and quantum dots.

**Objective**
At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:
1. The integer quantum Hall effect
2. Conductance quantization in quantum point contacts
3. the Aharonov-Bohm effect
4. Coulomb blockade in quantum dots

**Content**
1. Introduction and overview
2. Semiconductor crystals: Fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k.p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

**Lecture notes**

**Literature**
In addition to the lecture notes, the following supplementary books can be recommended:

**Prerequisites / notice**
The lecture is suitable for all physics students, students of Quantum Engineering, and students of Micro- and Nanosystems beyond the bachelor of science degree. Basic knowledge of solid state physics is a prerequisite. Very ambitioned students in the third year of Physics may be able to follow. The lecture can be chosen as part of the PhD-program. The course is taught in English.

**Competencies**
- Subject-specific Competencies: Concepts and Theories assessed
- Method-specific Competencies: Analytical Competencies assessed

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402-2203-01L  
**Classical Mechanics**  
*W 7 credits 4V+2U  M. Gaberdiel*

**Abstract**
A conceptual introduction to theoretical physics: Newtonian mechanics, central force problem, oscillations, Lagrangian mechanics, symmetries and conservation laws, Hamiltonian mechanics, canonical transformations, Hamilton-Jacobi equation, spinning top, relativistic space-time structure.

**Objective**
Fundamental understanding of the description of Mechanics in the Lagrangian and Hamiltonian formulation. Detailed understanding of important applications, in particular, the Kepler problem, the physics of rigid bodies (spinning top) and of oscillatory systems.

**Competencies**
- Subject-specific Competencies: Concepts and Theories assessed
- Method-specific Competencies: Analytical Competencies assessed

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529-0051-00L  
**Analytical Chemistry I**  
*W 3 credits 3G  D. Günther, M.-O. Ebert, G. Schwarz, R. Zenobi*

**Abstract**
Introduction into the most important spectroscopical methods and their applications to gain structural information.
This course will build upon the basic knowledge of structure and reactivity of organic molecules gained in AC/OCI and AC/OCII. The students will learn and understand the methodological basics of binding theory in complexes of transition metals. They will be able to analyze synthetic methods including important reactions of aldehydes, ketones, addition reactions, and the addition of organometallic compounds. Synthesis and reactivity of carboxylic acid derivatives (nucleophilic addition-elimination reactions). Introduction to the concepts of protecting groups and retrosynthesis.

**Objective**
Knowledge about the necessary theoretical background of spectroscopical methods and their practical applications

**Content**
Application oriented basics of organic and inorganic instrumental analysis and of the empirical employment of structure elucidation methods:
- Mass spectrometry: Ionization methods, mass separation, isotope signals, rules of fragmentation, rearrangements.
- NMR spectroscopy: Experimental basics, chemical shift, spin-spin coupling.
- IR spectroscopy: Revisiting topics like harmonic oscillator, normal vibrations, coupled oscillating systems (in accordance to the basics of the related lecture in physical chemistry); sample preparation, acquisition techniques, law of Lambert and Beer, interpretation of IR spectra; Raman spectroscopy.
- UV/VIS spectroscopy: Basics, interpretation of electron spectra. Circular dichroism (CD) and optical rotation dispersion (ORD).

**Lecture notes**
Script will be for the production price. A (commented) collection of slides and a script will be made available via Moodle.

**Literature**
- M. Hesse, H. Meier, B. Zeeh, Spektroskopische Methoden in der organischen Chemie, 5. überarbeitete Auflage, Thieme, Stuttgart, 1995;

**Prerequisites / notice**
Exercises are integrated in the lectures. In addition, attendance in the lecture 529-0289-00 “Instrumental analysis of organic compounds” (4th semester) is recommended.

**529-0121-00L Inorganic Chemistry I**

**Abstract**
The students will learn and understand the methodological basics of binding theory in complexes of transition metals. They will be able to explain the structure, chemical bonding, spectroscopic properties as well as general strategies for the synthesis of complexes of transition metals. In this context, students will master the basics of group theory and its application.

**Content**
This course consists of the following parts, which introduce the students to the chemistry of transition metals as well as lanthanides and actinides: 1) General definitions and terms in coordination chemistry; 2) Coordination numbers and structures; 3) Ligand types; 4) The chemical bond in coordination compounds part A: Crystal field theory and ligand field theory; 5) The chemical bond in coordination compounds part B: Qualitative MO theory; 6) Reactivity and reaction mechanisms of coordination compounds; 7) Group theory and character tables; 8) Vibrational spectroscopy; 9) Electronic excitation.

**Lecture notes**
A commented collection of slides and a script will be made available via Moodle.

**Literature**

**Competencies**
**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered
In the course "Atmosphere", the competencies of process understanding, system understanding and data analysis & interpretation are taught, applied and examined.

Objective
- Students are able to explain the physical structure and chemical composition of the atmosphere
- to quantitatively describe and understand the fundamental physical and chemical process in the atmosphere
- to explain the interactions and feedbacks between atmosphere - ocean - land surface, troposphere - stratosphere and weather - climate.

Content
Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds.

Lecture notes
Written information will be supplied.

Literature

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Conceptual and Theoretical</th>
<th>Assessed</th>
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</thead>
<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>Assessed</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>Fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>Fostered</td>
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</tbody>
</table>

701-0473-00L Weather Systems

Abstract
Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; Potential Vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer; water isotopes

Objective
The students are able to:
- explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- to discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain the dynamics of the global circulation and of synoptic- and meso-scale flow features
- to explain how mountains influence the atmospheric flow on different scales
- basic understanding of stable water isotopes as tracers for moist adiabatic processes in weather systems

Content
Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; Potential Vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer; water vapour transport in the atmosphere; water isotopes

Lecture notes
Lecture notes and slides

Literature
Atmospheric Science, An Introductory Survey
John M. Wallace and Peter V. Hobbs, Academic Press

Prerequisites / notice
Basic physics

Competencies

<table>
<thead>
<tr>
<th>Social Competencies</th>
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<th>Fostered</th>
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<tbody>
<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>Fostered</td>
</tr>
</tbody>
</table>

701-0475-00L Atmospheric Physics

Abstract
This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation, especially prediction of showers and severe convective storms, and optical phenomena

Objective
Students are able to explain the mechanisms of convective storm formation using knowledge of thermodynamics and cloud microphysics.
- to interpret precipitation radar images
- to evaluate the significance of clouds and aerosol particles for artificial weather modification.

Content
The course starts with introducing selected concepts of thermodynamics for atmospheric processes. The students learn the concept of the thermodynamic equilibrium and derive the Clausius-Clayperon equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Lecture notes
Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=20400

Prerequisites / notice
Basic physics

Competencies

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<tr>
<th>Social Competencies</th>
<th>Cooperation and Teamwork</th>
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<tbody>
<tr>
<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>Fostered</td>
</tr>
</tbody>
</table>

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1479 of 2653
Lecturers
Subject-specific Competencies

R. Kretzschmar

Introduction to the formation and properties of soils as a function of parent rock, landscape position, climate, and soil organisms. Complex

D. Dirin, T. Segawa, M. La Fortezza

Critical Thinking

M. Bezdek

Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial

M. Pilhofer, S. Robinson

Personal Competencies

Critical Thinking

M. Bezdek

assessed

Pedosphere

W 3 credits 2V

R. Kretzschmar

Definition of the pedosphere, soil functions, rocks as parent materials, minerals and weathering, soil organisms, soil organic matter, soil

The course "Pedosphäre" teaches and examines the competencies process understanding and systems understanding.

content

The relationship between soil forming processes, physical and chemical soil properties, soil biota, and ecological soil properties are explained

and illustrated by numerous examples.

Lecture notes

Polybook

content


Prerequisites / notice

There is a additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The

participation is recommended but voluntary.

Competencies

Subject-specific Competencies

Concepts and Theories

assessed

Techniques and Technologies

fostered

Method-specific Competencies

Analytical Competencies

assessed

Problem-solving

assessed

Social Competencies

Communication

assessed

Personnel Competencies

Critical Thinking

assessed

Self-direction and Self-management

assessed

701-0501-00L Pedosphere

Abstract

Introduction to the formation and properties of soils as a function of parent rock, landscape position, climate, and soil organisms. Complex

relationships between soil forming processes, physical and chemical soil properties, soil biota, and ecological soil properties are explained

and illustrated by numerous examples.

Objective

Understanding of soils as integral parts of ecosystems, development and distribution of soils as a function of environmental factors, and

processes leading to soil degradation.

Content

Definition of the pedosphere, soil functions, rocks as parent materials, minerals and weathering, soil organisms, soil organic matter, soil

formation, principles of soil classification, global soil regions, physical soil properties and functions, chemical soil properties and functions,

soil fertility, land use and soil degradation.

Literature


Prerequisites / notice

Prerequisites: Basic knowledge in chemistry, biology and geology.

Competencies

Subject-specific Competencies

Concepts and Theories

assessed

Techniques and Technologies

fostered

Method-specific Competencies

Analytical Competencies

assessed

Problem-solving

assessed

Personal Competencies

Critical Thinking

assessed

Social Competencies

Communication

assessed

Personnel Competencies

Critical Thinking

assessed

Self-direction and Self-management

assessed

752-4001-00L Microbiology

Abstract

Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial

Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Objective

Teaching of basic knowledge in microbiology.

Content Der Schwerpunkt liegt auf den Themen: Bakterielle Zellbiologie, Molekulare Genetik, Wachstumspathologie, Biochemische Diversität, Phylogenie und Taxonomie, Prokaryotische Vielfalt, Interaktion zwischen Menschen und Mikroorganismen sowie Biotechnologie.

Lecture notes

Wird von den jeweiligen Dozenten ausgegeben.

Literature

Die Behandlung der Themen erfolgt auf der Basis des Lehrbuchs Brock, Biology of Microorganisms

Competencies

Subject-specific Competencies

Concepts and Theories

assessed

Techniques and Technologies

fostered

Method-specific Competencies

Analytical Competencies

assessed

Problem-solving

assessed

Personal Competencies

Critical Thinking

assessed

Social Competencies

Communication

assessed

Personal Competencies

Critical Thinking

assessed

Self-direction and Self-management

assessed

Laboratory Courses, Semester Papers, Proseminars, Field Trips

Further laboratory courses must be applied for at the respective Director of Studies.

Number Title Type ECTS Hours Lecturers

529-0011-04L Practical Course General Chemistry ■

Latest online enrolment is 18.09.2023.

Abstract

The general chemistry practical course aims at preparing the students for the work in modern chemistry laboratory. The students are

trained to behave safely in the laboratory and use chemicals, chemistry glassware, and related equipment to perform and analyze the

equilibrium in basic chemical reactions.

Objective

The students are expected to gain practical experience with as well as establish understanding of the following concepts and phenomena:

- Safe behavior and safety regulations in chemistry laboratory;

- Best practices in common techniques (purification, recrystallization, distillation, etc.);

- Analysis of measured values (measuring error, average value, error analysis);

- Acid-base-equilibria (strengths of acids and bases, pH- and pKa-values, titrations, buffer systems);

- Precipitation equilibria (gravimetry, potentiometry, conductivity measurements);

- Oxidation state and redox reactions (redox-titrations, galvanic elements);

- Metal complexes (syntheses of complexes, ligand exchange reactions, complexometric titration)

- Qualitative analysis (cation and anion separation, determination of cations and anions).
In the general chemistry practical course students are introduced to the work in chemistry laboratory. During the course they become familiar with common chemistry glassware and related equipment as well as learn basic experimental procedures, such as distillation, recrystallization, purification, digestion etc. Upon the measurements of pH, conductivity, and potential in the course of reactions, students establish the understanding of the chemical equilibrium concept.

Students work with various classes of inorganic compounds and types of chemical reactions, e.g. acid-base, redox, precipitation. They also obtain first experience with the synthesis of metal complexes as well as learn basics of qualitative analysis of an unknown substance.

Moodle Lernplattform

Compulsory: online enrolment latest one week after start of the semester

By enrolling in the laboratory course, students confirm to study all safety information thoroughly and to follow instructions.

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Analytical Competencies

- Decision-making
- Problem-solving

Communication

- Cooperation and Teamwork

Adaptability and Flexibility

- Critical Thinking

Ethics

- Integrity and Work Ethics

Self-awareness and Self-reflection

- Self-direction and Self-management

W 11 credits 16P V. Mougel

Latest online enrolment is one week before the beginning of the semester.

Introduction to the experimental methods of Inorganic Chemistry

The teaching laboratory offers an insight into different aspects of Inorganic Chemistry, including solid state chemistry, organometallic chemistry, kinetics, etc. The synthesis, characterization and analysis of inorganic compound are a main topic. Special emphasis on experimental techniques of synthetic inorganic chemistry, in particular the safe handling of reactive and pyrophoric chemical and solvent purification and drying techniques.

Organic chemistry part: Synthesis and analysis of elemento-organic compounds, metal complexes, and organometallic compounds.

Introduction to Schlenk techniques, solid state synthesis, and kinetics. Introduction in the chemistry library: literature data banks and collections of spectra.

Organic synthesis with organometallic compounds and catalysts: Experiments in the framework of a selected specialised project. Possible projects: Rh catalysed asymmetric hydrogenation of enamides, Mn-catalysed epoxidation of olefins, Cu catalysed Diels-Alder reactions, synthesis of organo-boron compounds and Pd catalysed coupling with halides, Ru catalysed transfer hydrogenation.

A manual is distributed in the teaching laboratory.

By enrolling in the laboratory course, students confirm to study all safety information thoroughly and to follow instructions.

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Analytical Competencies

- Decision-making
- Problem-solving

Communication

- Cooperation and Teamwork

Adaptability and Flexibility

- Critical Thinking

Integrity and Work Ethics

- Self-awareness and Self-reflection

Self-direction and Self-management

529-0129-00L Inorganic and Organic Chemistry II

Latest online enrolment is one week before the beginning of the semester.

Introduction to the experimental methods of Inorganic Chemistry

The teaching laboratory offers an insight into different aspects of Inorganic Chemistry, including solid state chemistry, organometallic chemistry, kinetics, etc. The synthesis, characterization and analysis of inorganic compound are a main topic. Special emphasis on experimental techniques of synthetic inorganic chemistry, in particular the safe handling of reactive and pyrophoric chemical and solvent purification and drying techniques.

Emphasis is given to scientific writing (experiment reports).

Organic chemistry part: Synthesis and analysis of elemento-organic compounds, metal complexes, and organometallic compounds.

Introduction to Schlenk techniques, solid state synthesis, and kinetics. Introduction in the chemistry library: literature data banks and collections of spectra.

Organic synthesis with organometallic compounds and catalysts: Experiments in the framework of a selected specialised project. Possible projects: Rh catalysed asymmetric hydrogenation of enamides, Mn-catalysed epoxidation of olefins, Cu catalysed Diels-Alder reactions, synthesis of organo-boron compounds and Pd catalysed coupling with halides, Ru catalysed transfer hydrogenation.

A manual is distributed in the teaching laboratory.

By enrolling in the laboratory course, students confirm to study all safety information thoroughly and to follow instructions.

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Analytical Competencies

- Decision-making
- Problem-solving

Communication

- Cooperation and Teamwork

Adaptability and Flexibility

- Critical Thinking

Integrity and Work Ethics

- Self-awareness and Self-reflection

Self-direction and Self-management

529-0450-00L Semester Project

Latest online enrolment is one week before the beginning of the semester.

In a semester project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic.

Number Title Type ECTS Hours Lecturers
529-0450-00L Semester Project W 18 credits 18A Lecturers

5. Semester (Physical-Chemical Direction)

Laboratory Courses, Seminar Papers, Proseminars, Field Trips

Further laboratory courses must be applied for at the respective Director of Studies.
<table>
<thead>
<tr>
<th>Objective</th>
<th>Students are accustomed to scientific work and they get to know one specific research field.</th>
</tr>
</thead>
</table>

**402-0000-09L Physics Lab 3**

**Abstract**

This laboratory course provides basic training of experimental skills. These are experimental design, implementation, measurement, data analysis and interpretation, as well as error analysis. The experimental work has to be complemented by a concise written report, which trains the scientific writing skills.

**Manuals for the individual experiments are available in English.**

**Objective**

Students learn to independently perform advanced experiments and document them scientifically correct.

Students are required to attend a safety lecture on the first day of the course and pass the corresponding online moodle-test before being allowed to access the laboratory rooms and perform the experiments.

The following aspects are emphasized:
- understanding complicated physical phenomena
- structured approach to experiments with complex instruments
- various practical aspects of experimenting and determining uncertainties
- learning the relevant statistical methods for data analysis
- interpretation of measurements and uncertainties
- describing the experiments and the results in a scientifically proper manner, in direct analogy to publishing
- ethical aspects of experimental research and scientific communication

**Content**

We offer experiments covering the following topics:
- Basic topics from mechanics, optics, thermodynamics, electromagnetism and electronics; as well as central topics from nuclear and particle physics, quantum electronics, quantum mechanics, solid state physics and astrophysics.

- Encourages students to show independence, to produce scientifically structured work and to apply engineering working methods.

**Lecture notes**

Instructions for experiments are available in English.

**Prerequisites / notice**

From a variety of over 50 experiments, students have to perform 4 experiments covering different topics. The experimental work is complemented by writing a scientific report.

If a student intends to perform a semester exchange abroad, then experimental activities must be discussed with lecturers of Physics Lab 3 before beginning of the semester, and in any case before leaving.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
</tr>
</tbody>
</table>

**529-0053-00L Polymer Physics Methods for Unstructured Biomolecules**

**Enrollment limited to 12 students. Enrollment is done by the D-BIOL study administration.**

**Abstract**

Establishing a link between known phenomena, concepts and spectroscopic techniques in polymer physics on the one hand and the study of unstructured biological macromolecules on the other. Attention is paid to the relationship between molecular interactions in biopolymers and their tendency to form molecular condensates, such as membraneless organelles.

**Objective**

Expansion of competences for the experimental and analytical treatment and structural characterization of partially and completely unstructured biomacromolecules as well as their interactions and self-organization.

**Content**

- Part I: Molecular interactions, concepts of polymer physics, spectroscopic methods; Part II: Polymer types in biology - proteins, DNA/RNA, polysaccharides, lipids; Part III: Molecular modeling and determination of conformational ensembles.

**Lecture notes**

Script for part I of the course in HS2024; slides for all three parts

**Literature**


**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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</table>

<table>
<thead>
<tr>
<th>Bachelor's Thesis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number</strong></td>
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<tr>
<td><strong>Title</strong></td>
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<tr>
<td><strong>Type</strong></td>
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<tr>
<td><strong>ECTS</strong></td>
</tr>
<tr>
<td><strong>Hours</strong></td>
</tr>
<tr>
<td><strong>Lecturers</strong></td>
</tr>
</tbody>
</table>

**Abstract**

It completes the Bachelor program and consists of a scientific project carried out independently.

**Objective**

Encourages students to show independence, to produce scientifically structured work and to apply engineering working methods.

**Biochemical-Physical Direction**

**1. Semester (Biochemical-Physical Direction)**

**Compulsory Subjects First Year Examinations**

<table>
<thead>
<tr>
<th>Number</th>
<th>402-0043-00L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title</strong></td>
<td>Physics I</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>O</td>
</tr>
<tr>
<td><strong>ECTS</strong></td>
<td>4 credits</td>
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<tr>
<td><strong>Hours</strong></td>
<td>3x+1U</td>
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<tr>
<td><strong>Lecturers</strong></td>
<td>R. Grange</td>
</tr>
</tbody>
</table>

**Abstract**

Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics of point-like and ridged bodies, periodic motion and mechanical waves.

**Objective**

The concepts and tools in physics, as well as the methods of an experimental science are taught. The student should learn to identify, communicate and solve physical problems in his/her own field of science.

**Content**

- Mechanics (motion, Newton's laws, work and energy, conservation of momentum, rotation, gravitation, fluids)
- Periodic Motion and Waves (periodic motion, mechanical waves, acoustics).

**Lecture notes**

The lecture follows the book "Physics" by Paul A. Tipler.
Introduction to the structures of organic compounds as well as the structural and energetic basis of organic chemistry.

**General Chemistry (Inorganic Chemistry) I**
6 credits
**Fundamentals of Biology I: From Molecules to the Biochemistry of Cells**
5 credits
**Mathematical Foundations I: Analysis A**
5 credits
**General Chemistry (Inorganic Chemistry) I**
3 credits
**General Chemistry (Organic Chemistry) I**
3 credits

**Literature**
- Paul A. Tipler and Gene P. Mosca, Physics (for Scientists and Engineers), W. H. Freeman and Company
- G. B. Thomas, M. D. Weir, J. Hass: Analysis 1, Lehr- und Übungsbuch, Pearson-Verlag
- Paul A. Tipler and Gene P. Mosca, Physics (for Scientists and Engineers), W. H. Freeman and Company
- L. Papula: Mathematik für Ingenieure und Naturwissenschaftler (3 Bände), Vieweg
- R. Glockshuber, K. Locher, J. Piel

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**
- Problem-solving
- Critical Thinking

**Personal Competencies**
- fostered

**Objective**

- introduced

**Content**

- stereochemistry, chemical bonds and bonding, symmetry, nomenclature, organic thermochemistry, conformational analysis, basics of chemical reactions.

- isomerism, Fischer projections, CIP rules, point groups, molecular symmetry and chirality, topicity, chemical bonding: Lewis bonding model and resonance theory in organic chemistry, description of linear and cyclic conjugated molecules, aromaticity, Huckel rules, organic thermochemistry, learning of organic chemistry reactions, intramolecular interactions.

**Lecture notes**

- Copies of the course slides as well as other documents will be provided as pdf files via the moodle platform.

**Literature**


Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1483 of 2653
### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td>Decision-making</td>
<td>fostered</td>
<td></td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>fostered</td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
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<td></td>
</tr>
<tr>
<td>Project Management</td>
<td>fostered</td>
<td></td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
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<tr>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
<td></td>
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<tr>
<td>Customer Orientation</td>
<td>fostered</td>
<td></td>
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<tr>
<td>Leadership and Responsibility</td>
<td>fostered</td>
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<tr>
<td>Self-presentation and Social Influence</td>
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<tr>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
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<tr>
<td>Negotiation</td>
<td>fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
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<tr>
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<tr>
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<tr>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<tr>
<td>Self-direction and Self-management</td>
<td>assessed</td>
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</tr>
</tbody>
</table>

### 529-0011-01L General Chemistry (Physical Chemistry) I

**Objective**

After the lecture, students will be able to,

- to calculate physical quantities and their units which are important for chemistry,
- name some properties of chemically relevant particles and propose experimental methods to determine these properties,
- name applications and hazards of radioactivity,
- categorize radioactive decay processes and mathematically represent the time course of simple decay reactions and qualitatively predict and represent them,
- describe wave and particle properties of electromagnetic radiation and matter and propose experimental methods for their detection,
- to explain the basics of quantum mechanics (meaning of the wave function, Heisenberg's uncertainty principle, operators, commutators) and to perform simple calculations with them,
- analyze and calculate absorption and emission spectra of single-electron atoms,
- to set up the Schrödinger equation for a molecular multi-particle system,
- independently solve the Schrödinger equation for the model systems of particles in a box and harmonic oscillator in one dimension and generalize to higher dimensional non-interacting problems,
- model molecular vibrations of diatomic molecules using the harmonic and anharmonic oscillator model,
- explain the concept of an orbital and represent mathematically and pictorially the qualitative form of the orbitals of the hydrogen atom,
- explain the structure of the periodic table of elements with the help of the orbital concept,
- recognize and use similarities in the electronic structure of atoms to predict chemically relevant properties, and
- establish term symbols for atomic ground states.

### Content

Atomic structure and structure of matter: atomic theory, elementary particles, atomic nuclei, radioactivity, nuclear reactions. Atomic orbitals and energy levels: ionisation energies, atomic spectroscopy, term values and symbols. Quantum mechanical atom model: wave-particle duality, the uncertainty principle, Schrödinger's equation, the hydrogen atom, construction of the periodic table of the elements. Chemical bonding: ionic bonding, covalent bonding, molecular orbitals.

### Literature

See homepage of the lecture.

### Prerequisites / notice

Voraussetzungen: Maturastoff. Insbesondere Integral- und Differentialrechnung.

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>assessed</td>
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</tbody>
</table>

### Additional First Year Compulsory Subjects

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0011-04L</td>
<td>Practical Course General Chemistry</td>
<td>O</td>
<td>8 credits</td>
<td>12P</td>
<td>M. Bezdek, D. Dirin, T. Segawa, A. Yakimov</td>
</tr>
</tbody>
</table>

*Information about the practical course will be given on the first day.*

**Abstract**

The general chemistry practical course aims at preparing the students for the work in modern chemistry laboratory. The students are trained to behave safely in the laboratory and use chemicals, chemistry glassware, and related equipment to perform and analyze the equilibrium in basic chemical reactions.

**Objective**

The students are expected to gain practical experience with as well as establish understanding of the following concepts and phenomena:

- Safe behavior and safety regulations in chemistry laboratory;
- Best practices in common techniques (purification, recrystallization, distillation, etc.);
- Analysis of measured values (measuring error, average value, error analysis);
- Acid-base-equilibria (strengths of acids and bases, pH- and pKa-values, titrations, buffer systems);
- Precipitation equilibria (gravimetry, potentiometry, conductivity measurements);
- Oxidation state and redox reactions (redox-titrations, galvanic elements);
- Metal complexes (syntheses of complexes, ligand exchange reactions, complexometric titration);
- Qualitative analysis (cation and anion separation, determination of cations and anions).
In the general chemistry practical course students are introduced to the work in chemistry laboratory. During the course they become familiar with common chemistry glassware and related equipment as well as learn basic experimental procedures, such as distillation, recrystallization, purification, digestion etc. Upon the measurements of pH, conductivity, and potential in the course of reactions, students establish the understanding of the chemical equilibrium concept.

Students work with various classes of inorganic compounds and types of chemical reactions, e.g. acid-base, redox, precipitation. They also obtain first experience with the synthesis of metal complexes as well as learn basics of qualitative analysis of an unknown substance.

By enrolling in the laboratory course, students confirm to study all safety information thoroughly and to follow instructions.

### Literature

Moodle Lernplattform

#### Prerequisites / notice

Compulsory: online enrolment latest one week after start of the semester

### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: fostered
- Problem-solving: fostered

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### 3. Semester (Biochemical-Physical Direction)

#### Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-0373-00L</td>
<td>Mathematics III: Partial Differential Equations</td>
<td>O</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>N. Moshayedi</td>
</tr>
</tbody>
</table>

**Abstract**


**Objective**

Classical tools to solve the most common linear partial differential equations.

**Content**

1) Examples of partial differential equations
   - Classification of PDEs
   - Superposition principle
2) One-dimensional wave equation
   - D'Alembert's formula
   - Duhamel's principle
3) Fourier series
   - Representation of piecewise continuous functions via Fourier series
   - Examples and applications
4) Separation of variables
   - Solution of wave and heat equation
   - Homogeneous and inhomogeneous boundary conditions
   - Dirichlet and Neumann boundary conditions
5) Laplace equation
   - Solution of Laplace's equation on the rectangle, disk and annulus
   - Poisson formula
   - Mean value theorem and maximum principle
6) Fourier transform
   - Derivation and definition
   - Inverse Fourier transformation and inversion formula
   - Interpretation and properties of the Fourier transform
   - Solution of the heat equation
7) Laplace transform (if time allows)
   - Definition, motivation and properties
   - Inverse Laplace transform of rational functions
   - Application to ordinary differential equations

**Lecture notes**

See the course web site (linked under Lernmaterialien)

**Literature**


Additional books:

2. E. Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons (chapters 1, 2, 11, 12, 6)

For additional sources, see the course web site (linked under Lernmaterialien)
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<tr>
<td>529-0450-00L</td>
<td>Semester Project</td>
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<td>18</td>
<td>18A</td>
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<tr>
<td></td>
<td>In a semester project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic.</td>
<td></td>
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<tr>
<td></td>
<td>Students are accustomed to scientific work and they get to know one specific research field.</td>
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</table>

### 5. Semester (Biochemical-Physical Direction)

#### Laboratory Courses, Semester Papers, Proseminars, Field Trips

Further laboratory courses must be applied for at the respective Director of Studies.

#### Bachelor's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<td>Bachelor's Thesis</td>
<td>O</td>
<td>15</td>
<td>15D</td>
<td>Lecturers</td>
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<td></td>
<td>It completes the Bachelor program and consists of a scientific project carried out independently.</td>
<td></td>
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<tr>
<td></td>
<td>Encourages students to show independence, to produce scientifically structured work and to apply engineering working methods.</td>
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</tbody>
</table>
Second and Third Year Additional Subjects

The Bachelor's programme in Interdisciplinary Sciences allows students to choose from any subject taught at a Bachelor level at ETH Zurich.

In consultation with the Director of Studies of Interdisciplinary Sciences, every student must establish his/her own individual study programme at the beginning of the 2nd year. See the Programme Regulations 2018 for further details.

Other Electives ETH

Further combinations of compulsory elective subjects arising upon specific written request by the students and permission by the Director of studies.

Selection of courses from entire course catalogue of ETH, according to individual study plan

Science in Perspective

Science in Perspective

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-CHAB

Language Courses

see Science in Perspective: Language Courses ETH/UZH

Interdisciplinary Sciences Bachelor - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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<td>O</td>
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<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
<td></td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Key for Hours

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<td>U</td>
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<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Interdisciplinary Sciences Master

The Master's programme in Interdisciplinary Sciences allows students to choose from any subject taught at the Master's level at ETH Zurich.

In consultation with the Director of Studies of Interdisciplinary Sciences, every student must establish his/her own individual study programme at the beginning of the Master's programme. See the Programme Regulations 2020 for further details.

▶ Majors

The following list provides various Majors that can be chosen from: https://ethz.ch/content/dam/ethz/special-interest/chab/chab-dept/studies/documents/IN/WL_IN_SR19192101_EN.pdf

In addition it is possible to create an individual Major in accordance with the Programme Regulations (Art. 19 paragraph 3).

Selection of courses from entire course catalogue of ETH, according to individual study plan

▶ General Courses

Selection of courses from entire course catalogue of ETH, according to individual study plan

▶ Proseminars, Laboratory Courses, Research Projects and Sem. Papers

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0020-00L</td>
<td>Research Project</td>
<td>W</td>
<td>20</td>
<td>20A</td>
<td>Professors</td>
</tr>
<tr>
<td>Abstract</td>
<td>In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Students are accustomed to scientific work and they get to know one specific research field.</td>
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</tr>
</tbody>
</table>

Selection of courses from entire course catalogue of ETH, according to individual study plan

▶ Science in Perspective

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-CHAB

▶ Master's Thesis

Only students who fulfill the following criteria are allowed to begin with their Master's thesis:

- a. successful completion of the Bachelor's programme;
- b. fulfilling of any additional requirements necessary to gain admission to the Master's programme.

Duration of the Master's Thesis: 4 months.

In the Master's thesis students prove their ability to independent, structured and scientific working. The Master's thesis is usually carried out in a core or optional subject area as chosen by the student.

Duration of the Master's Thesis 6 months, possible only with permission of the Director of Studies.

In the Master Thesis students prove their ability to independent, structured and scientific working.

Interdisciplinary Sciences Master - Key for Type

<table>
<thead>
<tr>
<th>W+</th>
<th>Eligible for credits and recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Interdisciplinary Brain Sciences Master

Core Modules
The Core Modules take place at University of Zurich: https://www.neuroscience.uzh.ch/en/Master-Studies/Program/Core-Modules.html

Elective Core Modules
Courses listed here take place at ETH Zurich.
Further courses and a complete list of the Elective Core Modules can be found here: https://www.neuroscience.uzh.ch/en/Master-Studies/Program/Elective-Core-Modules.html

Please register for ETH-courses at ETH Zurich, for UZH-courses at UZH.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1414-00L</td>
<td>Current Topics in Brain Research (HS)</td>
<td>W</td>
<td>1 credit</td>
<td>1.5K</td>
<td>I. Mansuy, further lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Different national and international scientific guests are invited to present and discuss their actual scientific results.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>To exchange scientific knowledge and data and to promote communication and collaborations among researchers. For students: Critical discussion of current research. Students aiming at getting a credit point for this colloquium choose one topic and write a critical essay on the presented research topic.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Different scientific guests working in the field of molecular cognition, neurochemistry, neuromorphology and neurophysiology present their latest scientific results.</td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>No handout</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Literature</td>
<td>No literature</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Some of the seminars will be shared with the Institute of Neuroinformatics (INI) of UZH.</td>
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</tbody>
</table>

<table>
<thead>
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<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1219-00L</td>
<td>Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>R. Riener, O. Lambercy</td>
</tr>
<tr>
<td>Abstract</td>
<td>Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.</td>
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</tr>
<tr>
<td>Objective</td>
<td>Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution. This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Introduction, problem definition, overview Rehabilitation of visual function - Anatomy and physiology of the visual sense - Technical aids (glasses, sensor substitution) - Retina and cortex implants Rehabilitation of hearing function - Anatomy and physiology of the auditory sense - Hearing aids - Cochlea Implants Rehabilitation of vestibular function - Anatomy and physiology of the vestibular sense - Rehabilitation strategies and devices (e.g. BrainPort) Rehabilitation of vegetative Functions - Cardiac Pacemaker - Phrenic stimulation, artificial breathing aids - Bladder stimulation, artificial sphincter Brain stimulation and recording - Deep brain stimulation for patients with Parkinson, epilepsy, depression - Brain-Computer Interfaces</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Literature

Introductory Books:


Selected Journal Articles and Web Links:


Prerequisites / notice

Target Group:
Students of higher semesters and PhD students of
- D-MAVT, D-ITET, D-INFK, D-HEST
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich

Students of other departments, faculties, courses are also welcome

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed

Method-specific Competencies
- Communication fostered

Social Competencies
- Leadership and Responsibility fostered

Personal Competencies
- Creative Thinking fostered
- Critical Thinking assessed
- Integrity and Work Ethics fostered

227-0971-00L Computational Psychiatry

W 3 credits 4S K. Stephan

Please note that participation in this course and the practical sessions requires additional registration at: http://www.translationalneuromodeling.org/cpcourse/

Abstract
This six-day course teaches state-of-the-art methods in computational psychiatry. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples.

Objective
This course aims at bridging the gap between mathematical modelers and clinical neuroscientists by teaching computational techniques in the context of clinical applications. The hope is that the acquisition of a joint language and tool-kit will enable more effective communication and joint translational research between fields that are usually worlds apart.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1490 of 2653
This six-day course teaches state-of-the-art methods in computational psychiatry. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples. Furthermore, practical exercises provide in-depth exposure to different software packages. Please see http://www.translationalneuromodeling.org/cpcourse/ for details.

**Methods & Models for fMRI Data Analysis**

**Objective**
To obtain in-depth knowledge of the theoretical foundations of SPM and DCM and of their practical application to empirical fMRI data.

**Content**
This course teaches state-of-the-art methods and models for fMRI data analysis in lectures and exercises. It covers all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, frequentist and Bayesian inference, multiple comparison corrections, and event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. A particular emphasis of the course will be on methodological questions arising in the context of clinical studies in psychiatry and neurology. Practical exercises serve to consolidate the skills taught in lectures.

**Neuromorphic Engineering I**

**Objective**
Understanding the characteristics of neuromorphic circuit elements.

**Content**
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. 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**Applied Analysis of Variance and Experimental Design**

**Objective**
Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

**Content**
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

**Methods of Experimentation in Biotechnology**

**Objective**
Thissemester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their technological application. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences.
Objective

This course is tailored to students who want to become familiar with the analysis of ethical issues in all the different domains of life sciences and biotechnology. The course aims at equipping students with the necessary knowledge and analytic skills to understand, discuss and address the ethical aspects of science and technology in the domain of human health. The specific learning objectives of this course are:

A. Identify ethical issues in life sciences and biotechnology.
B. Analyze and critically discuss ethical issues in life sciences and biotechnology.
C. Become aware of relevant legal and public policy frameworks.
D. Distinguish different ethical approaches and argumentative strategies in applied ethics.
E. Recognize how ethical issues relate to different accounts of technology and innovation.
F. Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
G. Autonomously anticipate ethical issues.
H. Propose and communicate solutions to ethical challenges and dilemmas.

Content

The course starts off with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain of applied ethics. The students will also be introduced to current theoretical accounts of technology and will start to appreciate the relevance of ethics especially with respect to new and emerging technologies. Usable analytic tools will also be provided, thus enabling the students to engage with the discipline in a practical way from the very onset of the semester.

The course will continue with thematic sessions covering a broad variety of topics all of which are relevant to the different study tracks offered by the department. In particular, the course will cover the following domains: digital health technologies and medical AI; food, nutrition and healthy longevity; biomedical engineering; genetics; neuroscience and Neurotechnologies; medical robotics; disability and rehabilitation; environmental ethics. The course will also include sessions on cross-cutting ethically relevant aspects of health sciences and technologies, namely: access to innovation, translational research, and the relation between science and public policy.

All the topics of the course will be illustrated and interactively discussed through many case studies, offering the students the opportunity to prepare and present them, and to use them in individual as well as group exercises. Throughout the course, the students will have multiple opportunities to experiment with ethical argumentation and to practice their evolving skills.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Analytical Competencies</th>
<th>Media and Digital Technologies</th>
<th>Problem-solving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>fostered</td>
<td>fostered</td>
<td>fostered</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
<td>fostered</td>
<td></td>
</tr>
<tr>
<td>Cooperation and Teamwork</td>
<td>Leadership and Responsibility</td>
<td>fostered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
<td>Creative Thinking</td>
<td>fostered</td>
</tr>
<tr>
<td>Leadership and Responsibility</td>
<td>Critical Thinking</td>
<td>assessed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Internship

Further information: https://www.neuroscience.uzh.ch/en/Master-Studies/Program/Internship.html

Master's Thesis and Exam


Interdisciplinary Brain Sciences Master - Key for Type

| O | Compulsory |
| W+ | Eligible for credits and recommended |
| W | Eligible for credits |
| E- | Recommended, not eligible for credits |
| Z | Courses outside the curriculum |
| Dr | Suitable for doctorate |

Key for Hours

| V | lecture |
| G | lecture with exercise |
| U | exercise |
| S | seminar |
| K | colloquium |
| P | practical/laboratory course |
| A | independent project |
| D | diploma thesis |
| R | revision course / private study |

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Landscape Architecture Master

➡ Compulsory Basic Courses

All basic courses (in terms of content and methodology linked to "Foundation Studio I") must be completed.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
Lectures, exercises and excursions serve as an introduction to atmospheric sciences, soil science and hydrology. Students gain a broad vision of the cutting edge topics that are being researched and studied at the Department of Environmental Systems Science at ETH, Eawag, WSL a.o. This will be the base for a future dialog between the field of landscape architecture and the field of sciences.

Objective
Students acquire basic knowledge in atmospheric sciences, hydrology and soil science:
- Understanding basic chemical and physical processes in the atmosphere that influence weather and climate
- Fundamentals about the classification of soils, soil-forming processes, physical and chemical soil properties, soil biology and ecology, soil degradation and protection
- Knowledge of water balance, principles of integral water management and climatic factors in the field of hydrology

Students develop an understanding of the relevance of these topics in the field of landscape architecture. Temporal and physical scale, research methods, units of measurement, lexicon, modes of representation and critical literature form the framework for the joint discourse.

Content
The course unit consists of the three courses "Climate", "Soil" and "Water", which are organized in modules.

Module 1 "Climate", 23.–27.09.2024
- Atmospheric dynamics: weather conditions, precipitation formation, weather forecast
- Carbon Cycle: atmospheric CO2 concentrations and its interaction with the physical climate system
- Land-climate dynamics: interaction between the land surface and the climate system
- Hydrology and water cycle: extreme precipitation, influence of climate change on the cryosphere
- Introduction to geology: formation of rocks, geologic times, structural geology

Module 2 "Soil", 30.09.–04.10.24
- Introduction to soils: definition, function, formation, classification and mapping
- Soil physics: soil texture, soil structure, soil water potentials, hydraulic conductivity
- Soil chemistry and fertility: clay minerals and oxides, cation exchange capacity, soil pH, essential plant nutrients
- Soil biology and ecology: soil fauna and microflora, fungi, bacteria, food web, organic matter
- Soil degradation and threats to soil resources: erosion, compaction, sealing, contamination, salinization

Module 3 "Water", 11.11.–15.11.2024
- Water supply: water balance, groundwater, water quality (water protection)
- River restoration
- Flooding, evapotranspiration/cooling of landscapes
- Hydropower (everything is managed - lake levels, water flows, pumping) - hydrology in the anthropocene
- Water management and storage

Lecture notes
Course material will be provided.

Literature
The course material includes a reading list.

Prerequisites / notice
The courses "Climate", "Water" and "Soil" are organized with the Fundamental Studio I as joint one-week modules. The weekly schedules will be provided with the course materials.

Module 1 "Climate", 23.–27.09.2024
Module 2 "Soil", 30.09.–04.10.24
Module 3 "Water", 11–15.11.2024

- The courses are held in English
- The written session examination covers all three courses "Climate", "Soil" and "Water".

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making

Social Competencies
- Media and Digital Technologies
- Communication

Personal Competencies
- Cooperation and Teamwork
- Creative Thinking

Self-awareness and Self-reflection

Assessed

Autumn Semester 2024
The fundamental course “Plant Ecology” is an introduction to the field of living systems, starting with the history of ecology, followed by an introduction to plant physiology. The course will also introduce students to the specifics of the rhizosphere, disturbance ecology and forests. Lastly, the course will focus on the specifics of tree structure and function.

The relevant literature and content for the examination will be indicated during the course. Course material will be provided.

Module 5 “Plant Ecology”, 28.10.–08.11.2024

The course is held in English.

Competencies

Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed

Social Competencies

- Communication: assessed
- Cooperation and Teamwork: assessed

Personal Competencies

- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed

061-0105-00L Plant Systematics I

Objectives

- 0 credits
- 3G
- S. Hassold

Abstract

This fundamental course provides an introduction to the basics of botany and forms a solid foundation of knowledge for the following semesters. The course covers the following areas: Species knowledge of native shrubs and trees in autumn and winter conditions and their habitat requirements, introduction to the identification of plants and consolidation of botanical terms.

Objective

Students will be introduced to botany and after the course they will be able to identify about sixty native trees and shrubs in order to use them appropriately in their designs. They will be familiar with botanical terms, which will enable them to understand information written in botanical literature.

Content

This course focuses on excursions with a botanical expert. In addition, the students are supported by theoretical and conceptual lectures. This gives the students a good basis of botanical knowledge, which can be professionally integrated into their designs.

The module is divided into different subject areas:

1) Consolidation of botanical terms. These form the basis for the identification and recognition of plants. The most important technical terms are explained and illustrated with suitable plant material.

2) Species knowledge is taught on regular field excursions and supplemented with theoretical input. The species can also be studied in the classroom using fresh material. In addition to site characteristics and seasonal changes, growth forms are also taught.

3) Through the introduction to identification, the students will understand how a simple identification key is constructed and how it is used, so that unknown species can be identified independently.

4) Besides the species knowledge the students will get a basic introduction into systematic botany to better navigate through the content of this week.

5) Making sketches enables close observation of the structures and shapes of leaves

Lecture notes

The weekly schedule is published on the course website (and is included in the reader).

Literature

The reader will be distributed during the course.

Prerequisites / notice

The relevant literature and content for the examination will be indicated during the course.

The course is aimed exclusively at the students of the master's programme in landscape architecture.

The detailed course schedule is published on the course website (and is included in the reader).

Comprehensiveness

The lectures might take place outside. It is necessary to foresee clothes adapted to the weather.

Competencies

Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed

Social Competencies

- Communication: assessed
- Cooperation and Teamwork: assessed

Personal Competencies

- Adaptability and Flexibility: assessed
- Sensitivity to Diversity: assessed
- Critical Thinking: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

061-0107-00L Materials and Construction I

Objectives

- O
- 2 credits
- 3G
- T. Galí-Izard

Abstract

Focused on ground materiality, this course explores constructed potentials of working with biotic and abiotic materials, and techniques for modifying ground conditions. The shape and properties of the ground are fundamental for water movement, vegetative growth and microclimatic conditions on site. Learning the mechanisms for transforming earth’s surface opens up site-based design possibilities.

Objective

Students learn comprehensive skills for reading and modifying topography, soil and water, and for working with material life-cycles, behaviors and qualities to define new potentials for the constructed ground.
Content
Through a series of lectures, short exercises and on-site fieldwork, this course teaches the fundamental techniques of land, water and substrate manipulation, focusing on earthwork, drainage, soil and material properties. During the two-week module, students learn analog and digital grading techniques in Rhino and Grasshopper, and experiment with techniques for working with hybrid materials.

The fundamental course Materials and Construction I (14-18 October and 18-22 November 2024) is closely linked to the Foundation Studio I course.

Lecture notes
A course reader is provided during the course.

Assessed

Literature
Relevant literature is included in the reader.

Prerequisites / notice
The course is aimed exclusively at the students of the master's program in landscape architecture.

The detailed course schedule is provided at the beginning of the semester and is included in the reader.

Course dates:
8:45 - 11:30:
14.10; 15.10; 16.10; 17.10; 18.11; 19.11; 20.11; 21.11
8:45 - 12:30:
18.10; 22.11

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management fostered

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Leadership and Responsibility fostered
Sensitivity to Diversity fostered

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

061-0109-00L History and Theory of Landscape Architecture I O 2 credits 2V A. Bucher

Abstract
The course deals with phenomena, terms and social contexts of designing nature since the 19th century, in order to derive a basis for ways of thinking and action for the present.

Objective
Students acquire an overview of the history of landscape architecture as well as an insight into the changing concepts and ways of thinking about designing nature. They become familiar with historical developments and their actuality and learn "from history". Students also analyse examples and design contexts and develop a basis for ways of thinking and action for current landscape architectural proposals.

Content
Designing nature accompanies the history of mankind. Since industrialisation and with the establishment of landscape architecture as a profession, the understanding of nature and design concepts have changed from the green lung of cities to the current saving of the planet in the Anthropocene. The course deals with the relevant phenomena of designing nature (park, garden city, garden reform, new gardens, modern gardens, natural gardens, postmodern parks and landscapes, ecosystem repair, urban agriculture, slum upgrading, nature-cultures, etc.), terms (nature, landscape, garden, ecology, agriculture, etc.) and their wider contexts. Based on the history and theory of the profession, students develop a strong fundament for designing in the present.

Lecture notes
Course material will be provided.

Literature
The course material includes a reading list.

Prerequisites / notice
The course takes place as a block course alternating with "Ethics in Landscape Architecture".

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Decision-making assessed
Problem-solving assessed
Project Management fostered

Social Competencies
Communication assessed
Self-presentation and Social Influence assessed
Sensitivity to Diversity assessed

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

061-0111-00L Ethics in Landscape Architecture O 2 credits 2G A. Kirchengast

Abstract
This course covers basic positions of philosophical ethics with a strong emphasis on central debates in landscape architecture.

Objective
The course aims to provide basic knowledge of concepts and terms within moral philosophy; engage with current debates in landscape architecture through lectures, text analysis, discussions and presentations; develop an understanding of the relation between science/society/design as well as practice and theory; help establish one's own design attitude; provide tools for argumentation; put to practice scientific working methods.

Content
Between the poles of theory and practice and through the development of a foundation in ethics, the students' sensitivity for ecological, political and social issues will be awakened and strengthened. In response to current issues touched upon in the disciplinary media or journalism, we will reflect upon the role of landscape architects in today's society as well as one's own individual attitude within the profession. The overall goal is for students to gain a critical understanding of a range of design approaches as well as an awareness of the specific role of design and design quality in the context of ethical debates.

Texts will be read in German and English.

Detailed information regarding the course will be communicated at the beginning of the semester.
The core courses build on the basic courses and convey basic, broad knowledge in the core areas of landscape architecture in relation to design lessons. Some of the core courses are compulsory and some are freely selectable. Further details, in particular about taking these subjects, performance assessments and for compensating for failed subjects, are regulated in Art. 27 and Art. 31 Paragraph 4.

Compulsory Core Courses

Courses are offered in Spring Semester.

Elective Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>052-0717-24L</td>
<td>Territory of the City: Turin</td>
<td>W</td>
<td>2</td>
<td>2</td>
<td>to be announced</td>
</tr>
<tr>
<td></td>
<td>Does not take place this semester.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enrolment in agreement with the lecturer only.</td>
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</tr>
</tbody>
</table>

Abstract

The elective deals with current transformation processes of metropolitan landscapes in Europe and introduces landscape architecture design on a territorial scale. On the basis of cartographic analysis and field trips, students will develop concrete strategies for the urban landscape of the Città Metropolitana di Torino.

Objective

The elective introduces to the subject and complexity of the urbanized landscape and teaches the critical engagement with the challenges and potentials of current tendencies in Landscape Architecture. On the basis of a concrete study area, students examine the large-scale processes of reuse, reform and reinterpretation of metropolitan landscapes in Europe and develop new approaches and strategies on various scales. They become familiar with GIS as an analytical tool, model building as a design methodology and the representation of landscape through plans. They develop a project based on the perception of place, knowledge of landscape-architectonic typologies and conception of public space. The design process is accompanied by workshops, lectures, excursions, critiques and a workbook.


## Lecture notes
A workbook with texts and background information is available for purchase (CHF 20.-). A digital version is also available free.

## Prerequisites / notice
The participation in the course is subject to the following three conditions:
1) The course is limited to 12 students. The restriction follows the time of the inscription according to the first-come-first-served-principle.
2) A two-days trip to Turin is mandatory for all students, which will take place on the weekend of October 8-9.
3) The contribution to expenses will be max. 250.- CHF per student. In case of short-notice cancellation, these costs will be charged to the student.

## Content
### Analytical Competencies
- Adaptability and Flexibility fostered
- Serendipity: Zurich Section assessed

### Subject-specific Competencies
- Learning Materials and Software Tutorials will be provided during the classes.

### Method-specific Competencies
- CAD Software and reproduced in a section. Students will use scanners to scan the slopes and forests of the Uetliberg in fieldwork and get an impression of what digital tools are needed to work with large datasets.

### Social Competencies
- Communication assessed
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity assessed
- Negotiation assessed

### Personal Competencies
- Adaptability and Flexibility assessed
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

## Serendipity: Zurich Section

### Objective
The course Serendipity: Züriberg Section will combine two research approaches at the D-Arch and teaches current methods for recording, analysing and documenting the existing urban environment in 3D models and processing it into CAD drawings. Students will reflect on the urban environment and the methods used to map and model the existing context – discussing, how different methodologies shape the way we perceive our environment. Therefore 3D tools such as laser scanning and photogrammetry will be tested in the field. Their application in the urban context and the workflow from scan to drawing will become known to the students.

### Content
«The layout of the city of Zurich is well known. Not only is it continuously surveyed by official bodies in maps or plans, it has also served architects and historians time and again in the past as a basis for examining the development of the city. But what does the city look like in section? And what insights can be derived from it?»

This is the question that the teaching and research project Schnitt durch Zürich (Section through Zurich) has been investigating by the Chair of Laurent Stalder. As an Addition to the existing work, this course will create a section of the Uetliberg. In the course of methodical refinement 3D laser scanning and point cloud modeling methods, developed at the Chair of Christophe Girot are used to digitally model the topography and vegetation as well as pathways and buildings. Following the data collection the materials will be transferred to common CAD Software and reproduced in a section. Students will use scanners to scan the slopes and forests of the Uetliberg in fieldwork and get introduced to the workflow from scan to CAD drawing. This should give a tool for a better understanding of the existing context in future projects and thus broaden the students’ methodological scope.

### License notes
- Learning Materials and Software Tutorials will be provided during the classes.
- Students will generally work in groups of 2

## Literature
Literature will be provided during the course.

### Prerequisites / notice
The lectures will be held in English, assistance in English and German.

## Topology

### Objective
The elective course "Topology" in the Autumn Semester 2023 builds on a long standing specialization in the spatial exploration of the landscape. We will embark the participants on a terrain that we shape through our own thoughts and actions, adopting different perceptual perspectives, supported by examples from art, literature, technology and history.

### Abstract
This elective course gives architecture students the opportunity to further develop their perception of space through a site-specific approach in the field of landscape architecture. The students will learn to use 3D point cloud technology and other spatial sensing technologies in order to analyze complex urban landscape and develop new ways of editing and representing these intertwined spaces.
Content
Students will document and analyze a case-study site to reveal its topological potentials and sensory qualities. This understanding will be gained through point cloud modeling and audiovisual composition. In particular, we will develop a new, comprehensive sectional model of a topologically interesting site situation.

Students will become acquainted to working with point cloud models produced with laser-scanning. Through a series of steps, they will learn how a laser-scanning survey is conducted, how the raw data is processed, how point cloud models are assembled, what qualities these models can provide to analyze, explore and represent space as an audiovisual experience.

Collected samples from the field will be assembled and built into an interactive application in the «Landscape Visualization and Modelling Lab». All software required is open source and can also be installed on private laptops, facilitating work from home if necessary.

Lecture notes
Literature will be provided during the course.

Prerequisites / notice
- The course is limited to 20 students (based on available computer stations)
- Students will work in groups of 2
- The lectures will be held in English, assistance in English and German
- The enrolment will be prioritized by the time of inscription and balanced between departments

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>fostered</td>
<td>assessed</td>
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<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
<td>assessed</td>
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<tr>
<td>Analytical Competencies</td>
<td>assessed</td>
<td>appreciated</td>
<td></td>
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<tr>
<td>Media and Digital Technologies</td>
<td>assessed</td>
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<td></td>
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<tr>
<td>Problem-solving</td>
<td>fostered</td>
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<tr>
<td>Project Management</td>
<td>fostered</td>
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<tr>
<td>Communication</td>
<td>appreciated</td>
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<tr>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
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<tr>
<td>Leadership and Responsibility</td>
<td>fostered</td>
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<tr>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
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<tr>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
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<tr>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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</tr>
<tr>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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</tbody>
</table>

Compensatory Course for Core Courses

In the first semester of the curriculum no compensation courses for compulsory courses offered.

Advanced Courses
In the first semester of the curriculum there are no main courses offered.

Design Studios
The design studios deal with problem and practice-related tasks on a local, regional, supra-regional, national and international level. Teaching of digital analysis, design and planning methods.

Foundation Studio I and II
- Fundamental Studio I: basic knowledge;
- Fundamental Studio II: Design tasks in the context of the contemporary landscape;

Number | Title                           | Type | ECTS | Hours | Lecturers          |
<table>
<thead>
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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>061-0141-24L</td>
<td>Foundation Studio I</td>
<td>W</td>
<td>14 credits</td>
<td>26U</td>
<td>T. Gali-Izard, C. L. Turett</td>
</tr>
</tbody>
</table>

Abstract
This course introduces a design methodology for landscape architecture that emphasizes the design of living systems and dynamic landscape processes in dialogue with the environmental sciences. With a focus on translating and synthesizing scientific information through rigorous drawing and critically engaging with the primary matter of landscapes, this course teaches core tools of the discipline.

Objective
This design studio builds on a series of precise exercises that translate and synthesize the scientific information learned in the linked fundamental module courses required by the MScLA program. Through these exercises, students acquire essential analytical and methodological skills to support design in the field of Landscape Architecture.

Content
The Foundation Studio I in the autumn semester 2024 focuses on the Klausenpass, a high mountain pass connecting the Swiss cantons of Uri and Glarus. Throughout the semester students translate the particular conditions of this peripheral and often extreme landscape, rigorously drawing local climatic, geologic, hydrological, pedological and vegetative processes, and situating these systems in a larger context. Working with this method of translation, students make design proposals that respond to the unique material and ecological potentials of the pass.

Course desk crits, pin-ups, site visits and reviews are generally scheduled in the afternoon, and are linked to the content covered in the lectures and other theoretical inputs from the morning fundamental course.

Lecture notes
The reader is handed out during the first week of the semester.

Literature
Relevant literature is included in the reader
The weekly schedule is published at the beginning of the semester and is included in the reader.

No course 21th-25th of October 2024 (seminar week).

8:50 - 11:30:
18.09; 19.09; 23.09; 13.11; 15.11; 25.11; 26.11; 27.11; 28.11; 02.12; 03.12; 04.12; 05.12; 09.12; 10.12; 11.12; 12.12; 17.12

8:50 - 12:30:
20.09; 04.10; 01.11; 29.11; 06.12; 13.12

15:45 - 18:30:
17.09; 24.09; 01.10; 29.10; 05.11; 12.11; 19.11; 26.11

12:45 - 18:30:
18.09; 23.09; 25.09; 30.09; 02.10; 14.10; 16.10; 17.10; 28.10; 30.10; 06.11; 11.11; 13.11; 18.11; 20.11; 21.11; 25.11; 27.11; 02.12; 03.12; 04.12; 09.12; 10.12; 11.12; 17.12

12:45 - 16:30:
19.09; 07.11

13:45 - 17:30:
04.10; 28.11; 06.12; 13.12

12:45 - 17:30:
15.11; 05.12; 12.12

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Advanced Studio

Complex design tasks involving social, topographical, hydrological and ecological issues.

Seminar Week and Internship Report

In MScLA at least one week of seminar must be completed. Furthermore, part of the course is a six-month internship in the field of landscape architecture, the achievements (work phases, learning success) must be documented in an internship report.

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
061-0153-00L | Internship Report | O | 2 credits | 4P | T. Galí-Izard

Does not take place this semester.

Abstract

Part of the course is a six-month internship in the field of landscape architecture. The internship should include as many work phases as possible in the work of a landscape architect. The students prepare an internship report in which they describe the various internship activities in detail and reflect on the learning success.

Objective

The internship report should cover as many work phases as possible in the work of a landscape architect.

Content

Part of the course is a six-month internship in the field of landscape architecture. The internship should include as many work phases as possible in the work of a landscape architect. The students prepare an internship report in which they describe the various internship activities in detail and reflect on the learning success.

Prerequisites / notice

Internship report (of 6 months, within the field of landscape architecture).

The report can be written in German or English language.

052-0151-24L | Seminar Week Autumn Semester 2024 | W | 2 credits | 3S | T. Galí-Izard

Abstract

This seminar week will take place at the bottom of the Mississippi River in the landscape paradox of New Orleans, a city largely below sea level which continues to sink as the sea rises outside the levee walls which protect it. Through the lens of the Garden of the 21st Century, we will explore the potential of the city’s subtropical climate and deltaic soils to produce an urban forest.

Objective

Throughout the week, we will explore the mechanisms which created the hyper-controlled drainage system of New Orleans, and the soil conditions which resulted from the massive restructuring of the landscape in the 20th century. We will pay particular attention to the city’s urban canopy, which was largely wiped out during a severe hurricane. By visiting the watery landscapes outside the city’s walls by canoe, we will imagine what might be possible for the regeneration of a city which is on the frontlines of climate breakdown—starting with a garden of trees.
Prerequisites / notice
Details of travel, accommodations, and food will be communicated before registration of seminar week opens.
Contact: Bonnie-Kate Walker, bk.walker@arch.ethz.ch

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication assessed
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity assessed
- Negotiation assessed

Personal Competencies
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management fostered

Science in Perspective
Courses of the "Science in Perspective" programme have to be completed (details see study guidelines Art. 27).

- see Science in Perspective: Language Courses ETH/UZH
- see Science in Perspective: Type A: Enhancement of Reflection Capability
- Recommended Science in Perspective (Type B) for D-ARCH

Master's Thesis
The master's thesis is the successful completion of the course. It confirms the ability to work independently in the field of landscape architecture and is tutored by D-ARCH professors (for details see Art. 30 of the study regulations).

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>061-0900-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Professors</td>
</tr>
</tbody>
</table>

Abstract
The Master's thesis is the completion of the study program. The students develop a solution to a problem and practice-oriented task in the field of landscape architecture. All students will share a common site and region, that they will address at a scale of their choice.

Objective
It is intended to demonstrate the students' ability to design their own work and is proof of the successful completion of their studies. The Master's thesis is supervised by professors of the D-ARCH. The processing time for the master's thesis is fourteen weeks.

Prerequisites / notice
The Master's Thesis in Landscape Architecture starts on 09 September and ends on 16 December 2024.

Landscape Architecture Master - Key for Type

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
### Educational Science

**Bitte beachten Sie, dass sich die Lerneinheitsnummer ab dem HS24 geändert hat. Diese Änderung hat keinen Einfluss auf die bisher absolvierten Lerneinheiten und erbrachten Leistungen und wird für den jeweiligen Studienabschluss anerkannt.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>871-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern, M. Rau</td>
</tr>
<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in the programs &quot;Teaching Diploma&quot; or &quot;Teaching Certificate&quot;. It is about learning in childhood and adolescence.</td>
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<tr>
<td></td>
<td>Abstrakt</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>This course looks into scientific theories and also empirical studies on human learning and relates them to the school.</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Content</td>
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</tr>
<tr>
<td></td>
<td>Thematicische Schwerpunkte: Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen</td>
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<td></td>
</tr>
</tbody>
</table>

Lernformen:

**Lecture notes**
- Folien werden zur Verfügung gestellt.

**Literature**

**Prerequisites / notice**
- This course is only apt for students who intend to enrol in the programs "Teaching Diploma" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>871-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>R. Schumacher</td>
</tr>
<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<td></td>
<td>Abstrakt</td>
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<td>This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.</td>
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<td>Objective</td>
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<td></td>
<td>- Get to know cognitively activating instructions in MINT subjects</td>
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<td>- Get information about recent literature on learning and instruction</td>
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<td>Prerequisites / notice</td>
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<td></td>
<td>Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.</td>
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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>871-0242-07L</td>
<td>Human Intelligence</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>E. Stern</td>
</tr>
<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<td>Abstrakt</td>
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<td>The focus will be on the book &quot;Intelligenz: Grosse Unterschiede und ihre Folgen&quot; by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.</td>
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<td>- Understanding of research methods used in the empirical human sciences</td>
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<td>- Getting to know intelligence tests</td>
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<td>- Understanding findings relevant for education</td>
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<tbody>
<tr>
<td>871-0240-22L</td>
<td>Coping with Psychosocial Demands of Teaching (EW4 W DZ)</td>
<td>W</td>
<td>2</td>
<td>3S</td>
<td>S. Maurer, P. Caprez, I. Sargenti</td>
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<td></td>
<td>The successful participation in EW1 (&quot;Human Learning&quot;) and EW2 (&quot;Designing Learning Environments for School&quot;) is recommended, but not a mandatory prerequisite.</td>
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<td>Abstrakt</td>
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<td></td>
<td>Students possess theoretical knowledge and practical competences to be able to cope with the psychosocial demands of teaching.</td>
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<td>(1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks).</td>
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<td>(2) They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. illegal or psychological services).</td>
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<tbody>
<tr>
<td>871-0228-00L</td>
<td>Formation of Knowledge in STEM Fields in Primary and Secondary School</td>
<td>W</td>
<td>2</td>
<td>1S</td>
<td>U. Markwalder</td>
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<td>Address to students enrolled either in Teaching Diploma* (TD) or Teaching Certificate (TC) (excluding Teaching Diploma Sport).</td>
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<td>Abstrakt</td>
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<td></td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1501 of 2653
Adaptability and Flexibility

Communication

- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.

G. Kaufmann

Analytical Competencies

Die Literatur ist themenspezifisch. Sie muss je nach Situation selber beschafft werden oder wird zur Verfügung gestellt.

Subject-specific Competencies

Course promotes exchange between student teachers and elementary school teachers in STEM teaching with 3 parts: 1) block seminar (ca. 16 h), 2) collaboration with elementary school teacher in a class (ca. 34 h, with approx. 50% spent in the elementary or middle school class and ca. 50% for preparation), and 3) final report (ca. 10 h). Registration implies participation in all 3 parts.

Content

Students learn more about the potential and challenges of pupils. They get to know the early stages of knowledge as well as the development of pre-concepts of students in their subject area. The seminar with a phase of cooperation consists of three phases: in the block seminar, pre-concepts are discussed in their own subject as well as theoretical inputs from developmental and cognitive psychology. During the cooperation phase, a teaching task defined by the primary and secondary school teachers is actively undertaken in a class. Finally, a final report is written, which contains a description of the students' level of knowledge. This seminar is only suitable for students who can adapt flexibly to the needs of pupils from lower class levels.

Prerequisites / notice

https://www.minterlink.ch/student

Competencies


Personal Competencies: Adaptability and Flexibility, Creative Thinking, Critical Thinking, Self-awareness and Self-reflection.

Subject Didactics and Professional Training

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
752-9005-00L | Mentored Work Subject Didactics Food Science | O | 2 credits | 4A | G. Kaufmann

Abstract

In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

Objective

The aim is for the students:
- to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.
- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.
- To try out different options for specialist further training in their profession.

Content

Thematische Schwerpunkte:


Lernformen:

Lecture notes

Eine Anleitung zur mentorierten Arbeit in FV wird zur Verfügung gestellt.

Literature

Die Literatur ist themenspezifisch. Sie muss je nach Situation selber beschafft werden oder wird zur Verfügung gestellt.

Prerequisites / notice

Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.

Competencies

Subject-specific Competencies: Concepts and Theories, Analytical Competencies, Decision-making, Problem-solving.


Personal Competencies: Adaptability and Flexibility, Creative Thinking.

752-9020-00L | Teaching Internship Including Examination Lessons Food Science | W | 6 credits | 13P | G. Kaufmann

The teaching internship can just be visited if all other courses of TC are completed.
Repetition of the teaching internship is excluded even if the examination lessons are to be repeated.

Abstract

Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.

Objective

- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Anlässlich der Hospitationen erläutert die Praktikumslehrperson ihre fachlichen, fachdidaktischen und pädagogischen Überlegungen, auf deren Basis sie den Unterricht geplant hat und tauscht sich mit dem/der Studierenden aus. Die von dem/der Studierenden gehaltenen Lektionen werden vor- und nachbesprochen.

Die Themen für die beiden Prüfungslektionen am Schluss des Praktikums erfahren die Studierenden in der Regel eine Woche vor dem Prüfungstermin. Sie erstellen eine Vorbereitung gemäß Anleitung und reichen sie bis am Vortrag um 12 Uhr den beiden Prüfungsexperten (Fachdidaktiker/-in, Departementsvertreter/-in) ein. Die gehaltenen Lektionen werden kriteriumsbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/der Kandidatin über die gehaltenen Lektionen im Rahmen eines kurzen Kolloquiums.

Lecture notes
Dokument: schriftliche Vorbereitung für Prüfungslektionen.

Literature
Wird von der Praktikumslehrperson bestimmt.

Competencies
Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving fostered

Social Competencies
Communication assessed
Customer Orientation assessed
Leadership and Responsibility assessed
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered

Personal Competencies
Adaptability and Flexibility fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered

Food Science TC - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>E- Recommended, not eligible for credits</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z Courses outside the curriculum</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr Suitable for doctorate</td>
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Key for Hours

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<thead>
<tr>
<th>Key</th>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td>P practical/laboratory course</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A independent project</td>
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<td>U</td>
<td>exercise</td>
<td>D diploma thesis</td>
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<tr>
<td>S</td>
<td>seminar</td>
<td>R revision course / private study</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Food Science and Nutrition Master
► Master Studies (Programme Regulations 2017)
►► Major in Food Processing
►►► Disciplinary Subjects

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<thead>
<tr>
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<tbody>
<tr>
<td>752-3103-00L</td>
<td>Food Rheology</td>
<td>W+</td>
<td>3 credits</td>
<td>2V</td>
<td>P. A. Fischer</td>
</tr>
<tr>
<td>Abstract</td>
<td>Rheology is the science of flow and deformation of matter such as polymers, dispersions (emulsions, foams, suspensions), and colloidal systems. The fluid dynamical basis, measuring techniques (rheometry), and the flow properties of different fluids (Newtonian, non-Newtonian, viscoelastic) are introduced and discussed.</td>
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<tr>
<td>Objective</td>
<td>The course provides an introduction on the link between flow and structural properties of flowing material. Rheometrical techniques and appropriate measuring protocols for the characterization of complex fluids will be discussed. The concept of rheological constitutive equations and the application to different material classes are established.</td>
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<tr>
<td>Content</td>
<td>Lectures will be given on general introduction (4h), fluid dynamics (2h), complex flow behavior (4h), influence of temperature (2h), rheometers (4h), rheological tests (6h) and structure and rheology of complex fluids (4h).</td>
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<td>Notes will be handed out during the lectures.</td>
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<tr>
<td>Literature</td>
<td>Provided in the lecture notes.</td>
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<tr>
<td>Competencies</td>
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<td>Concepts and Theories</td>
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<td></td>
<td>Techniques and Technologies</td>
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<td>Decision-making</td>
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<td>Creative Thinking</td>
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<td>fostered</td>
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<td></td>
<td>Critical Thinking</td>
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<tr>
<td>752-2003-00L</td>
<td>Selected Topics in Food Technology</td>
<td>W+</td>
<td>3 credits</td>
<td>2V</td>
<td>R. Stadler, C. Bolten</td>
</tr>
<tr>
<td>Abstract</td>
<td>Part 1 of the course deals with global market trends, food technologies, food health benefits. Physical and chemical fundamental knowledge help grasp the molecular composition of food. Part 2 entails management of risks across the food supply chain. The focus is on technological solutions to mitigate hazards, as well as their management upstream.</td>
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<tr>
<td>Objective</td>
<td>The objectives of the course are for students to understand the key drivers (market and consumer trends, health benefits, sustainability, etc.) that impact innovation in a food business environment. The course also illustrates food safety and quality considerations across the whole supply chain, using concrete examples and how certain technologies assist in reducing or eliminating food safety risks.</td>
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<tr>
<td>Content</td>
<td>Lectures include interfacial tension (4h), protein aggregation in bulk and interfaces (4h), Pickering emulsions (2h), gels (2h), aggregation of complex mixtures (4h), and the use of light scattering in investigation complex food structures (8h). Most chapters include some hand-ons examples of the gain knowledge to common food products.</td>
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<td>Lecture notes</td>
<td>Notes will be handed out during the lectures.</td>
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<tr>
<td>752-2314-00L</td>
<td>Physics of Food Colloids</td>
<td>W+</td>
<td>3 credits</td>
<td>2V</td>
<td>P. A. Fischer, R. Mezzenga, M. Radiom</td>
</tr>
<tr>
<td>Abstract</td>
<td>In Physics of Food Colloids the principles of colloid science will applied to the aggregation of food materials based on proteins, polysaccharides, and emulsifiers. Mixtures of such raw material determine the appearance and performance of our daily food. In a number of examples, colloidal laws are linked to food science and the manufacturing and processing of food.</td>
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<tr>
<td>Objective</td>
<td>The aggregation of food material determines the appearance and performance of complex food system as well as nutritional aspects. The underlying colloidal laws reflect the structure of the individual raw material (length scale, time scale, and interacting forces). Once these concepts are appreciated the aggregation of most food systems falls into recognizable patterns that can be used to modify and structure exiting food or to design new products. The application and use of these concepts are discussed in light of common food production.</td>
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<td></td>
<td>fostered</td>
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<tr>
<td>752-3201-00L</td>
<td>Emerging Thermal and Non Thermal Food Processing</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>A. Mathys, J. Dumpler</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course is built on the holistic approach in sustainable food processing via the consideration of the total value chain. Selected mechanical, biotechnological, thermal and non-thermal techniques for best biomass and energy use efficiency will be investigated. Focused technologies are new thermal processes, high pressure techniques, electroporation and different radiation based sources.</td>
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<tr>
<td>Objective</td>
<td>Understanding of selected emerging food processing concepts with focus on lower process intensity for healthy and high quality food production, waste reduction as well as biomass and energy use efficiency. Updates from academia and industry around new trends in food processing are fostered.</td>
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<tr>
<td>Content</td>
<td>Emerging combined processes based on mechanical, thermal and non-thermal techniques, Multi hurdle technology concept for food preservation, Extreme high temperature-short time processes, high pressure techniques, electroporation, radiation, Biorefineries based on emerging process elements, Ongoing industry initiatives.</td>
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<tr>
<td>Lecture notes</td>
<td>Script will be distributed before the course via Moodle.</td>
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</table>
Subject-specific Competencies

Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Methodology Subjects

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0625-01L</td>
<td>Applied Analysis of Variance and Experimental Design</td>
<td>W+</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>L. Meier</td>
</tr>
</tbody>
</table>

Abstract

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Objective

Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Content

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

### Literature

### Prerequisites / notice
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

### Competencies
- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
- **Personal Competencies**
  - Critical Thinking: assessed

### 401-0649-00L Applied Statistical Regression

**Abstract**
This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

**Objective**
The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

**Content**
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

### Lecture notes
A script will be available.

### Literature
- Faraway (2005): Linear Models with R
- Faraway (2006): Extending the Linear Model with R
- Draper & Smith (1998): Applied Regression Analysis
- Fox (2008): Applied Regression Analysis and GLMs
- Montgomery et al. (2006): Introduction to Linear Regression Analysis

### Prerequisites / notice
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

### Competencies
- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed
  - Project Management: fostered
- **Social Competencies**
  - Communication: assessed
  - Customer Orientation: fostered
  - Leadership and Responsibility: fostered
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered
  - Negotiation: fostered
- **Personal Competencies**
  - Adaptability and Flexibility: assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

### Optional Subjects

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
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<tbody>
<tr>
<td>752-3105-00L</td>
<td>Physiology Guided Food Structure and Process Design</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>P. A. Fischer, M. Devezeeux de Lavergne, B. von der Weid, T. Wooster</td>
</tr>
</tbody>
</table>

### Abstract
A sound understanding of physiological implications of food design will allow to shape new products, which feature health as well as environmental benefits and on the other side do not compromise on organoleptic qualities, formulation and manufacturing, and quality and safety. The course links the physiological driven requirements with food structure design and subsequent engineering steps.

### Objective
The objective of this course is to highlight the link between human physiology, product sensory, nutritional functions, and engineering approaches to facilitate the design of food matrices reflecting the requirements for the beforementioned properties. To identify and manipulate these properties, the pathways that control the interaction of food structures and their physiological action will be introduced.

Students are introduced to a skill set that will encompass basic digestion, sensory physiology knowledge, and food structures. Students will be exposed to the interplay along the gastrointestinal tract including taste, aroma, and texture perception, swallowing mechanics, and gastrointestinal digestion with an engineering or physical sciences angle.

### Content
- Chapter 1: Introduction - The need for physiology guided structure and process design in the context of personalized nutrition (Peter Fischer)
- Chapter 2: Food Oral Processing: the impact of food oral breakdown on sensory perception (Marine Devezeeux de Lavergne)
- Chapter 3: Chewing and swallowing across the lifespan, from infants to elderly (Marine Devezeeux de Lavergne)
- Chapter 4: Perception physiology in humans and other species (Benoit von der Weid)
- Chapter 5: Biophysics of food digestion & how it can be exploited in the development of strategies for delivery (Timothy J. Wooster)
- Chapter 6: Numerical and experimental modelling of the intestinal system (Peter Fischer)
Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication

Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

Competencies

Subject-specific Competencies
- Concepts and Theories

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication

Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

Major in Food Quality and Safety

Disciplinary Subjects

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>752-0801-00L</td>
<td>Food Law and Legislation</td>
<td>W+</td>
<td>1 credit</td>
<td>1V</td>
<td>K. Krell Zbinden, E. Zbinden Kaessner</td>
</tr>
</tbody>
</table>

Abstract
- Introduction to the principles of the EU and international Organisations. Set up and Application of the Swiss Food Law.

Objective
- Knowledge of the principles and the structure of the EU in general and in the area of food safety, overview of the relevant bilateral agreements CH-EU as well as on the most important international organisations.
- Basic knowledge of the structure of Swiss food law and its implementation in the context of self-controll in food companies. The process of food enforcement is known and issues can be assessed from a legal perspective.

Content
- General introduction into the EU and in the area of food safety (regulation on food safety), legislative procedures in the EU, introduction into the relevant bilateral agreements CH-EU, introduction into international organisations, general principles of the Swiss food law and the most important regulations as well as the most important legal procedures, legal settlement and the duties and responsibilities of the Food control authorities.

Prerequisites / notice
- Qualifications: General knowledge of the food sciences.
- The lecture will be held in German.

Competencies

Subject-specific Competencies
- Concepts and Theories

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

752-1021-00L Food Enzymology

Abstract
- The course covers the fundamentals of food enzymology, application of endogenous and exogenous enzymes in food processing, as well as use of enzymes in analytics.

Objective
- Students can describe what enzymes are and can explain their use and functions in food and food products.
- Students can argue why and how enzymes are used in food processing and analysis.
- Students execute a research project independently and defend their findings during a presentation to peer students and an expert panel.

Content
- Enzymes in foods: the use of added enzymes in food processing, control and/or utilization of endogenous enzymes, production of enzyme preparations for food use, and chemical analysis of food components by enzymatic methods.

Prerequisites / notice
- Course prerequisites: Food Chemistry I/II and Food Analysis I/II (or equivalent)

Competencies

Subject-specific Competencies
- Concepts and Theories

Method-specific Competencies
- Analytical Competencies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity
- Negotiation

Person Competencies
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection

752-4009-00L Molecular Biology of Foodborne Pathogens

Abstract
- The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.
Objective
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content
Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Literature
Recommendations will be given in the first lecture

Prerequisites / notice
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break!

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
Method-specific Competencies
- Analytical Competencies
- Decision-making
Social Competencies
- Communication
Personal Competencies
- Critical Thinking

ECTS
- 5 credits

752-1301-00L Special Topics in Toxicology

Abstract
Journal-club style course involving student presentations and active discussion and critique of recent publications and modern experimental strategies. The focus is on chemical, biochemical, and nutritional aspects of selected topics in Toxicology, with a new group of topics addressed each semester

Objective
- To stimulate student interest and provide advanced knowledge of current research in Toxicology and its related sciences.
- To develop skills in critical evaluation of scientific literature, oral presentation and questioning.
- To understand modern experimental techniques and research approaches relevant to toxicology

Content
The journal-club style course involves student presentations and active discussion of recent publications. The primary focus is on chemical, biochemical, and nutritional aspects of selected current topics in Toxicology. Participants are masters or PhD students in Food Sciences and related disciplines (i.e. Chemistry, Biochemistry, Pharmaceutical Sciences, etc.).

Literature
A selection of approximately 20 papers from recent primary scientific literature.

Prerequisites / notice
The course is open to Masters or PhD level students.

For Masters level participants, a strict prerequisite is (a) previously taken and passed "Introduction to Toxicology" (752-1300) and/or (b) previous courses supporting equivalent knowledge plus permission from the instructor. Please contact the instructor before the start of the class, explaining the basis of your previous knowledge other than the Introduction course, to request special permission.

If you would like to take "Special Topics in Toxicology", do not register at the same time for "Advanced Topics in Toxicology". It is only possible to take one, and it is only possible to take the advanced level after completing this course.

Methodology Subjects

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<td>L. Meier</td>
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| 401-0649-00L    | Applied Statistical Regression       | W+   | 5    | 2V+1U | M. Dettling |
|                 | **Abstract**                        |      |      |       |           |
|                 | This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning “good practice” that can be applied in every student’s own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis. |
|                 | **Objective**                       |      |      |       |           |
|                 | The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling. |
|                 | **Content**                         |      |      |       |           |
|                 | The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies. The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data. |
|                 | **Lecture notes**                   |      |      |       |           |
|                 | A script will be available.         |      |      |       |           |
Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving

Social Competencies
Communication
Cooperation and Teamwork

Personal Competencies
Adaptability and Flexibility

Abstract
Learn to apply practical bioinformatics/computational skills for analysis of microbiomes in foods and human health! Students will apply basic programming skills for scientific computing and bioinformatics, and learn and discuss the importance of microbiomes to foods and human health, through recognition and comparison of ecological theory, methodology, and experimental design across systems.

Objective
Learn to apply bioinformatics and computational methods for analysis of microbiome next-generation sequencing data. A secondary goal is to critically examine the relevance of microbiomes to food quality, safety, and human health, through application of theory and appropriate experimental design. Students completing this course will thus be able to both apply appropriate methodology to study microbiomes (or other high-dimensional data) in different systems, as well as evaluate and interpret bioinformatics results.

Content
1. Introduction to microbiomes and microbial bioinformatics toolkit. Python, Pandas, Jupyter, GitHub, visualization libraries for Python.
3. Microbial diversity, function, and ecology. Molecular ecology, diversity metrics, ordination methods.

This course requires extensive engagement in learning outside of the classroom (using online resources and practical exercises), with a focus on active learning in the classroom.

Prerequisites
No specific pre-requisites, but students should have some familiarity with microbiology, molecular biology, programming (Python), bioinformatics, and statistics.

Students will bring and work on their own laptop computers.

All software used in the course is free and open-source.

Literature
Faraway (2005): Linear Models with R
Faraway (2006): Extending the Linear Model with R
Draper & Smith (1998): Applied Regression Analysis
Fox (2008): Applied Regression Analysis and GLMs
Montgomery et al. (2006): Introduction to Linear Regression Analysis

Optional Subjects

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<td>752-1302-00L</td>
<td>Advanced Topics in Toxicology</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>S. J. Sturla</td>
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</tbody>
</table>

Abstract
Journal-club style course that involves student presentations of selected topics in Toxicology on the basis of current primary research and review papers.

Objective
The goals are to stimulate student interest and provide advanced knowledge of current research in the interdisciplinary area of Food and Nutrition Toxicology and its related sciences. The student should develop skills in the critical evaluation of scientific literature, oral presentation and questioning, and understanding modern experimental techniques in Molecular Toxicology.

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1509 of 2653
The journal-club style course involves student presentations of recent publications. The primary focus is on chemical and biochemical aspects of selected topics in Toxicology. Participants are generally masters or PhD students in Food Sciences and related disciplines (i.e. Chemistry, Pharmaceutical Sciences, etc.), and strong knowledge of organic chemistry and biochemistry is prerequisite. Selected course topics change every semester.

Participants are required to have completed previously "Special Topics in Toxicology" (752-1301-00L). Both courses are run concurrently every semester. It is only possible to register for one course at a time. Do not register for "Advanced Topics in Toxicology" until after you have completed "Special Topics in Toxicology."

### 376-1353-00L Nanostructured Materials Safety

**Abstract**

Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection.

**Objective**

Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials.

**Content**

Building upon new technologies to engineer and functionalize well-defined nanostructured materials, a plethora of exciting discoveries were made and found their way in our daily live. These customized nanomaterials provides extraordinary properties and make them attractive for many innovative applications. Exactly these new properties may have the potential to be responsible for unforeseen side effects, which hamper a straightforward translation into new products. Therefore, the safety research provide the evidence for a responsible and sustainable use of nanomaterials.

The lecture will focus on basic principles of nanotoxicology, provide the understanding of the potential side effects of nanomaterial in a context-specific way addressing the main exposure routes such as inhalation, ingestion, topical applications and intravenous injections as well as it will provide impulses for safer material designs.

Structure of the planned lecture (2 x 45 min)

1. Introduction: the principles of nanotoxicology
2. Lung - particles interactions: two disease scenarios and their molecular mechanism
3. GI – particles interactions: intentional and unintentional particle exposure via food
4. Skin – particles interactions: body care products and their influence on skin physiology
5. Intravenous injection: colloidal stability, protein corona and cellular effects
6. Micro - Nanoplastics and development of a safety research plan
7. End of semester exam

### Lecture notes

Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website.

### Prerequisites / notice

Course "Introduction to Toxicology" is recommended. Knowledge of basic principles of nanotoxicology is mandatory.

### Competencies

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies
- Decision-making
- Problem-solving

**Social Competencies**

- Communication
- Cooperation and Teamwork

### Data: 15.06.2024 12:39

### Autumn Semester 2024

### Page 1510 of 2653
The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.

The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

### Competencies

<table>
<thead>
<tr>
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<td><strong>Cooperation and Teamwork</strong></td>
<td><strong>Critical Thinking</strong></td>
</tr>
</tbody>
</table>

### Literature

- M. Dettling: *Statistical Modelling*.
- Montgomery et al. (2006): *Introduction to Linear Regression Analysis*.

### Prerequisites / notice

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

### Content

- Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.
- The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

### Abstract

This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

The first part of the course is dedicated to an introduction to linear regression analysis and are also familiar with its extensions to generalized linear modeling.

The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

### Personal Competencies

- Critical Thinking
- Decision-making
- Problem-solving
- Creative Thinking

### Type

- 2V+1U

### ECTS

- 5 credits

### Hours

- 2V+1U

### Lecturers

- L. Meier
- M. Dettling

### Notice

The exercises are based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.
Learn to apply practical bioinformatics/computational skills for analysis of microbiomes in foods and human health! Students will apply basic programming skills for scientific computing and bioinformatics, and learn and discuss the importance of microbiomes to foods and human health, through recognition and comparison of ecological theory, methodology, and experimental design across systems.

**Course Content**

1. Introduction to microbiomes and microbial bioinformatics toolkit. Python, Pandas, Jupyter, GitHub, visualization libraries for Python.
3. Microbial diversity, function, and ecology. Molecular ecology, diversity metrics, ordination methods.

This course requires extensive engagement in learning outside of the classroom (using online resources and practical exercises), with a focus on active learning in the classroom.

**Prerequisites / Notice**

No specific pre-requisites, but students should have some familiarity with microbiology, molecular biology, programming (Python), bioinformatics, and statistics.

Students will bring and work on their own laptop computers.

All software used in the course is free and open-source.

### Optional Subjects

<table>
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<th>Number</th>
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<th>Hours</th>
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<tr>
<td>752-6301-00L</td>
<td>Nutrition-Related Physiology</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>F. von Meyenn, E. Gasser</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>Some basic knowledge in physiology is recommended for this course, which revisits important physiological topics, emphasizing their relation to nutrition. The aim is to give the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand. For students with a background in medicine, pharmacy or biology, the course is useful as a review of previously acquired knowledge. Major topics are basic neuroanatomy and neurophysiology; general endocrinology; the physiology of taste and smell; nutrient digestion and absorption; intermediary metabolism and energy homeostasis; and some aspects of cardiovascular physiology and water balance.</td>
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<td></td>
<td>Lecture notes</td>
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<td></td>
<td>Handouts for each lecture will be uploaded to Moodle every week.</td>
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<tr>
<td>752-6403-00L</td>
<td>Nutrition and Performance</td>
<td>W+</td>
<td>2</td>
<td>2V</td>
<td>S. Mettler</td>
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<tr>
<td></td>
<td>Abstract</td>
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<tr>
<td></td>
<td>The course introduces basic concepts of the interaction between nutrition and exercise performance.</td>
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</table>
Objective
To understand the potential effects of nutrition on exercise performance, with a focus on concepts and principles of nutrition before, during, and after exercise.

Content
The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise. Although this is a scientific course, it is a goal of the course to translate basic sports nutrition science into practical sports nutrition examples.

Lecture notes
Lecture slides and required handouts will be available on the ETH website (moodle).

Literature
Information on further reading will be announced during the lecture. There will be some mandatory as well as voluntary readings.

Prerequisites / notice
General knowledge about nutrition, human biology, physiology and biochemistry is a prerequisite for this course. The course builds on basic nutrition and biochemistry knowledge to address exercise and performance related aspects of nutrition.

The course is designed for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).

752-1301-00L Special Topics in Toxicology W 2 credits 2G K. Hecht, S. J. Sturla

Objective
Journal-club style course involving student presentations and active discussion and critique of recent publications and modern experimental strategies. The focus is on chemical, biochemical, and nutritional aspects of selected topics in Toxicology, with a new group of topics addressed each semester

Content
The journal-club style course involves student presentations and active discussion of recent publications. The primary focus is on chemical, biochemical, and nutritional aspects of selected current topics in Toxicology. Participants are masters or PhD students in Food Sciences and related disciplines (i.e. Chemistry, Biochemistry, Pharmaceutical Sciences, etc.).

Literature
A selection of approximately 20 papers from recent primary scientific literature.

Prerequisites / notice
The course is open to Masters or PhD level students.

For Masters level participants, a strict prerequisite is (a) previously taken and passed "Introduction to Toxicology" (752-1300) and/or (b) previous courses supporting equivalent knowledge plus permission from the instructor. Please contact the instructor before the start of the class, explaining the basis of your previous knowledge other than the Introduction course, to request special permission.

If you would like to take "Special Topics in Toxicology", do not register at the same time for "Advanced Topics in Toxicology". It is only possible to take one, and it is only possible to take the advanced level after completing this course.

752-2122-00L Food and Consumer Behaviour W 2 credits 2V M. Siegrist, F. Michel

Objective
This course focuses on food consumer behavior, consumer's decision-making processes and consumer's attitudes towards food products. Students will be able...

- to describe heuristics that influence consumer behavior in the food domain
- to explain the consumer led food product development
- to summarise how consumers perceive the environmental impact and the healthiness of foods
- to assess the cultural, the environmental and the food policy impact on consumer behavior
- to explain psychological factors influencing eating behavior

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Social Competencies
Communication fostered
Customer Orientation assessed
Sensitivity to Diversity assessed

Personal Competencies
Critical Thinking assessed

766-6304-00L Nutrition Research Procedure 3 credits 2G J. Rigutto

Objective
This course provides students interested in nutrition with fundamental tools and concepts in human nutrition research, including topics such as study design, statistical analysis, scientific writing and communicating results. Preparation of a research proposal will consolidate student learning. The course is designed for MAS and first semester MSc Nutrition and Health students.

This course will familiarise students with the fundamental concepts, methodologies and terminology that apply to human nutrition research. The course features both didactic presentations and in-class practical exercises including topics such as study design, statistics, scientific writing and communicating results. Students will have the opportunity to consolidate their learning by preparing a research protocol to study a nutrition-related health problem, which will be submitted for grading and presented in an end-of-semester graded poster presentation.

On completion of this course, students will have improved:

- Understanding of experimental study design in basic and clinical research
- Familiarity with the research process and methods used in human nutrition
- Understanding of basic statistics and analytical skills used in preparing and reporting research, including in tables and graphs
- Ability to report scientific results in writing and orally
- Skills in scientific writing and an understanding of the publication process
- Proficiency in retrieval and interpretation of scientific literature

Lecture notes
The teaching slides used in the lectures will be made available weekly on Moodle before each class, as pdf files.

Literature
There is no recommended textbook or prior reading required for this class. Students will be provided with recommendations for further reading where relevant, with the lecture notes.

Prerequisites / notice
Students are expected to attend and actively participate in the course, which includes the preparation of a research protocol that will be presented and graded during a poster presentation at the end of the semester.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Problem-solving assessed
Project Management assessed

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

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At the end of this module students are able:

- assessed

Title

We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (~ 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

Lecturers

Schmid Hempel 2011 Evolutionary Parasitology
Stearns & Medzhitov 2016 Evolutionary Medicine
Prerequisites / notice
A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

Competencies

### Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies fostered

### Method-specific Competencies
- Problem-solving fostered
- Project Management fostered

### Social Competencies
- Communication assessed
- Cooperation and Teamwork fostered

### Personal Competencies
- Creative Thinking fostered
- Critical Thinking assessed

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**701-1471-00L  Ecological Parasitology**

**W 3 credits  1V+1P  F. Feijen, J. Jokela, C. Vorburger**

**Abstract**
The course will not take place fall semester 2024.

**Objective**
1. Identify common macroparasites in invertebrates.
2. Understand ecological and evolutionary processes in host-parasite interactions.
3. Conduct parasitological research

**Content**
- Lectures:
  1. Diversity and natural history of parasites (i.e. systematic groups and life-cycles).
  2. Adaptations of parasites (e.g. evolution of life-cycles, host manipulation).
  3. Ecology of host-parasite interactions (e.g. parasite communities, effects of environmental changes).
  4. Ecology and evolution of parasitoids and their applications in biocontrol
  5. Human macroparasites (schistosomiasis, malaria).

Practical exercises:
1. Examination of parasites in molluscs (identification and examination of host exploitation strategies).
2. Examination of parasites in amphipods (identification and examination of effects on hosts).
3. Examination of parasitoids of aphids.

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**551-0223-00L  Immunology III**


**Abstract**
This course provides a detailed understanding of
- development of T and B cells
- the dynamics of a immune response during acute and chronic infection
- mechanisms of immunopathology
- modern vaccination strategies

Key experimental results will be shown to help understanding how immunological text book knowledge has evolved.

**Objective**
Obtain a detailed understanding of
- the development, activation, and differentiation of different types of T cells and their effectormechanisms during immune responses,
- Recognition of pathogenic microorganisms by the host cells and molecular events thereafter,
- events and signals for maturation of naive B cells to antibody producing plasma cells and memory B cells.
- Optimization of B cell responses by intelligent design of new vaccines

**Content**
- Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg)
- NK T cells and responses to lipid antigens
- Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17
- Overview of cytokines and their effector function
- Co-stimulation (signals 1-3)
- Dendritic cells
- Evolution of the "Danger" concept
- Cells expressing Pattern Recognition Receptors and their downstream signals
- T cell function and dysfunction in acute and chronic viral infections

**Literature**
Documents of the lectures are available for download at:
https://moodle-app2.let.ethz.ch/course/view.php?id=2581

752-2009-00L Molecular Biology of Foodborne Pathogens  

**Abstract**
The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

**Objective**
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

**Content**
Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

**Lecture notes**
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

**Prerequisites / notice**
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break!

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701-0263-01L Seminar in Evolutionary Ecology of Infectious Diseases  

**Abstract**
Students of this course will discuss current topics from the field of infectious disease biology. From a list of publications, each student chooses some themes that he/she is going to explain and discuss with all other participants and under supervision. The actual topics will change from year to year corresponding to the progress and new results occurring in the field.

**Objective**
This is an advanced course that will require significant student participation. Students will learn how to evaluate and present scientific literature and trace the development of ideas related to understanding the ecology and evolutionary biology of infectious diseases.

**Content**
A core set of ~10 classic publications encompassing unifying themes in infectious disease ecology and evolution, such as virulence, resistance, metapopulations, networks, and competition will be presented and discussed. Pathogens will include bacteria, viruses and fungi. Hosts will include animals, plants and humans.

**Lecture notes**
Publications and class notes can be downloaded from a web page announced during the lecture.

**Prerequisites / notice**
No compulsory prerequisites, but prior completion of the course “Introduction to Nutritional Science” and “Advanced Topics in Nutritional Sciences” is recommended but not compulsory.

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752-6101-00L Nutrition and Chronic Disease  

**Abstract**
To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Objective**
To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic disease, as well as the progression of complications of the chronic diseases.

**Content**
The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Lecture notes**
There is no script. Powerpoint presentations will be made available on-line to students.

**Prerequisites / notice**
No compulsory prerequisites, but prior completion of the courses “Introduction to Nutritional Science” and “Advanced Topics in Nutritional Science” is strongly advised.

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752-2122-00L Food and Consumer Behaviour  

**Abstract**
This course focuses on food consumer behavior, consumer’s decision-making processes and consumer’s attitudes towards food products. Students will be able...

- to describe heuristics that influence consumer behavior in the food domain
- to explain the consumer led food product development
- to summarise how consumers perceive the environmental impact and the healthiness of foods
- to assess the cultural, the environmental and and the food policy impact on consumer behavior
- to explain psychological factors influencing eating behavior

**Objective**

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This course provides students interested in nutrition with fundamental tools and concepts in human nutrition research, including topics such as study design, statistical analysis, scientific writing and communicating results. Preparation of a research proposal will consolidate student learning. The course is designed for MAS and first semester MSc Nutrition and Health students.

On completion of this course, students will have improved:
- Understanding of experimental study design in basic and clinical research
- Familiarity with the research process and methods used in human nutrition
- Understanding of basic statistics and analytical skills used in preparing and reporting research, including in tables and graphs
- Ability to report scientific results in writing and orally
- Skills in scientific writing and an understanding of the publication process
- Proficiency in retrieval and interpretation of scientific literature

The teaching slides used in the lectures will be made available weekly on Moodle before each class, as pdf files. Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website.

Objective
This course will familiarise students with the fundamental concepts, methodologies and terminology that apply to human nutrition research. The course features both didactic presentations and in-class practical exercises including topics such as study design, statistics, scientific writing and communicating results. Students will have the opportunity to consolidate their learning by preparing a research protocol to study a nutrition-related health problem, which will be submitted for grading and presented in an end-of-semester graded poster presentation.

Literature
There is no recommended textbook or prior reading required for this class. Students will be provided with recommendations for further reading where relevant, with the lecture notes.

Prerequisites / notice
Students are expected to attend and actively participate in the course, which includes the preparation of a research protocol that will be presented and graded during a poster presentation at the end of the semester.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Customer Orientation: assessed
- Sensitivity to Diversity: assessed

Personal Competencies
- Critical Thinking: assessed

Module Environment and Health

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
376-1353-00L | Nanostructured Materials Safety | W | 2 credits | 1V | P. Wick, T. Bürki-Thurnherr

Abstract
Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection

Objective
Understanding the potential side effects of nanomaterials in a context-sensitive way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials

Content
Building upon new technologies to engineer and functionalize well-defined nanostructured materials, a plethora of exciting discoveries were made and found their way in our daily life. These customized nanomaterials provide extraordinary properties and make them attractive for many innovative applications. Exactly these new properties may have the potential to be responsible for unforeseen side effects, which hamper a straightforward translation into new products. Therefore, the safety research provide the evidence for a responsible and sustainable use of nanomaterials. The lecture will focus on basic principles of nanotoxicology, provide the understanding of the potential side effects of nanomaterial in a context-specific way addressing the main exposure routes such as inhalation, ingestion, topical applications and intravenous injection as well as it will provide impulses for safer material designs.

Structure of the planned lecture (2 x 45 min)
1. Introduction: the principles of nanotoxicology
2. Lung- particles interactions: two disease scenarios and their molecular mechanism
3. GI – particles interactions: intended and unintended particle exposure via food
4. Skin – particles interactions: body care products and their influence on skin physiology
5. Intravenous injection: colloidal stability, protein corona and cellular effects
6. Micro- / Nanoplastics and development of a safety research plan
7. End of semester exam

Lecture notes
Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website.

Prerequisites / notice
course “Introduction to Toxicology”

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: fostered
- Problem-solving: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

Term Paper

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---

Only for students of the Major Human Health, Nutrition
Bioinformatics Computation in Microbiome Research

Abstract
Writing of a review paper of scientific quality on a topic in the domain of Human Health, Nutrition and Environment based on critical evaluation of scientific literature.

Objective
- Acquisition of knowledge in the field of the review paper
- Assessment of original literature as well as synthesis and analysis of the findings
- Practising of academic writing in English
- Giving an oral presentation with discussion on the topic of the review paper

Content
Topics are offered in the domains of the major ‘Human Health, Nutrition and Environment’ covering ‘Public Health’, ‘Infectious Diseases’, ‘Nutrition and Health’ and ‘Environment and Health’.

Lecture notes
Guidelines will be handed out in the beginning.

Literature
Literature will be identified based on the topic chosen.

Competencies

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<th>Competencies</th>
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<th>Social Competencies</th>
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<td>Analytical Competencies</td>
<td>Communication</td>
<td>Critical Thinking</td>
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<td>Techniques and Technologies</td>
<td>Media and Digital Technologies</td>
<td>Cooperation and Teamwork</td>
<td>Integrity and Work Ethics</td>
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<td>Self-direction and Self-management</td>
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ECTS
3 credits

Lecturers
R. Mira de Orduna Heldinger, N. Bokulich, M. Rienth

Methodology Subjects
The courses are offered in the spring semester

Minors

Food Biotechnology

Number  Title  Type  ECTS  Hours  Lecturers
752-5105-00L  Biotechnology of Alcoholic Beverage Production  W+  2 credits  2V  R. Mira de Orduna Heldinger, N. Bokulich, M. Rienth

Abstract
This course introduces fundamental aspects of the production of beer and grape wine.

Objective
- Introduction of alcoholic beverage production within industrial microbiology
- Brewing
  - Raw materials, and malting
  - Brewhouse processes, wort production, fermentations, lagering
  - Sensory aspects and diacetyl management
- Winemaking
  - Grape growing and grape processing
  - Crush and pressing
  - Fermentations and microbial transformations
  - Fining, stabilizations, filtration and bottling
  - Aroma and macromolecule chemistry, climate change
- Sensory aspects and wine faults

Content
- Introduction to alcoholic beverage production within industrial microbiology
- Brewing
  - Raw materials, and malting
  - Brewhouse processes, wort production, fermentations, lagering
  - Sensory aspects and diacetyl management
- Winemaking
  - Grape growing and grape processing
  - Crush and pressing
  - Fermentations and microbial transformations
  - Fining, stabilizations, filtration and bottling
  - Aroma and macromolecule chemistry, climate change
- Sensory aspects and wine faults

Literature
A list of learning materials will be provided online.

Prerequisites / notice
Students taking 752-5105-00L require a sound knowledge of basic chemistry, biochemistry, molecular genetics, microbiology and microbial physiology.

In order to decipher the costs of tastings, a financial participation of CHF25 will be required per student.

Competencies

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<th>Method-specific Competencies</th>
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<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
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<td>Critical Thinking</td>
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<td>Techniques and Technologies</td>
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<td>Self-direction and Self-management</td>
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752-5500-00L  Applied Bioinformatics: Microbiomes  5 credits  2V+2U  N. Bokulich, M. Ziemski

Abstract
Learn to apply practical bioinformatics/computational skills for analysis of microbiomes in foods and human health! Students will apply programming skills for scientific computing and bioinformatics, and learn and discuss the importance of microbiomes to foods and human health, through recognition and comparison of ecological theory, methodology, and experimental design across systems.

Objective
Learn to apply bioinformatics and computational methods for analysis of microbiome next-generation sequencing data. A secondary goal is to critically examine the relevance of microbiomes to food quality, safety, and human health, through application of theory and appropriate experimental design. Students completing this course will thus be able to both apply appropriate methodology to study microbiomes (or other high-dimensional data) in different systems, as well as evaluate and interpret bioinformatics results.

Content
1. Introduction to microbiomes and microbial bioinformatics toolkit. Python, Pandas, Jupyter, GitHub, visualization libraries for Python.
3. Microbial diversity, function, and ecology. Molecular ecology, diversity metrics, ordination methods.

This course requires extensive engagement in learning outside of the classroom (using online resources and practical exercises), with a focus on active learning in the classroom.

Prerequisites / notice
No specific pre-requisites, but students should have some familiarity with microbiology, molecular biology, programming (Python), bioinformatics, and statistics.

Students will bring and work on their own laptop computers.

All software used in the course is free and open-source.
Food Chemistry

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<tr>
<th>Number</th>
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<tr>
<td>752-1021-00L</td>
<td>Food Enzymology</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>L. Nyström, M. Erzinger</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course covers the fundamentals of food enzymology, application of endogenous and exogenous enzymes in food processing, as well as use of enzymes in analytics.</td>
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<tr>
<td>Objective</td>
<td>Students can describe what enzymes are and can explain their use and functions in food and food products. Students can argue why and how enzymes are used in food processing and analysis. Students execute a research project independently and defend their findings during a presentation to peer students and an expert panel.</td>
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<tr>
<td>Content</td>
<td>Enzymes in foods: the use of added enzymes in food processing, control and/or utilization of endogenous enzymes, production of enzyme preparations for food use, and chemical analysis of food components by enzymatic methods.</td>
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Modern Mass Spectrometry, Hyphenated Methods, and Chemometrics

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<tr>
<td>529-0041-00L</td>
<td>Modern Mass Spectrometry, Hyphenated Methods, and Chemometrics</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>R. Zenobi, B. Hattendorf, P. Sinués Martinez-Lozano</td>
</tr>
<tr>
<td>Abstract</td>
<td>Modern mass spectrometry, hyphenated analytical methods, speciation, chemometrics.</td>
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</tr>
<tr>
<td>Objective</td>
<td>Comprehensive knowledge about the analytical methods introduced in this course and their practical applications.</td>
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<tr>
<td>Content</td>
<td>Hyphenation of separation with identification methods such as GC-MS, LC-MS, GC-IR, LC-IR, LC-NMR etc.; importance of speciation. Modern mass spectrometry: time-of-flight, orbitrap and ion cyclotron resonance mass spectrometry, ICP-MS. Soft ionization methods, desorption methods, spray methods. Mass spectrometry imaging. Use of statistical and computer-assisted methods for processing analytical data (chemometrics).</td>
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</table>

Lecture notes
Lecture notes will be made available online.

Literature
Information about relevant literature will be available in the lecture & in the lecture notes.

Prerequisites / notice
Exercises are an integral part of the lecture.

Prerequisites:
- 529-0051-00 "Analytische Chemie I (3. Semester)"
- 529-0058-00 "Analytische Chemie II (4. Semester)"
(or equivalent)
### Food Microbiology

<table>
<thead>
<tr>
<th>Number</th>
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<tbody>
<tr>
<td>752-4009-00L</td>
<td>Molecular Biology of Foodborne Pathogens</td>
<td>W+</td>
<td>3 credits</td>
<td>2V</td>
<td>M. Loessner, A. Harms, M. Schuppler, E. Slack</td>
</tr>
</tbody>
</table>

**Abstract**
The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

**Objective**
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

**Content**
Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

**Lecture notes**
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

**Prerequisites / notice**
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break!

### Food Sensory Science and Consumer Behaviour

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>752-2122-00L</td>
<td>Food and Consumer Behaviour</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>M. Siegrist, F. Michel</td>
</tr>
</tbody>
</table>

**Abstract**
This course focuses on food consumer behavior, consumer’s decision-making processes and consumer’s attitudes towards food products. Students will be able...
- to describe heuristics that influence consumer behavior in the food domain
- to explain the consumer led food product development
- to summarise how consumers perceive the environmental impact and the healthiness of foods
- to assess the cultural, the environmental and and the food policy impact on consumer behavior
- to explain psychological factors influencing eating behavior

**Competencies**
- Subject-specific Competencies: Concepts and Theories, Techniques and Technologies
- Method-specific Competencies: Analytical Competencies, Decision-making, Problem-solving
- Social Competencies: Communication
- Personal Competencies: Creative Thinking, Critical Thinking

### Public Nutrition and Health

<table>
<thead>
<tr>
<th>Number</th>
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<td>752-6101-00L</td>
<td>Nutrition and Chronic Disease</td>
<td>W+</td>
<td>3 credits</td>
<td>2V</td>
<td>F. von Meyenn, M. Andersson</td>
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</tbody>
</table>

**Abstract**
To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.
### 752-6105-00L Epidemiology and Prevention

**Abstract**
The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.

**Objective**
The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

**Content**
The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

**Competencies**

<table>
<thead>
<tr>
<th>Type</th>
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<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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<td>fostered</td>
<td>Project Management</td>
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<td>Critical Thinking</td>
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### 752-2122-00L Food and Consumer Behaviour

**Abstract**
This course focuses on food consumer behavior, consumer's decision-making processes and consumer's attitudes towards food products.

**Objective**
Students will be able:
- to describe heuristics that influence consumer behavior in the food domain
- to explain the consumer led food product development
- to summarise how consumers perceive the environmental impact and the healthiness of foods
- to assess the cultural, the environmental and the food policy impact on consumer behavior
- to explain psychological factors influencing eating behavior

**Competencies**

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<td>Critical Thinking</td>
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### 752-2307-00L Nutritional Aspects of Food Composition and Processing

**Abstract**
Lecture type course with an interdisciplinary approach for the evaluation of nutritional aspects of changes in food composition due to processing.

**Objective**
Students should be able to:
- describe and compare the major concepts /criteria used for the evaluation of the nutritional quality of food
- apply these criteria when assessing the effects of selected processing technologies on nutritional quality
- evaluate recent formulation strategies aimed to achieve additional physiological benefits for targeted population groups (i.e. functional foods).

**Content**
The course gives inputs on compositional changes in food due to processing (with focus on thermal/chilling, enzymatic, chemical, separation and emerging technologies) or new formulation strategies. New approaches for evaluating these changes (e.g. nutritional profiles) and how these are communicated to consumers are also discussed.

**Lecture notes**
There is no script. Powerpoint presentations and relevant scientific articles will be available on-line for students. A selection of recommended readings will be given at the beginning of the course.

### 751-6001-00L Forum: Livestock in the World Food System

**Abstract**
This forum is a platform for the critical reflection of relevant topics of livestock in the frame of the world food system comprising issues from basic knowledge to acceptance in society. The exchange is operated by scientific writing and presentation.

**Objective**
In the Forum "Livestock in the World Food System", a topic of significance for livestock agriculture is selected by the students and subsequently dealt with from various angles (from scientific basis to production systems, environmental aspects and to the acceptance by society).

The students learn to present a scientific subject in writing and orally to an audience and to defend the presentation in a discussion. Further, feedback is intended to improve the presentation style. Furthermore, the review process of a scientific paper will be demonstrated and applied.
fostered

Concepts and Theories
Advanced Topics in Toxicology
fostered

Lecturers
At the end of this course, the students are aware of food and feed as sources of different bioactive compounds. By a comprehensive

2G

S. J. Sturla

Information about books and other references will be communicated during the course.

Bioactive Food and Feed Components
fostered

The course gives an introduction into different classes of bioactive components present in food and feed including fatty acids and

ECTS

W

2 credits

2V

to be announced

Toxicology

The course is open to Masters or PhD level students.

Sciences and related disciplines (i.e. Chemistry, Biochemistry, Pharmaceutical Sciences, etc.).

Subject-specific Competencies
- Adaptability and Flexibility
- Communication
- Creative Thinking
- Critical Thinking
- Decision-making
- Negotiation
- Problem-solving
- Sensitivity to Diversity
- Cooperation and Teamwork

Method-specific Competencies
- Concepts and Theories
- Decision-making
- Techniques and Technologies

Social Competencies
- fostered
- fostered
- fostered
- fostered
- fostered
- fostered
- fostered
- fostered
- fostered
- fostered

Personal Competencies
- fostered
- fostered
- fostered

Abstract
The course provides students with the basic knowledge to understand the connection between the structure of nutritive and non-nutritive

751-7310-00L

Does not take place this semester.

Bioactive Food and Feed Components

Objective
At the end of this course, the students are aware of food and feed as sources of different bioactive compounds. By a comprehensive

Content
The course gives an introduction into different classes of bioactive components present in food and feed including fatty acids and

Secondary Plant Compounds
- Secondary plant compounds such as carotenoids, polyphenols, phytoestrogens, glucosinolates, protease inhibitors and monoterpenes.

- to develop skills in critical evaluation of scientific literature, oral presentation and questioning
- to understand modern experimental techniques and research approaches relevant in toxicology
- to stimulate student interest and provide advanced knowledge of current research in Toxicology and its related sciences
- to understand modern experimental techniques and research approaches relevant in toxicology
- to understand chemical, biochemical, and nutritional aspects of selected topics in Toxicology, with a new group of topics addressed each semester
- to develop skills in critical evaluation of scientific literature, oral presentation and questioning
- to develop skills in critical evaluation of scientific literature, oral presentation and questioning

Journal-club style course involving student presentations and active discussion of recent publications. The primary focus is on chemical, biochemical, and nutritional aspects of selected topics in Toxicology.

Introduction course, to request special permission.

For Masters level participants, a strict prerequisite is (a) previously taken and passed "Introduction to Toxicology" (752-1300) and/or (b)

Prerequisites / notice
- oral talk with sufficient handout
- delivery of the scientific writing in sufficient quality
- active participation during all presentations (in case of absence there will be additional tasks)
- feedback on the presentation style of a student

Competencies

- feedback on the presentation style of a student

Social Competencies

Instructed presentation forms will be given by the lecturer.

Lecture notes

Prerequisites
- no scriptum

Requirements for allocation of the two credit points:
- oral talk with sufficient handout
- delivery of the scientific writing in sufficient quality
- active participation during all presentations (in case of absence there will be additional tasks)
- feedback on the presentation style of a student

Literature

Information about books and other references will be communicated during the course.

Food Toxicology

Number
752-1300-00L

Title
Special Topics in Toxicology

Abstract
Journal-club style course involving student presentations and active discussion of recent publications and modern experimental strategies. The focus is on chemical, biochemical, and nutritional aspects of selected topics in Toxicology, with a new group of topics addressed each semester

Objective
- to stimulate student interest and provide advanced knowledge of current research in Toxicology and its related sciences
- to develop skills in critical evaluation of scientific literature, oral presentation and questioning
- to understand modern experimental techniques and research approaches relevant in toxicology

Content
The journal-club style course involves student presentations and active discussion of recent publications. The primary focus is on chemical, biochemical, and nutritional aspects of selected current topics in Toxicology. Participants are masters or PhD students in Food Sciences and related disciplines (i.e. Chemistry, Biochemistry, Pharmaceutical Sciences, etc.).

Literature
A selection of approximately 20 papers from recent primary scientific literature.

Prerequisites / notice
The course is open to Masters or PhD level students.

For Masters level participants, a strict prerequisite is (a) previously taken and passed "Introduction to Toxicology" (752-1300) and/or (b)

Lecturers
K. Hecht, S. J. Sturla

Data: 15.06.2024 12:39

Autumn Semester 2024

Page 1522 of 2653
Abstract
Journal-club style course that involves student presentations of selected topics in Toxicology on the basis of current primary research and review papers.

Objective
The goals are to stimulate student interest and provide advanced knowledge of current research in the interdisciplinary area of Food and Nutrition Toxicology and its related sciences. The student should develop skills in the critical evaluation of scientific literature, oral presentation and questioning, and understanding modern experimental techniques in Molecular Toxicology.

Content
The journal-club style course involves student presentations of recent publications. The primary focus is on chemical and biochemical aspects of selected topics in Toxicology. Participants are generally masters or PhD students in Food Sciences and related disciplines (i.e. Chemistry, Pharmaceutical Sciences, etc.), and strong knowledge of organic chemistry and biochemistry are prerequisite. Selected course topics change every semester.

Prerequisites / notice
Participants are required to have completed previously "Special Topics in Toxicology" (752-1301-00L). Both courses are run concurrently every semester. It is only possible to register for one course at a time. Do not register for "Advanced Topics in Toxicology" until after you have completed "Special Topics in Toxicology".

752-4009-00L
Molecular Biology of Foodborne Pathogens

Abstract
The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Objective
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganisms or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content
Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Lecture Literature
Recommendations will be given in the first lecture

Prerequisites / notice
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break!

Competencies

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752-6105-00L
Epidemiology and Prevention

Abstract
The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.

Objective
The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

Content
The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

Competencies

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376-1353-00L
Nanostructured Materials Safety

Abstract
Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection.

Objective
Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials

Content
Building upon new technologies to engineer and functionalize well-defined nanostructured materials, a plethora of exciting discoveries were made and found their way in our daily life. These customized nanomaterials provides extraordinary properties and make them attractive for many innovative applications. Exactly these new properties may have the potential to be responsible for unforeseen side effects, which hamper a straightforward translation into new products. Therefore, the safety research provide the evidence for a responsible and sustainable use of nanomaterials.

The lecture will focus on basic principles of nanotoxicology, provide the understanding of the potential side effects of nanomaterial in a context-specific way addressing the main exposure routes such as inhalation, ingestion, topical applications and intravenous injections as well as it will provide impulses for safer material designs.

Structure of the plained lecture (2 x 45 min)
1. Introduction: the principles of nanotoxicology
2. Lung- particles interactions: two disease scenarios and their molecular mechanism
3. GI – particles interactions: intendent and unintendent particle exposure via food
4. Skin – particles interactions: body care products and their influence on skin physiology
5. Intravenous injection: colloidal stability, protein corona and cellular effects
6. Micro- / Nanoplastics and development of a safety research plan
7. End of semester exam
Physics of Food Colloids

In Physics of Food Colloids the principles of colloid science will be applied to the aggregation of food materials based on proteins, polysaccharides, and emulsifiers. Mixtures of such raw materials determine the appearance and performance of our daily food. In a number of examples, colloidal laws are linked to food science and the manufacturing and processing of food.

The aggregation of food material determines the appearance and performance of complex food systems as well as nutritional aspects. The underlying colloidal laws reflect the structure of the individual raw material (length scale, time scale, and interacting forces). Once these concepts are appreciated, the aggregation of most food systems falls into recognizable patterns that can be used to modify and structure exiting food or to design new products. The application and use of these concepts are discussed in light of common food production.

In this seminar, students will explain one concept in each course to the groups and practice their argumentative and writing skills in a final essay, applying the acquired tools to a topic of their choice. While specific inputs from external lecturers broaden our perspective, enough time for critical discussion and reflection will be granted.

Questions regarding the application to johanna.jacobi@usys.ethz.ch.

In this seminar, students are introduced to the multi-disciplinary field of political ecology to investigate human-environment relationships in food and agricultural systems.

We will review common narratives in agri-food systems informed by a range of different theories and assisted by different analytical tools.

For this purpose, we will start from different conceptual frameworks and explore different ontologies and epistemologies through a set of topics such as hunger, obesity, agrobiodiversity and seeds, forests and deforestation, climate change and food production. Students will explain one concept in each course to the groups and practice their argumentative and writing skills in a final essay, applying the acquired tools to a topic of their choice. While specific inputs from external lecturers broaden our perspective, enough time for critical discussion and reflection will be granted.

A motivational application is required:
- presenting yourself and your studies
- stating what topic in the field of Political Ecology that you are interested in
- suggesting one paper to enrich the literature list for the course

Questions regarding the application to johanna.jacobi@usys.ethz.ch.

The objectives are to become familiar with and stimulate interest in leading-edge science related to the research topics of the Institute of Food, Nutrition and Health. Participants attend weekly seminars given by external and internal speakers, and are also required to deliver a presentation on a recent research article inspired by a topic from the semester presentations.

Cooperation and Teamwork

Foreign Language Competencies

Personal Competencies

Social Competencies

Method-specific Competencies

Techniques and Technologies

Decision-making

Problem-solving

Analytical Competencies

Concepts and Theories

Mixtures of such raw materials determine the appearance and performance of our daily food. In a number of examples, colloidal laws are linked to food science and the manufacturing and processing of food.

Most chapters include some hand-ons examples of the gain knowledge to common food products.

Lectures include interfacial tension (4h), protein aggregation in bulk and interfaces (4h), Pickering emulsions (2h), gels (2h), aggregation of complex mixtures (4h), and the use of light scattering in investigation complex food structures (8h). Most chapters include some hand-ons examples of the gain knowledge to common food products.

In Physics of Food Colloids the principles of colloid science will be applied to the aggregation of food materials based on proteins, polysaccharides, and emulsifiers. Mixtures of such raw material determine the appearance and performance of our daily food. In a number of examples, colloidal laws are linked to food science and the manufacturing and processing of food.
Lecture notes

20.9.2024 Introduction to political ecology
27.9.2024 Ontologies and epistemologies
4.10.2024 Green revolution, industrial agriculture, and agroecology
11.10.2024 Don't blame the rain: Water management in agriculture
18.10.2024 Climate justice and food systems
25.10.2024 Conservation: Protecting what from what?
1.11.2024 Deforestation: Root causes and alternatives
8.11.2024 Pandemics, syndemics and the food system
15.11.2024 Technology and the politics of knowledge
22.1.2024 Land-sharing, land-sparing
29.11.2024 Feminist (political) agroecology
6.12.2024 Food: Commons or commodity?
13.12.2024 Alternatives to sustainable development
20.12.2024 Final session (The Hunger Banquet)

Literature

Literaturelist provided on Moodle when the course starts.

https://moodle-app2.let.ethz.ch/course/view.php?id=20544

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Method-specific Competencies

Analytical Competencies fostered
Decision-making fostered
Problem-solving fostered
Social Competencies

Cooperation and Teamwork fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity assessed
Negotiation fostered
Personal Competencies

Adaptability and Flexibility assessed
Critical Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management fostered

Master's Thesis

<table>
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<th>Title</th>
<th>Type</th>
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<th>Hours</th>
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<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Supervisors</td>
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</table>

Only students who fulfill the following criteria are allowed to begin with their master thesis:

a. successful completion of the bachelor programme;
b. fulfilling of any additional requirements necessary to gain admission to the master programme;
c. has acquired at least 30 CPs in the master programme.

The topic of the thesis and - if they are not Professors of D-HEST - the examiner and the co-examiner have to be approved by the D-HEST Department Conference.

Abstract

The Master thesis completes the master programme and is an independent scientific project. Generally, the topic is selected from the specific field of the major. It is supervised by a professor/Privatdozents at D-HEST or D-USYS, Agricultural Sciences.

Objective

The Master Thesis must demonstrate the student's ability to independent, structured and scientific working.

Master Studies (Programme Regulations 2024)

Major in Food Science and Technology

Minor Human Nutrition

The minor Human Nutrition can only be chosen in connection with the major in Food Science and Technology.

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To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.
Epidemiology and Prevention

- **Objective**: The module Epidemiology and Prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.
- **Content**: The module Epidemiology and Prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

Food Enzymology

- **Objective**: Students can describe what enzymes are and can explain their use and functions in food and food products.
- **Content**: Enzymes in foods: the use of added enzymes in food processing, control and/or utilization of endogenous enzymes, production of enzyme preparations for food use, and chemical analysis of food components by enzymatic methods.

Food Rheology

- **Objective**: The course provides an introduction on the link between flow and structural properties of flowing material. Rheometrical techniques and appropriate measuring protocols for the characterization of complex fluids will be discussed. The concept of rheological constitutive equations and the application to different material classes are established.
- **Content**: Rheology is the science of flow and deformation of matter such as polymers, suspensions (emulsions, foams, suspensions), and colloidal systems. The fluid dynamical basis, measuring techniques (rheometry), and the flow properties of different fluids (Newtonian, non-Newtonian, viscoelastic) are introduced and discussed.

Physics of Food Colloids

- **Objective**: Students can argue why and how enzymes are used in food processing and analysis.
- **Content**: Food Rheology

Core courses FST

- **Number**: 752-1021-00L
- **Title**: Food Enzymology
  - **Type**: W+ 3 credits 2V
  - **Lecturers**: L. Nyström, M. Erzinger
- **Abstract**: The course covers the fundamentals of food enzymology, application of endogenous and exogenous enzymes in food processing, as well as use of enzymes in analytics.
- **Objective**: Students can describe what enzymes are and can explain their use and functions in food and food products. Students can argue why and how enzymes are used in food processing and analysis.
- **Content**: Enzymes in foods: the use of added enzymes in food processing, control and/or utilization of endogenous enzymes, production of enzyme preparations for food use, and chemical analysis of food components by enzymatic methods.
- **Comprehensiveness**: The lectures are supplemented with handouts.
- **Prerequisites / notice**: Course prerequisites: Food Chemistry I/II and Food Analysis I/II (or equivalent)
- **Competencies**: Subject-specific Competencies, Concepts and Theories, assessed
  - **Method-specific Competencies**: Analytical Competencies, assessed
  - **Social Competencies**: Communication, fostered
  - **Personal Competencies**: Creative Thinking, fostered

- **Number**: 752-3103-00L
- **Title**: Food Rheology
  - **Type**: W+ 3 credits 2V
  - **Lecturers**: P. A. Fischer
- **Abstract**: Rheology is the science of flow and deformation of matter such as polymers, suspensions (emulsions, foams, suspensions), and colloidal systems. The fluid dynamical basis, measuring techniques (rheometry), and the flow properties of different fluids (Newtonian, non-Newtonian, viscoelastic) are introduced and discussed.
- **Objective**: The course provides an introduction on the link between flow and structural properties of flowing material. Rheometrical techniques and appropriate measuring protocols for the characterization of complex fluids will be discussed. The concept of rheological constitutive equations and the application to different material classes are established.
- **Content**: Rheology is the science of flow and deformation of matter such as polymers, suspensions (emulsions, foams, suspensions), and colloidal systems. The fluid dynamical basis, measuring techniques (rheometry), and the flow properties of different fluids (Newtonian, non-Newtonian, viscoelastic) are introduced and discussed.
- **Lecture notes**: Notes will be handed out during the lectures.
- **Competencies**: Subject-specific Competencies, Concepts and Theories, assessed
  - **Method-specific Competencies**: Analytical Competencies, assessed
  - **Personal Competencies**: Creative Thinking, fostered

- **Number**: 752-2314-00L
- **Title**: Physics of Food Colloids
  - **Type**: W+ 3 credits 2V
  - **Lecturers**: P. A. Fischer, R. Mezzenga
In Physics of Food Colloids the principles of colloid science will be applied to the aggregation of food materials based on proteins, polysaccharides, and emulsifiers. Mixtures of such raw material determine the appearance and performance of our daily food. In a number of examples, colloidal laws are linked to food science and the manufacturing and processing of food.

The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware of how epidemiological facts are used in prevention, practice and politics.

The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies. The underlying colloidal laws reflect the structure of the individual raw material (length scale, time scale, and interacting forces). Once these concepts are appreciated the aggregation of most food systems falls into recognizable patterns that can be used to modify and structure exiting food or to design new products. The application and use of these concepts are discussed in light of common food production.

The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Lectures include interfacial tension (4h), protein aggregation in bulk and interfaces (4h), Pickering emulsions (2h), gels (2h), aggregation of complex mixtures (4h), and the use of light scattering in investigation complex food structures (8h). Most chapters include some hand-ons examples of the gain knowledge of common food products.

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<tr>
<td>752-6101-00L</td>
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<td>W+</td>
<td>3</td>
<td>2V</td>
<td>F. von Meyenn, M. Andersson</td>
</tr>
<tr>
<td>752-6105-00L</td>
<td>Epidemiology and Prevention</td>
<td>W+</td>
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<td>2V</td>
<td>M. Puhan, R. Heusser</td>
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The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health. The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware of how epidemiological facts are used in prevention, practice and politics.

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<td>Project Management</td>
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### 752-0005-00L Colloquium in Food and Nutrition Science

<table>
<thead>
<tr>
<th>Objective</th>
<th>The objectives are to become familiar with and stimulate interest in leading-edge science related to the research topics of the Institute of Food, Nutrition and Health. Participants attend weekly seminars given by external and internal speakers, and are also required to deliver a presentation on a recent research article inspired by a topic from the seminar presentations.</th>
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</table>

### 752-0801-00L Food Law and Legislation

<table>
<thead>
<tr>
<th>Objective</th>
<th>Knowledge of the principles and the structure of the EU in general and in the area of food safety, overview of the relevant bilateral agreements CH-EU as well as on the most important international organisations. Basic knowledge of the structure of Swiss food law and its implementation in the context of self-controll in food companies. The process of food enforcement is known and issues can be assessed from a legal perspective.</th>
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</table>

### 752-1301-00L Special Topics in Toxicology

<table>
<thead>
<tr>
<th>Objective</th>
<th>The journal-club style course involves student presentations and active discussion of recent publications and modern experimental strategies. The focus is on chemical, biochemical, and nutritional aspects of selected topics in Toxicology, with a new group of topics addressed each semester.</th>
</tr>
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</table>

### 752-1302-00L Advanced Topics in Toxicology

<table>
<thead>
<tr>
<th>Objective</th>
<th>The goals are to stimulate student interest and provide advanced knowledge of current research in the interdisciplinary area of Food and Nutrition Toxicology and its related sciences. The student should develop skills in the critical evaluation of scientific literature, oral presentation and questioning, and understanding modern experimental techniques in Molecular Toxicology.</th>
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</thead>
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Data: 15.06.2024 12:39  
Autumn Semester 2024  
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Analytical Competencies

Subject-specific Competencies

Concepts and Theories

Fostered

Assessed

Critical Thinking

Fostered

Assessed

Method-specific Competencies

Analytical Competencies

Fostered

Assessed

Decision-making

Fostered

Assessed

Problem-solving

Assessed

Social Competencies

Communication

Fostered

Customer Orientation

Fostered

Sensitivity to Diversity

Assessed

Personal Competencies

Critical Thinking

Assessed

M. Siegrist

Communication

Fostered

Assessed

W+

Chapter 1: Introduction - The need for physiology guided structure and process design in the context of personalized nutrition (Peter Fischer)

Chapter 2: Food Oral Processing: the impact of food oral breakdown on sensory perception (Marine Devezeaux de Lavergne)

Chapter 3: Chewing and swallowing across the lifespan, from infants to elderly (Marine Devezeaux de Lavergne)

Chapter 4: Perception physiology in humans and other species (Benot von der Weid)

Chapter 5: Biophysics of food digestion & how it can be exploited in the development of strategies for delivery (Timothy J. Wooster)

Chapter 6: Numerical and experimental modelling of the intestinal system (Peter Fischer)

Lecture notes

Students are introduced to a skill set that will encompass basic digestion, sensory physiology knowledge, and food structures. Students will be exposed to the interplay along the gastrointestinal tract including taste, aroma, and texture perception, swallowing mechanics, and gastrointestinal digestion with an engineering or physical sciences angle.

The course links the physiological driven requirements with food structure design and subsequent engineering steps.

The objectives of the course are for students to understand the key drivers (market and consumer trends, health benefits, sustainability, etc.) that impact innovation in a food business environment. The course also illustrates food safety and quality considerations across the whole supply chain, using concrete examples and how certain technologies assist in reducing or eliminating food safety risks.

A sound understanding of physiological implications of food design will allow to shape new products, which feature health as well as environmental benefits and on the other side do not compromise on organoleptic qualities, formulation and manufacturing, and quality and safety. The course links the physiological driven requirements with food structure design and subsequent engineering steps.

The objectives of the course are for students to understand the key drivers (market and consumer trends, health benefits, sustainability, etc.) that impact innovation in a food business environment. The course also illustrates food safety and quality considerations across the whole supply chain, using concrete examples and how certain technologies assist in reducing or eliminating food safety risks.

The objectives of the course are for students to understand the key drivers (market and consumer trends, health benefits, sustainability, etc.) that impact innovation in a food business environment. The course also illustrates food safety and quality considerations across the whole supply chain, using concrete examples and how certain technologies assist in reducing or eliminating food safety risks.

The course gives inputs on compositional changes in food due to processing (with focus on thermal/chilling, enzymatic, chemical, separation and emerging technologies) or new formulation strategies. New approaches for evaluating these changes (e.g. nutritional profiles) and how these are communicated to consumers are also discussed.

Selected Topics in Food Technology

Methods and Technologies

Fostered

Assessed

Chapter 6: Numerical and experimental modelling of the intestinal system (Peter Fischer)

Chapter 5: Biophysics of food digestion & how it can be exploited in the development of strategies for delivery (Timothy J. Wooster)

Chapter 4: Perception physiology in humans and other species (Benot von der Weid)

Chapter 3: Chewing and swallowing across the lifespan, from infants to elderly (Marine Devezeaux de Lavergne)

Chapter 2: Food Oral Processing: the impact of food oral breakdown on sensory perception (Marine Devezeaux de Lavergne)

Chapter 1: Introduction - The need for physiology guided structure and process design in the context of personalized nutrition (Peter Fischer)

Lecture notes

There is no script. Powerpoint presentations and relevant scientific articles will be available on-line for students. A selection of recommended readings will be given at the beginning of the course.

Prerequisites / notice

The course is open to Master and MAS students in food and science and nutrition or related. Basic knowledge of food chemistry and nutrition is expected, as well as an understanding of food processing.

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This course is built on the holistic approach in sustainable food processing via the consideration of the total value chain. Selected mechanical, biotechnological, thermal and non-thermal techniques for best biomass and energy use efficiency will be investigated. Focused technologies are new thermal processes, high pressure techniques, electroporation and different radiation based sources.

Understanding of selected emerging food processing concepts with focus on lower process intensity for healthy and high quality food production, waste reduction as well as biomass and energy use efficiency. Updates from academia and industry around new trends in food process development.

Emerging combined processes based on mechanical, thermal and non-thermal techniques, Multi hurdle technology concept for preservation, Extreme high temperature-short time processes, high pressure techniques, electroporation, radiation, Biorefineries based on emerging process elements, Ongoing industry initiatives

Script will be distributed before the course via Moodle.


Robert D. Axelrod, Julia Baumgartner, Michael Beyer and Alexander Mathys.Experimental and simulation-based investigation of the interplay between factor gradients following pulsed electric field treatments triggering whey protein aggregation. Journal of Food Engineering, vol. 340, pp. 111308

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<td>assessed</td>
<td>Self-direction and Self-management</td>
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752-5105-00L Biotechnology of Alcoholic Beverage Production

This course introduces fundamental aspects of the production of beer and grape wine.

The objective of the course is to provide participating students with a sound understanding of the raw materials, microorganisms, microbial and chemical transformations and processing aspects involved in the production of beer and grape wine. Sensory aspects and product stability will also be considered.

>> Introduction of alcoholic beverage production within industrial microbiology
>> Brewing
- Raw materials, and malting
- Brewhouse processes, wort production, fermentations, lagering
- Sensory aspects and diacetyl management
>> Winemaking
- Grapegrowing and grape processing
- Crush and pressing
- Fermentations and microbial transformations
- Fining, stabilizations, filtration and bottling
- Aroma and macromolecule chemistry, climate change
- Sensory aspects and wine faults

Lecture handouts will be provided electronically. The lectures will not be recorded.

A list of learning materials will be provided online.

Students taking 752-5105-00L require a sound knowledge of basic chemistry, biochemistry, molecular genetics, microbiology and microbial physiology.

In order to decipher the costs of tastings, a financial participation of CHF25 will be required per student.
Learn to apply bioinformatics and computational methods for analysis of microbiome next-generation sequencing data. A secondary goal is to critically examine the relevance of microbiomes to food quality, safety, and human health, through application of theory and appropriate experimental design. Students completing this course will thus be able to both apply appropriate methodology to study microbiomes (or other high-dimensional data) in different systems, as well as evaluate and interpret bioinformatics results.

This course requires extensive engagement in learning outside of the classroom (using online resources and practical exercises), with a focus on active learning in the classroom.

No specific pre-requisites, but students should have some familiarity with microbiology, molecular biology, programming (Python), bioinformatics, and statistics.

All software used in the course is free and open-source.

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<tr>
<th>752-5500-00L Applied Bioinformatics: Microbiomes</th>
<th>5 credits</th>
<th>2V+2U</th>
<th>N. Bokulich, M. Ziemski</th>
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</table>

**Abstract**

Learn to apply practical bioinformatics/computational skills for analysis of microbiomes in foods and human health! Students will apply basic programming skills for scientific computing and bioinformatics, and learn and discuss the importance of microbiomes to foods and human health, through recognition and comparison of ecological theory, methodology, and experimental design across systems.

**Objective**

Learn to apply bioinformatics and computational methods for analysis of microbiome next-generation sequencing data. A secondary goal is to critically examine the relevance of microbiomes to food quality, safety, and human health, through application of theory and appropriate experimental design. Students completing this course will thus be able to both apply appropriate methodology to study microbiomes (or other high-dimensional data) in different systems, as well as evaluate and interpret bioinformatics results.

<table>
<thead>
<tr>
<th>Content</th>
<th>1. Introduction to microbiomes and microbial bioinformatics toolkit. Python, Pandas, Jupyter, GitHub, visualization libraries for Python.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3. Microbial diversity, function, and ecology. Molecular ecology, diversity metrics, ordination methods.</td>
</tr>
</tbody>
</table>

**Prerequisites / notice**

No specific pre-requisites, but students should have some familiarity with microbiology, molecular biology, programming (Python), bioinformatics, and statistics.

Students will bring and work on their own laptop computers.

---

<table>
<thead>
<tr>
<th>752-6151-00L Public Health Concepts</th>
<th>3 credits</th>
<th>2V</th>
<th>R. Heusser</th>
</tr>
</thead>
</table>

**Abstract**

The module "public health concepts" offers an introduction to key principles of public health. Students get acquainted with the concepts and methods of epidemiology. Students also learn to use epidemiological data for prevention and health promotion purposes. Public health concepts and intervention strategies are presented, using examples from infectious and chronic diseases.

**Objective**

At the end of this module students are able:
- to interpret the results of epidemiological studies
- to critically assess scientific literature
- to know the definition, dimensions and determinants of health
- to plan public health interventions and health promotion projects
- to draw a bridge from evidence to policies and politics

**Content**

- Concepts of descriptive and analytical epidemiology, study designs, measures of effect, confounding and bias, screening, surveillance, definition of health and health promotion, health dimensions and health determinants, prevention strategies, public health interventions, public health action cycle, epidemiology and prevention of infectious and chronic diseases (HIV, COVID-19, Obesity, Iodine/PH nutrition).

**Lecture notes**

Handouts are provided to students in the classroom.

---

<table>
<thead>
<tr>
<th>752-6403-00L Nutrition and Performance</th>
<th>2 credits</th>
<th>2V</th>
<th>S. Mettler</th>
</tr>
</thead>
</table>

**Abstract**

The course introduces basic concepts of the interaction between nutrition and exercise performance.

**Objective**

To understand the potential effects of nutrition on exercise performance, with a focus on concepts and principles of nutrition before, during and after exercise.

**Content**

The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise. Although this is a scientific course, it is a goal of the course to translate basic sports nutrition science into practical sports nutrition examples.

**Lecture notes**

Lecture slides and required handouts will be available on the ETH website (moodle).

**Literature**

Information on further reading will be announced during the lecture. There will be some mandatory as well as voluntary readings.

**Prerequisites / notice**

General knowledge about nutrition, human biology, physiology and biochemistry is a prerequisite for this course. The course builds on basic nutrition and biochemistry knowledge to address exercise and performance related aspects of nutrition.

The course is designed for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).

---

<table>
<thead>
<tr>
<th>752-6301-00L Nutrition-Related Physiology</th>
<th>3 credits</th>
<th>2V</th>
<th>F. von Meyenn, E. Gasser</th>
</tr>
</thead>
</table>

**Abstract**

Gives the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand.
Objective

Some basic knowledge in physiology is recommended for this course, which revisits important physiological topics, emphasizing their relation to nutrition. The aim is to give the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand. For students with a background in medicine, pharmacy or biology, the course is useful as a review of previously acquired knowledge. Major topics are basic neuroanatomy and neurophysiology; general endocrinology; the physiology of taste and smell; nutrient digestion and absorption; intermediary metabolism and energy homeostasis; and some aspects of cardiovascular physiology and water balance.

Lecture notes

Handouts for each lecture will be uploaded to Moodle every week.

Competencies

Subject-specific Competencies

Concepts and Theories

Methods and Technologies

Analytical Competencies

Problem-solving

Personal Competencies

Critical Thinking

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Problem-solving

Critical Thinking

ECTS

Subject-specific Competencies

Type

401-0625-01L

Applied Analysis of Variance and Experimental Design

W

5 credits

2V+1U

L. Meier

Abstract

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial designs and fractional designs, power.

Objective

Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by planning and analyzing efficient experiments in the fields of natural sciences.

Content

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Prerequisites / notice

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Literature


Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Problem-solving

Personal Competencies

Critical Thinking

ECTS

752-3105-00L

Physiology Guided Food Structure and Process Design

W

3 credits

2V

L. Meier

M. Devzeauxs de Lavergne, B. von der Weid, T. Wooster

Abstract

A sound understanding of physiological implications of food design will allow to shape new products, which feature health as well as environmental benefits and on the other side do not compromise on organoleptic qualities, formulation and manufacturing, and quality and safety. The course links the physiological driven requirements with food structure design and subsequent engineering steps.

Objective

The objective of this course is to highlight the link between human physiology, product sensory, nutritional functions, and engineering approaches to facilitate the design of food matrices reflecting the requirements for the aforementioned properties. To identify and manipulate these properties, the pathways that control the interaction of food structures and their physiological action will be introduced. Students are introduced to a skill set that will encompass basic digestion, sensory physiology knowledge, and food structures. Students will be exposed to the interplay along the gastrointestinal tract including taste, aroma, and texture perception, swelling mechanics, and gastrointestinal digestion with an engineering or physical sciences angle.

Content

Chapter 1: Introduction - The need for physiology guided structure and process design in the context of personalized nutrition (Peter Fischer)

Chapter 2: Food Oral Processing: the impact of food oral breakdown on sensory perception (Marine Devezeaux de Lavergne)

Chapter 3: Chewing and swallowing across the lifespan, from infants to elderly (Marine Devezeaux de Lavergne)

Chapter 4: Perception physiology in humans and other species (Benet von der Weid)

Chapter 5: Biophysics of food digestion & how it can be exploited in the development of strategies for delivery (Timothy J. Wooster)

Chapter 6: Numerical and experimental modelling of the intestinal system (Peter Fischer)

Lecture notes

Lecture notes are available at Moodle.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Project Management

Social Competencies

Communication

Personal Competencies

Creative Thinking

Critical Thinking

Integrity and Work Ethics

ECTS

401-0625-01L

Applied Analysis of Variance and Experimental Design

W

5 credits

2V+1U

L. Meier

Abstract

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial designs and fractional designs, power.

Objective

Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Content

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial designs and fractional designs, power.

Literature


Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Personal Competencies

Critical Thinking

ECTS

752-3105-00L

Physiology Guided Food Structure and Process Design

W

3 credits

2V

P. A. Fischer

Abstract

Rheology is the science of flow and deformation of matter such as polymers, dispersions (emulsions, foams, suspensions), and colloidal systems. The fluid dynamical basis, measuring techniques (rheometry), and the flow property of different fluids (Newtonian, non-Newtonian, viscoelastic) are introduced and discussed.

Objective

The course provides an introduction on the link between flow and structural properties of flowing material. Rheometrical techniques and appropriate measuring protocols for the characterization of complex fluids will be discussed. The concepts of rheological constitutive equations and the application to different material classes are established.

Content

Lectures will be given on general introduction (4h), fluid dynamics (2h), complex flow behavior (4h), influence of temperature (2h), rheometers (4h), rheological tests (6h) and structure and rheology of complex fluids (4h).

Lecture notes

Notes will be handed out during the lectures.
To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

The course covers the fundamentals of food enzymology, application of endogenous and exogenous enzymes in food processing, as well as use of enzymes in analytics.

The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.

The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

Students can argue why and how enzymes are used in food processing and analysis.

There is no script. Powerpoint presentations will be made available on-line to students.

Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

There is no script. Powerpoint presentations will be made available on-line to students.

Recommendations will be given in the first lecture

Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break!

To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic diseases, as well as the progression of complications of the chronic diseases.

The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

The course covers the fundamentals of food enzymology, application of endogenous and exogenous enzymes in food processing, as well as use of enzymes in analytics.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1533 of 2653
Creativity and Innovation
Communication
Adaptability and Flexibility
Decision-making
Problem-solving
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

752-3103-00L  Food Rheology  W+  3 credits  2V  P. A. Fischer

Abstract
Rheology is the science of flow and deformation of matter such as polymers, dispersions (emulsions, foams, suspensions), and colloidal systems. The fluid dynamical basis, measuring techniques (rheometry), and the flow properties of different fluids (Newtonian, non-Newtonian, viscoelastic) are introduced and discussed.

Objective
The course provides an introduction on the link between flow and structural properties of flowing material. Rheometrical techniques and appropriate measuring protocols for the characterization of complex fluids will be discussed. The concept of rheological constitutive equations and the application to different material classes are established.

Content
Lectures will be given on general introduction (4h), fluid dynamics (2h), complex flow behavior (4h), influence of temperature (2h), rheometers (4h), rheological tests (6h) and structure and rheology of complex fluids (4h).

Lecture notes
Notes will be handed out during the lectures.

Literature
Provided in the lecture notes.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Techniques and Technologies</th>
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<tbody>
<tr>
<td>Method-specific Competencies</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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</table>

752-2314-00L  Physics of Food Colloids  W+  3 credits  2V  P. A. Fischer, R. Mezzenga, M. Radiom

Abstract
In Physics of Food Colloids the principles of colloid science will applied to the aggregation of food materials based on proteins, polysaccharides, and emulsifiers. Mixtures of such raw material determine the appearance and performance of our daily food. In a number of examples, colloidal laws are linked to food science and the manufacturing and processing of food.

Objective
The aggregation of food material determines the appearance and performance of complex food system as well as nutritional aspects. The underlying colloidal laws reflect the structure of the individual raw material (length scale, time scale, and interacting forces). Once these concepts are appreciated the aggregation of most food systems falls into recognizable patterns that can be used to modify and structure exiting food or to design new products. The application and use of these concepts are discussed in light of common food production.

Content
Lectures include interfacial tension (4h), protein aggregation in bulk and interfaces (4h), Pickering emulsions (2h), gels (2h), aggregation of complex mixtures (4h), and the use of light scattering in investigation complex food structures (8h). Most chapters include some hand-ons examples of the gain knowledge to common food products.

Lecture notes
Notes will be handed out during the lectures.

Literature
Provided in the lecture notes.

Competencies

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</tbody>
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752-0005-00L  Colloquium in Food and Nutrition Science  W+  1 credit  2K  S. J. Sturla

Abstract
Participation in weekly seminars on a variety of topics including Food Microbiology, Food Toxicology, Food Biochemistry, Food Processing, Consumer Behavior, Food Technology, and Food Materials and Technology, and oral presentation of a selected published study in one of these areas inspired by participation in the seminars.

Objective
The objectives are to become familiar with and stimulate interest in leading-edge science related to the research topics of the Institute of Food, Nutrition and Health. Participants attend weekly seminars given by external and internal speakers, and are also required to deliver a presentation on a recent research article inspired by a topic from the semester presentations.

752-0801-00L  Food Law and Legislation  W+  1 credit  1V  K. Krell, E. Zbinden, Kaessner

Abstract
Introduction to the principles of the EU and international Organisations, Set up and Application of the Swiss Food Law.

Objective
Knowledge of the principles and the structure of the EU in general and in the area of food safety, overview of the relevant bilateral agreements CH-EU as well as on the most important international organisations.

Basic knowledge of the structure of Swiss food law and its implementation in the context of self-controll in food companies. The process of food enforcement is known and issues can be assessed from a legal perspective.
### 752-1301-00L Special Topics in Toxicology

<table>
<thead>
<tr>
<th>Objective</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>- to stimulate student interest and provide advanced knowledge of current research in Toxicology and its related sciences. - to develop skills in critical evaluation of scientific literature, oral presentation and questionining - to understand modern experimental techniques and research approaches relevant in toxicology.</td>
<td>Participants are required to have completed previously “Special Topics in Toxicology” (752-1301-00L). Both courses are run concurrently every semester. It is only possible to register for one course at a time. Do not register for “Advanced Topics in Toxicology” until after you have completed “Special Topics in Toxicology”</td>
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<tr>
<th>Content</th>
<th>Literature</th>
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<tbody>
<tr>
<td>The journal-club style course involves student presentations and active discussion of recent publications. The primary focus is on chemical, biochemical, and nutritional aspects of selected current topics in Toxicology. Participants are masters or PhD students in Food Sciences and related disciplines (i.e. Chemistry, Biochemistry, Pharmaceutical Sciences, etc.).</td>
<td>A selection of approximately 20 papers from recent primary scientific literature.</td>
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<tr>
<th>Competencies</th>
<th>Content</th>
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<tbody>
<tr>
<td>Subject-specific Competencies</td>
<td>- to explain psychological factors influencing eating behavior - to assess the cultural, the environmental and the food policy impact on consumer behavior - to summarise how consumers perceive the environmental impact and the healthiness of foods - to explain the consumer led food product development - to describe heuristics that influence consumer behavior in the food domain - to explain how consumers perceive the environmental impact and the healthiness of foods - to assess the cultural, the environmental and the food policy impact on consumer behavior - to explain psychological factors influencing eating behavior</td>
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<tr>
<td>Concepts and Theories</td>
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### 752-1302-00L Advanced Topics in Toxicology

<table>
<thead>
<tr>
<th>Objective</th>
<th>Prerequisites / notice</th>
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</thead>
<tbody>
<tr>
<td>The lecture will be held in German.</td>
<td>If you would like to take &quot;Special Topics in Toxicology&quot;, do not register at the same time for &quot;Advanced Topics in Toxicology&quot;. It is only possible to take one, and it is only possible to take the advanced level after completing this course.</td>
</tr>
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<tr>
<th>Content</th>
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<tbody>
<tr>
<td>The course is open to Masters or PhD level students.</td>
<td>For Masters level participants, a strict prerequisite is (a) previously taken and passed &quot;Introduction to Toxicology&quot; (752-1300) and/or (b) previous courses supporting equivalent knowledge plus permission from the instructor. Please contact the instructor before the start of the class, explaining the basis of your previous knowledge other than the Introduction course, to request special permission.</td>
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### 752-2003-00L Selected Topics in Food Technology

<table>
<thead>
<tr>
<th>Objective</th>
<th>Prerequisites / notice</th>
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</thead>
<tbody>
<tr>
<td>The course deals with global market trends, food technologies, food health benefits. Physical and chemical fundamental knowledge help grasp the molecular composition of food. Part 2 entails management of risks across the food supply chain. The focus is on technological solutions to mitigate hazards, as well as their management upstream.</td>
<td>The objectives of the course are for students to understand the key drivers (market and consumer trends, health benefits, sustainability, etc.) that impact innovation in a food business environment. The course also illustrates food safety and quality considerations across the whole supply chain, using concrete examples and how certain technologies assist in reducing or eliminating food safety risks.</td>
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<tr>
<td>Part 1 of the course covers current research in Toxicology and related sciences. The student should develop skills in critical evaluation of scientific literature, oral presentation and questionining, and understanding modern experimental techniques in Molecular Toxicology.</td>
<td>Part 1 of the course covers global market trends, food technologies, food health benefits. Physical and chemical fundamental knowledge help grasp the molecular composition of food. Part 2 entails management of risks across the food supply chain. The focus is on technological solutions to mitigate hazards, as well as their management upstream.</td>
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### 752-2122-00L Food and Consumer Behaviour

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<tr>
<td>This course focuses on food consumer behavior, consumer's decision-making processes and consumer's attitudes towards food products. Students will be able...</td>
<td>The objectives of the course are for students to understand the key drivers (market and consumer trends, health benefits, sustainability, etc.) that impact innovation in a food business environment. The course also illustrates food safety and quality considerations across the whole supply chain, using concrete examples and how certain technologies assist in reducing or eliminating food safety risks.</td>
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<td>The objectives of the course are for students to understand the key drivers (market and consumer trends, health benefits, sustainability, etc.) that impact innovation in a food business environment. The course also illustrates food safety and quality considerations across the whole supply chain, using concrete examples and how certain technologies assist in reducing or eliminating food safety risks.</td>
<td>Part 1 of the course covers global market trends, food technologies, food health benefits. Physical and chemical fundamental knowledge help grasp the molecular composition of food. Part 2 entails management of risks across the food supply chain. The focus is on technological solutions to mitigate hazards, as well as their management upstream.</td>
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### 752-1300-00L Introduction to Toxicology

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<th>Objective</th>
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<tr>
<td>The main objective of this course is to develop skills in critical evaluation of scientific literature, oral presentation and questionining, and understanding modern experimental techniques in Molecular Toxicology.</td>
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</table>
Emerging combined processes based on mechanical, thermal and non-thermal techniques, Multi hurdle technology concept for physiology guided food structure and process fostering.

There is no script. Powerpoint presentations and relevant scientific articles will be available on-line for students. A selection of recommended readings will be given at the beginning of the course.

Prerequisites / notice

The course is open to Master and MAS students in food and science and nutrition or related. Basic knowledge of food chemistry and nutrition is expected, as well as an understanding of food processing.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making

Personal Competencies
- Critical Thinking

Chapter 1: Introduction - The need for physiology guided structure and process design in the context of personalized nutrition (Peter Fischer)

The objective of this course is to highlight the link between human physiology, product sensory, nutritional functions, and engineering approaches to facilitate the design of food matrices reflecting the requirements for the beforementioned properties. To identify and manipulate these properties, the pathways that control the interaction of food structures and their physiological action will be introduced. Students are introduced to a skill set that will encompass basic digestion, sensory physiology knowledge, and food structures. Students will be exposed to the interplay along the gastrointestinal tract including taste, aroma, and texture perception, swallowing mechanics, and gastrointestinal digestion with an engineering or physical sciences angle.

Content

Chapter 1: Introduction - The need for physiology guided structure and process design in the context of personalized nutrition (Peter Fischer)
Chapter 2: Food Oral Processing: the impact of food oral breakdown on sensory perception (Marine Devezeaux de Lavergne)
Chapter 3: Chewing and swallowing across the lifespan, from infants to elderly (Marine Devezeaux de Lavergne)
Chapter 4: Perception physiology in humans and other species (Benoit von der Weid)
Chapter 5: Biophysics of food digestion & how it can be exploited in the development of strategies for delivery (Timothy J. Wooster)
Chapter 6: Numerical and experimental modelling of the intestinal system (Peter Fischer)

Lecture notes

Lecture notes are available at Moodle

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making

Social Competencies
- Communication

Personal Competencies
- Critical Thinking
- Integrity and Work Ethics

Chapter 1: Introduction - The need for physiology guided structure and process design in the context of personalized nutrition (Peter Fischer)

This course is built on the holistic approach in sustainable food processing via the consideration of the total value chain. Selected mechanical, biotechnological, thermal and non-thermal techniques for best biomass and energy use efficiency will be investigated. Focused technologies are new thermal processes, high pressure techniques, electroporation and different radiation based sources.

Objective

Understanding of selected emerging food processing concepts with focus on lower process intensity for healthy and high quality food production, waste reduction as well as biomass and energy use efficiency. Updates from academia and industry around new trends in food process development.

Content

Emerging combined processes based on mechanical, thermal and non-thermal techniques, Multi hurdle technology concept for preservation, Extreme high temperature-short time processes, high pressure techniques, electroporation, radiation, Biorefineries based on emerging process elements, Ongoing industry initiatives

Lecture notes

Script will be distributed before the course via Moodle.
This course introduces fundamental aspects of the production of beer and grape wine.

### Literature


Robert D. Axelrod, Julia Baumgartner, Michael Beyer and Alexander Mathys. Experimental and simulation-based investigation of the interplay between factor gradients following pulsed electric field treatments triggering whey protein aggregation. Journal of Food Engineering, vol. 340, pp. 111308

### Competencies

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### 752-5105-00L Biotechnology of Alcoholic Beverage Production

**W+ 2 credits 2V**

#### Abstract

This course introduces fundamental aspects of the production of beer and grape wine.

#### Objective

The objective of the course is to provide participating students with a sound understanding of the raw materials, microorganisms, microbial and chemical transformations and processing aspects involved in the production of beer and grape wine. Sensory aspects and product stability will also be considered.

#### Content

- **Introduction of alcoholic beverage production within industrial microbiology**
  - **Brewing**
    - Raw materials, and malting
    - Brewhouse processes, wort production, fermentations, lagering
    - Sensory aspects and diacetyl management
  - **Winemaking**
    - Grape-growing and grape processing
    - Crush and pressing
    - Fermentations and microbial transformations
    - Fining, stabilizations, filtration and bottling
    - Aroma and macromolecule chemistry, climate change
    - Sensory aspects and wine faults

#### Lecture notes

Lecture handouts will be provided electronically. The lectures will not be recorded.

#### Literature

A list of learning materials will be provided online.

#### Prerequisites / notice

Students taking 752-5105-00L require a sound knowledge of basic chemistry, biochemistry, molecular genetics, microbiology and microbial physiology.

In order to decipher the costs of tastings, a financial participation of CHF25 will be required per student.

### Competencies

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### 752-5500-00L Applied Bioinformatics: Microbiomes

**W+ 5 credits 2V+2U**

Learn to apply practical bioinformatics/computational skills for analysis of microbiomes in foods and human health! Students will apply basic programming skills for scientific computing and bioinformatics, and learn and discuss the importance of microbiomes to foods and human health, through recognition and comparison of ecological theory, methodology, and experimental design across systems.
Learn to apply bioinformatics and computational methods for analysis of microbiome next-generation sequencing data. A secondary goal is to critically examine the relevance of microbiomes to food quality, safety, and human health, through application of theory and appropriate experimental design. Students completing this course will thus be able to both apply appropriate methodology to study microbiomes (or other high-dimensional data) in different systems, as well as evaluate and interpret bioinformatics results.

1. Introduction to microbiomes and microbial bioinformatics toolkit. Python, Pandas, Jupyter, GitHub, visualization libraries for Python.
3. Microbial diversity, function, and ecology. Molecular ecology; diversity metrics, ordination methods.

This course requires extensive engagement in learning outside of the classroom (using online resources and practical exercises), with a focus on active learning in the classroom.

No specific pre-requisites, but students should have some familiarity with microbiology, molecular biology, programming (Python), bioinformatics, and statistics.

Students will bring and work on their own laptop computers.

All software used in the course is free and open-source.

752-6151-00L Public Health Concepts

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<td>The module &quot;public health concepts&quot; offers an introduction to key principles of public health. Students get acquainted with the concepts and methods of epidemiology. Students also learn to use epidemiological data for prevention and health promotion purposes. Public health concepts and intervention strategies are presented, using examples from infectious and chronic diseases.</td>
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<td>At the end of this module students are able:</td>
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<td>- to interpret the results of epidemiological studies</td>
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<td>- to critically assess scientific literature</td>
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<td>- to know the definition, dimensions and determinants of health</td>
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<td>- to plan public health interventions and health promotion projects</td>
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<td>- to draw a bridge from evidence to policies and politics</td>
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<td>Concepts of descriptive and analytical epidemiology, study designs, measures of effect, confounding and bias, screening, surveillance, definition of health and health promotion, health dimensions and health determinants, prevention strategies, public health interventions, public health action cycle, epidemiology and prevention of infectious and chronic diseases (HIV, COVID-19, Obesity, iodine/PK nutrition).</td>
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752-6403-00L Nutrition and Performance

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<td>The course introduces basic concepts of the interaction between nutrition and exercise performance.</td>
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<td>To understand the potential effects of nutrition on exercise performance, with a focus on concepts and principles of nutrition before, during and after exercise.</td>
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<td>The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise. Although this is a scientific course, it is a goal of the course to translate basic sports nutrition science into practical sports nutrition examples.</td>
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<td>Lecture notes</td>
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<td>Lecture slides and required handouts will be available on the ETH website (moodle).</td>
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<td>Information on further reading will be announced during the lecture. There will be some mandatory as well as voluntary readings.</td>
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<td>General knowledge about nutrition, human biology, physiology and biochemistry is a prerequisite for this course. The course builds on basic nutrition and biochemistry knowledge to address exercise and performance related aspects of nutrition.</td>
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<td>The course is designed for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).</td>
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752-6301-00L Nutrition-Related Physiology

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<td>Gives the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand.</td>
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<td>Some basic knowledge in physiology is recommended for this course, which revisits important physiological topics, emphasizing their relation to nutrition. The aim is to give the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand. For students with a background in medicine, pharmacy or biology, the course is useful as a review of previously acquired knowledge. Major topics are basic neuroanatomy and neurophysiology; general endocrinology; the physiology of taste and smell; nutrient digestion and absorption; intermediary metabolism and energy homeostasis; and some aspects of cardiovascular physiology and water balance.</td>
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<td></td>
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<td>Lecture notes</td>
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<td>Handouts for each lecture will be uploaded to Moodle every week.</td>
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### Minors

#### Statistical Methods in Food Science and Nutrition

<table>
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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>401-0649-00L</td>
<td>Applied Statistical Regression</td>
<td>W</td>
<td>5</td>
<td>2V+1U</td>
<td>M. Dettling</td>
</tr>
</tbody>
</table>

**Abstract**
The course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

**Objective**
The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

**Content**
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

**Lecture notes**
A script will be available.

**Literature**
- Faraway (2005): Linear Models with R
- Draper & Smith (1998): Applied Regression Analysis
- Fox (2008): Applied Regression Analysis and GLMs
- Montgomery et al. (2006): Introduction to Linear Regression Analysis

**Prerequisites / notice**
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed
  - Project Management: fostered

- **Social Competencies**
  - Communication: assessed
  - Cooperation and Teamwork: fostered
  - Customer Orientation: fostered
  - Leadership and Responsibility: fostered
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered
  - Negotiation: fostered

- **Personal Competencies**
  - Adaptability and Flexibility: assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

---

#### Applied Analysis of Variance and Experimental Design

**Number** 401-0625-01L

**Title** Applied Analysis of Variance and Experimental Design

**Abstract**
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

**Objective**
Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

**Content**
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

**Literature**

**Prerequisites / notice**
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed

- **Personal Competencies**
  - Critical Thinking: assessed

---

#### Applied Bioinformatics: Microbiomes

**Number** 752-5500-00L

**Title** Applied Bioinformatics: Microbiomes

**Abstract**
Learn to apply practical bioinformatics/computational skills for analysis of microbiomes in foods and human health! Students will apply basic programming skills for scientific computing and bioinformatics, and learn and discuss the importance of microbiomes to foods and human health, through recognition and comparison of ecological theory, methodology, and experimental design across systems.

**Objective**
Learn to apply bioinformatics and computational methods for analysis of microbiome next-generation sequencing data. A secondary goal is to critically examine the relevance of microbiomes to food quality, safety, and human health, through application of theory and appropriate experimental design. Students completing this course will thus be able to both apply appropriate methodology to study microbiomes (or other high-dimensional data) in different systems, as well as evaluate and interpret bioinformatics results.
Content

1. Introduction to microbiomes and microbial bioinformatics toolkit. Python, Pandas, Jupyter, GitHub, visualization libraries for Python.
3. Microbial diversity, function, and ecology. Molecular ecology, diversity metrics, ordination methods.

This course requires extensive engagement in learning outside of the classroom (using online resources and practical exercises), with a focus on active learning in the classroom.

Prerequisites / notice

No specific pre-requisites, but students should have some familiarity with microbiology, molecular biology, programming (Python), bioinformatics, and statistics.

Students will bring and work on their own laptop computers.

All software used in the course is free and open-source.

Competencies

Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies

- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management fostered

Social Competencies

- Communication assessed
- Cooperation and Teamwork fostered

Personal Competencies

- Critical Thinking fostered
- Creative Thinking assessed
- Self-direction and Self-management fostered

ECTS: 4 credits

Objective

After this course students:

- can perform the data analysis using the statistical software R
- got introduced to Generalised Additive Models
- got introduced to Linear Mixed-Effects Models
- are able to select among these methods to solve an applied problem in Biostatistics
- can interpret the results of such an analysis and draw valid "biological" conclusions

Content

This course is structured into three parts. The first part focuses on Linear and Generalised Linear Models. The second part introduces more advanced methodologies such as Linear Mixed-Effects Models and Generalised Additive Models. Both, part one and two will include the following topics: exploratory data analysis, model fitting, model "selection", residual diagnostics, model validation and results interpretation. Analyses will be carried out using the statistical software R. Finally, in the third part of the course students will be analysing real-world datasets to put into practice the knowledge and skills acquired during the first two parts.

Prerequisites / notice

The statistical software R will be used in the exercises. If you are unfamiliar with R, it is highly recommend to view the online R course "etutoR".

►►► Consumer and Sensory Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>752-5105-00L</td>
<td>Biotechnology of Alcoholic Beverage Production</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>R. Mira de Orduna Heidinger, N. Bokulich, M. Rienth</td>
</tr>
</tbody>
</table>

Abstract

This course introduces fundamental aspects of the production of beer and grape wine.

Objective

The objective of the course is to provide participating students with a sound understanding of the raw materials, microorganisms, microbial and chemical transformations and processing aspects involved in the production of beer and grape wine. Sensory aspects and product stability will also be considered.

Content

- Introduction of alcoholic beverage production within industrial microbiology
- Brewing
  - Raw materials, and malting
  - Brewhouse processes, wort production, fermentations, lagering
  - Sensory aspects and diacetyl management
- Winemaking
  - Grapegrowing and grape processing
  - Crush and pressing
  - Fermentations and microbial transformations
  - Fining, stabilizations, filtration and bottling
  - Aroma and macromolecule chemistry, climate change
  - Sensory aspects and wine faults

Lecture notes

Lecture handouts will be provided electronically. The lectures will not be recorded.

Prerequisites / notice

Students taking 752-5105-00L require a sound knowledge of basic chemistry, biochemistry, molecular genetics, microbiology and microbial physiology.

In order to decipher the costs of tastings, a financial participation of CHF25 will be required per student.

Competencies

Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies

- Analytical Competencies assessed

Social Competencies

- Communication assessed

Personal Competencies

- Critical Thinking assessed

ECTS: 5 credits
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.


The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making

Personal Competencies
- Critical Thinking

Agri-Food Chain

Biotechnology of Alcoholic Beverage Production

This course introduces fundamental aspects of the production of beer and grape wine.

The objective of the course is to provide participating students with a sound understanding of the raw materials, microorganisms, microbial and chemical transformations and processing aspects involved in the production of beer and grape wine. Sensory aspects and product stability will also be considered.

In order to decipher the costs of tastings, a financial participation of CHF25 will be required per student.

Student Competencies
- Sensory aspects and wine faults
- Aroma and macromolecule chemistry, climate change
- Alcohol and fermentation processes
- Brewhouse processes, wort production, fermentations, lagering
- Sensory aspects and diacetyl management
- Brewing
- Raw materials, and malting
- Brewhouse processes, wort production, fermentations, lagering

Method-specific Competencies
- Analytical Competencies
- Decision-making

Personal Competencies
- Critical Thinking

Food Safety

Special Topics in Toxicology

Journal-club style course involving student presentations and active discussion and critique of recent publications and modern experimental strategies. The focus is on chemical, biochemical, and nutritional aspects of selected topics in Toxicology, with a new group of topics addressed each semester.

- to stimulate student interest and provide advanced knowledge of current research in Toxicology and its related sciences
- to develop skills in critical evaluation of scientific literature, oral presentation and questioning
- to understand modern experimental techniques and research approaches relevant in toxicology

Lecturers
- S. J. Sturla
- K. Hecht
- N. Bokulich, M. Rienth

Lecturers
- G. Oehlert
- R. Mira de Orduna Heidinger
- K. Hecht
- S. J. Sturla

Notice
- Students taking 752-5105-00L require a sound knowledge of basic chemistry, biochemistry, molecular genetics, microbiology and microbial physiology.

No further information provided for the Food Safety course.
The journal-club style course involves student presentations and active discussion of recent publications. The primary focus is on chemical, biochemical, and nutritional aspects of selected current topics in Toxicology. Participants are masters or PhD students in Food Sciences and related disciplines (i.e. Chemistry, Biochemistry, Pharmaceutical Sciences, etc.).

A selection of approximately 20 papers from recent primary scientific literature.

The course is open to Masters or PhD level students.

For Masters level participants, a strict prerequisite is (a) previously taken and passed “Introduction to Toxicology” (752-1300-00L) and/or (b) previous courses supporting equivalent knowledge plus permission from the instructor. Please contact the instructor before the start of the class, explaining the basis of your previous knowledge other than the Introduction course, to request special permission.

If you would like to take "Special Topics in Toxicology", do not register at the same time for “Advanced Topics in Toxicology”. It is only possible to take one, and it is only possible to take the advanced level after completing this course.

**752-1302-00L Advanced Topics in Toxicology**

<table>
<thead>
<tr>
<th>W</th>
<th>2 credits</th>
<th>G</th>
<th>S. J. Sturla</th>
</tr>
</thead>
</table>

**Abstract**

Journal-club style course that involves student presentations of selected topics in Toxicology on the basis of current primary research and review papers.

**Objective**

The goals are to stimulate student interest and provide advanced knowledge of current research in the interdisciplinary area of Food and Nutrition Toxicology and its related sciences. The student should develop skills in the critical evaluation of scientific literature, oral presentation and questioning, and understanding modern experimental techniques in Molecular Toxicology.

**Content**

The journal-club style course involves student presentations of recent publications. The primary focus is on chemical and biochemical aspects of selected topics in Toxicology. Participants are generally masters or PhD students in Food Sciences and related disciplines (i.e. Chemistry, Pharmaceutical Sciences, etc.), and strong knowledge of organic chemistry and biochemistry are prerequisite. Selected course topics change every semester.

**Prerequisites / notice**

Participants are required to have completed previously “Special Topics in Toxicology” (752-1301-00L). Both courses are run concurrently every semester. It is only possible to register for one course at a time. Do not register for “Advanced Topics in Toxicology” until after you have completed “Special Topics in Toxicology”

**736-1353-00L Nanostructured Materials Safety**

| 2 credits | 1V | P. Wick, T. Bülbki-Thurnherr |

**Abstract**

Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection

**Objective**

Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials

**Content**

Building upon new technologies to engineer and functionalize well-defined nanostructured materials, a plethora of exciting discoveries were made and found their way in our daily live. These customized nanomaterials provides extraordinary properties and make them attractive for many innovative applications. Exactly these new properties may have the potential to be responsible for unforeseen side effects, which hamper a straightforward translation into new products. Therefore, the safety research provide the evidence for a responsible and sustainable use of nanomaterials.

The lecture will focus on basic principles of nanotoxicology, provide the understanding of the potential side effects of nanomaterial in a context-specific way addressing the main exposure routes such as inhalation, ingestion, topical applications and intravenous injections as well as it will provide impulses for safer material designs.

**Structure of the planned lecture (2 x 45 min)**

1. Introduction; the principles of nanotoxicology
2. Lung- particles interactions: two disease scenarios and their molecular mechanism
3. GI – particles interactions: intendent and unintendent particle exposure via food
4. Skin – particles interactions: body care products and their influence on skin physiology
5. Intravenous injection: colloidal stability, protein corona and cellular effects
6. Micro-/ Nanoplastics and development of a safety research plan
7. End of semester exam

**Lecture notes**

Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website

**Prerequisites / notice**

course “Introduction to Toxicology”

**Competencies**

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

Social Competencies

- Communication
- Cooperation and Teamwork

**End of semester exam**

- Micro-/ Nanoplastics and development of a safety research plan
- End of semester exam

| 2 credits | 1V |

**Major-related Minors**

- Minor Human Nutrition
- Minor Food Processing

**Electives**

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers** |
---|---|---|---|---|---|
752-0005-00L | Colloquium in Food and Nutrition Science | | 1 credit | 2K | S. J. Sturla |

**Abstract**

Participation in weekly seminars on a variety of topics including Food Microbiology, Food Toxicology, Food Biochemistry, Food Processing, Consumer Behavior, Food Technology, and Food Materials and Technology, and oral presentation of a selected published study in one of these areas inspired by participation in the seminars.

**Objective**

The objectives are to become familiar with and stimulate interest in leading-edge science related to the research topics of the Institute of Food, Nutrition and Health. Participants attend weekly seminars given by external and internal speakers, and are also required to deliver a presentation on a recent research article inspired by a topic from the semester presentations.

751-2105-00L | Political Ecology of Food and Agriculture | | 3 credits | 2G | J. Jacobi |

A motivational application is required:
- presenting yourself and your studies
- stating what topic in the field of Political Ecology that you are interested in
Questions regarding the application to johanna.jacob@usys.ethz.ch.

Abstract
In this seminar, students are introduced to the multi-disciplinary field of political ecology to investigate human-environment relationships in food and agricultural systems.

Objective
- Being able to provide an overview of the multi-disciplinary field of political ecology for investigating the relationships of humans to our environment
- Learn to identify how power and interest influence social-ecological systems and to distinguish symptoms from systemic root causes
- Become enabled to analyse complex and sometimes distant human-environment relationships choosing from a broad range of methods

Content
We will review common narratives in agri-food systems informed by a range of different theories and assisted by different analytical tools. For this purpose, we will start from different concepts of nature, power and interests, explore different ontologies and epistemologies through a set of topics such as hunger, obesity, agrobiodiversity and seeds, forests and deforestation, climate change and food production. Students will explain one concept in each course to the groups and practice their argumentative and writing skills in a final essay, applying the acquired tools to a topic of their choice. While specific inputs from external lecturers broaden our perspective, enough time for critical discussion and reflection will be granted.

Lecture notes
20.9.2024 Introduction to political ecology
27.9.2024 Ontologies and epistemologies
4.10.2024 Green revolution, industrial agriculture, and agroecology
11.10.2024 Don't blame the rain: Water management in agriculture
18.10.2024 Climate justice and food systems
25.10.2024 Conservation: Protecting what from what?
1.11.2024 Deforestation: Root causes and alternatives
8.11.2024 Pandemics, syndemics and the food system
15.11.2024 Technology and the politics of knowledge
22.1.2024 Land-sharing, land-sparing
29.11.2024 Feminist (political) agroecology
6.12.2024 Food: Commons or commodity?
13.12.2024 Alternatives to sustainable development
20.12.2024 Final session (The Hunger Banquet)

Literature
Literaturelist provided on Moodle when the course starts.

https://moodle-app2.let.ethz.ch/course/view.php?id=20544

Competencies

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<tr>
<td>Subject-specific Competencies</td>
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<td>Problem-solving</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Critical Thinking</td>
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<td>Self-direction and Self-management</td>
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Science in Perspective

Recommended Science in Perspective (Type B) for D-HEST

see Science in Perspective: Type A: Enhancement of Reflection Capability

see Science in Perspective: Language Courses ETH/UZH

Master’s Thesis

<table>
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<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>752-0231-00L</td>
<td>Master’s Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Only students fulfilling the following criteria can start with their master thesis:

a. successful completion of the bachelor programme,
b. fulfillment of any additional requirements necessary to gain admission to the master programme, and
c. Acquisition of at least 40 CPs in the master programme.

The topic of the thesis and - if they are not Professors of D-HEST or D-USYS, Agricultural Sciences - the examiner and the co-examiner have to be approved by the D-HEST Department Conference.

Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

<table>
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<tr>
<th>Number</th>
<th>Title</th>
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<tr>
<td>752-1000-AAL</td>
<td>Food Chemistry I</td>
<td>E-</td>
<td>3 credits</td>
<td>6R</td>
<td>L. Nyström</td>
</tr>
</tbody>
</table>
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

### Abstract
To familiarise with the structure, properties and reactivity of food constituents. To understand the relationship between the multiple chemical reactions and the quality of food.

### Objective
To familiarise with the structure, properties and reactivity of food constituents. To understand the relationship between the multiple chemical reactions and the quality of food.

### Content
Descriptive chemistry of food constituents (proteins, lipids, carbohydrates, plant phenolics, flavour compounds). Reactions which affect the colour, flavour, texture, and the nutritional value of food raw materials and food products during processing, storage and preparation in a positive or in a negative way (e.g. lipid oxidation, Maillard reaction, enzymatic browning).

Links to food analysis, food processing, and nutrition.

### Literature
The lectures are supplemented with handouts.

### Literature

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>E</th>
<th>R</th>
<th>Authors</th>
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<tr>
<td>752-1101-AAL</td>
<td>Food Analysis I</td>
<td>3 credits</td>
<td>E-</td>
<td>6R</td>
<td>L. Nyström</td>
</tr>
<tr>
<td>752-3000-AAL</td>
<td>Food Process Engineering I</td>
<td>4 credits</td>
<td>E-</td>
<td>9R</td>
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<tr>
<td>752-6001-AAL</td>
<td>Introduction to Nutritional Science</td>
<td>3 credits</td>
<td>E-</td>
<td>6R</td>
<td>F. von Meyenn</td>
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<tr>
<td>551-0001-AAL</td>
<td>General Biology I</td>
<td>3 credits</td>
<td>E-</td>
<td>6R</td>
<td>U. Sauer, O. Y. Martin, A. Widmer</td>
</tr>
</tbody>
</table>

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

### Abstract
To understand the basic principles of analytical chemistry. To get acquainted with the principles and applications of important routine methods of instrumental food analysis (UV/VIS, IR, AAS, GC, HPLC).

### Objective
To understand the basic principles of analytical chemistry. To get acquainted with the principles and applications of important routine methods of instrumental food analysis (UV/VIS, IR, AAS, GC, HPLC).

### Content

Methods: Optical spectroscopy (basic principles, UV/VIS, IR, and atomic absorption spectroscopy). Chromatography (GC, HPLC).

### Literature
The lectures are supplemented with handouts.

### Literature

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>E</th>
<th>R</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-1101-AAL</td>
<td>Food Analysis I</td>
<td>3 credits</td>
<td>E</td>
<td>6R</td>
<td>L. Nyström</td>
</tr>
<tr>
<td>752-3000-AAL</td>
<td>Food Process Engineering I</td>
<td>4 credits</td>
<td>E</td>
<td>9R</td>
<td>P. A. Fischer</td>
</tr>
<tr>
<td>752-6001-AAL</td>
<td>Introduction to Nutritional Science</td>
<td>3 credits</td>
<td>E</td>
<td>6R</td>
<td>F. von Meyenn</td>
</tr>
<tr>
<td>551-0001-AAL</td>
<td>General Biology I</td>
<td>3 credits</td>
<td>E</td>
<td>6R</td>
<td>U. Sauer, O. Y. Martin, A. Widmer</td>
</tr>
</tbody>
</table>

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

### Abstract
To procure students with the basic physics of food process engineering, especially with the mechanical futures of food systems, i.e. basic principles of engineering mechanics, of thermodynamics, fluid dynamics and of dimension analyses for process design and Non-Newtonian fluid mechanics.

### Objective

### Content

### Literature
P. Grassmann: Einführung in die thermische Verfahrenstechnik, de Gruyter Berlin, 1997

### Competencies

<table>
<thead>
<tr>
<th>Course Code</th>
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<th>R</th>
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</tr>
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<td>E</td>
<td>6R</td>
<td>U. Sauer, O. Y. Martin, A. Widmer</td>
</tr>
</tbody>
</table>

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

### Abstract
This course introduces basic concepts of micro- and macronutrient nutrition. Macronutrients studied include fat-soluble and water-soluble vitamins, minerals and trace elements. Macronutrients include proteins, fat and carbohydrates. Special attention is given to nutrient digestion, bioavailability, metabolism and excretion with some focus on energy metabolism.

### Objective
To introduce the students to the both macro- and micronutrients in relation to food and metabolism.

### Content
This is a self-study course. The course is divided into two parts: micronutrients and macronutrients. The micronutrients include fat-soluble vitamins, water-soluble vitamins, minerals and trace elements. The part on macronutrients introduces basic nutritional aspects of proteins, fats, carbohydrates and energy metabolism.

### Lecture notes
A reading list will be provided to the students detailing chapters and lecture slides to be studied.

### Literature

### Competencies
Subject-specific Competencies: Concepts and Theories fostered.

<table>
<thead>
<tr>
<th>Course Code</th>
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<th>Credits</th>
<th>E</th>
<th>R</th>
<th>Authors</th>
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<td>E</td>
<td>6R</td>
<td>U. Sauer, O. Y. Martin, A. Widmer</td>
</tr>
</tbody>
</table>
Objective
The understanding of basic principles of biology (inheritance, evolution and phylogeny) and an overview of the diversity of life.

Content
The first semester focuses on the organismal biology aspects of genetics, evolution and diversity of life in the Campbell chapters 12-34.

Week 1-7 by Alex Widmer, Chapters 12-25
12 Cell biology Mitosis
13 Genetics Sexual life cycles and meiosis
14 Genetics Mendelian genetics
15 Genetics Linkage and chromosomes
20 Genetics Evolution of genomes
21 Evolution How evolution works
22 Evolution Phylogenetic reconstructions
23 Evolution Microevolution
24 Evolution Species and speciation
25 Evolution Macroevolution

Week 8-14 by Oliver Martin, Chapters 26-34
26 Diversity of Life Introduction to viruses
27 Diversity of Life Prokaryotes
28 Diversity of Life Origin & evolution of eukaryotes
29 Diversity of Life Nonvascular&seedless vascular plants
30 Diversity of Life Seed plants
31 Diversity of Life Introduction to fungi
32 Diversity of Life Overview of animal diversity
33 Diversity of Life Introduction to invertebrates
34 Diversity of Life Origin & evolution of vertebrates

Lecture notes
No script

Literature

Prerequisites / notice
This is a virtual self-study lecture for non-german speakers of the "Allgemeine Biology I (551-0001-00L) lecture. The exam will be written jointly with the participants of this lecture.

Example exam questions will be discussed during the lectures, and old exam questions are kept by the various student organisations. If necessary, please contact Prof. Uwe Sauer (sauer@ethz.ch) for details regarding the exam.

406-0063-AAL
Physics II
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to the "way of thinking" and the methodology in Physics. The Chapters treated are Magnetism, Refraction and Diffraction of Waves, Elements of Quantum Mechanics with applications to Spectroscopy, Thermodynamics, Phase Transitions, Transport Phenomena.

Objective
Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve the latter.

The student should acquire an overview over the basic concepts used in the theory of heat and electricity.

Content
Book:

Chapters:

Literature
see "Content"

Friedhelm Kuypers
Physik für Ingenieure und Naturwissenschaftler
Band 2 Elektrizität, Optik, Wellen
Verlag Wiley-VCH, 2003
4th edition 2022

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered
Method-specific Competencies
Analytical Competencies fostered
Problem-solving assessed
Self-direction and Self-management fostered

406-0603-AAL
Stochastics (Probability and Statistics)
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

Objective
The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

E- 4 credits

M. Kalisch
Abstract
Self-study course in microbiology.

Objective
Teaching of basic knowledge in microbiology.

Content
This is a self-study course for students with microbiology as an admission requirement. The goal of the course is that students acquire basics in microbiology, including bacterial cell biology, genetics, growth and physiology, metabolism, phylogeny and microbial diversity, and applications of microbiology.

Literature
This self-study course is based on the book 'Brock, Biology of Microorganisms'.

Abstract
The objective of the systems analysis course is to deepen and illustrate the mathematical concepts on the basis of a series of very concrete examples. Topics covered include: linear box models with one or several variables, time-discrete models, and continuous models in time and space.

Objective
Learning and applying of concepts (models) and quantitative methods to address concrete problems of environmental relevance. Understanding and applying the systems-analytic approach, i.e., Recognizing the core of the problem - simplification - quantitative approach - prediction.

Content
Introduction to principles of models; one-dimensional linear box models; multi-dimensional linear box models; nonlinear box models; models in space and time

Lecture notes
Teaching material: book (see literature).

Literature


Abstract
This lecture is the first part of a one-year course. It offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts and molds present in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.

Objective
The lecture offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts, molds and protozoa in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.

The focus of this first part of the two part lecture (Food Micro II is offered in the FS) will be on the organisms, but also on the factors which determine spoilage and foodborne disease.
Content
1. History of Food Microbiology
   1.1. Short synopsis of foodborne microorganisms
   1.2. Spoilage of Foods
   1.3. Foodborne Disease
   1.4. Food Preservation
   1.5. VIP's of Food Microbiology
2. Overview of Microorganisms in Foods
   2.1. Intrinsic and Extrinsic Parameters
   2.2. Bacteria
   2.3. Yeasts
   2.4. Molds
   3. Microbial Spoilage of Foods
      3.1. Meats, Seafoods, Eggs
      3.2. Milk and Milk Products
      3.3. Vegetable and Fruit Products
      3.4. Miscellaneous (baked goods, nuts, spices, ready-to-eat products)
   3.5. Drinks and Canned Foods
   4. Foodborne Disease
      4.1. Significance and Transmission of Foodborne pathogens
      4.2. Staphylococcus aureus
      4.3. Gram-positive Sporeformers (Bacillus & Clostridium)
      4.4. Listeria monocytogenes
      4.5. Salmonella, Shigella, Escherichia coli
      4.6. Vibrio, Yersinia, Campylobacter
      4.7. Brucella, Mycobacterium
      4.8. Parasites
      4.9. Viruses and Bacteriophages
      4.10. Mycotoxins
      4.11. Bioactive Amines
      4.12. Miscellaneous (Antibiotic-resistant Bacteria, Biofilms)

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download.

Competencies
<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td></td>
<td>Concepts and Theories assessed</td>
<td>Techniques and Technologies assessed</td>
<td>Communication fostered</td>
<td>Creative Thinking fostered</td>
</tr>
<tr>
<td></td>
<td>Analytical Competencies fostered</td>
<td>Decision-making fostered</td>
<td>Problem-solving assessed</td>
<td>Critical Thinking fostered</td>
</tr>
</tbody>
</table>

551-0003-AAL General Biology I+II Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
General Biology I: Organismic biology to teach the basic principles of classical and molecular genetics, evolutionary biology and phylogeny.

General Biology II: Molecular biology approach to teach the basic principles of biochemistry, cell biology, cgenetics, evolutionary biology and form and function of vascular plants.

Objective
General Biology I: The understanding of basic principles of biology (inheritance, evolution and phylogeny) and an overview of the diversity of life.

General Biology II: The understanding basic concepts of biology: the hierarchy of the structural levels of biological organisation, with particular emphasis on the cell and its molecular functions, the fundamentals of metabolism and molecular genetics, as well as form and function of vascular plants.
General Biology I:
General Biology I focuses on the organismal biology aspects of genetics, evolution and diversity of life in the Campbell chapters 12-34.

Week 1-7 by Alex Widmer, Chapters 12-25
12 Cell biology Mitosis
13 Genetics Sexual life cycles and meiosis
14 Genetics Mendelian genetics
15 Genetics Linkage and chromosomes
20 Genetics Evolution of genomes
21 Evolution How evolution works
22 Evolution Phylogenetic reconstructions
23 Evolution Microevolution
24 Evolution Species and speciation
25 Evolution Macroevolution

Week 8-14 by Oliver Martin, Chapters 26-34
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28 Diversity of Life Origin & evolution of eukaryotes
29 Diversity of Life Nonvascular&seedless vascular plants
30 Diversity of Life Seed plants
31 Diversity of Life Introduction to fungi
32 Diversity of Life Overview of animal diversity
33 Diversity of Life Introduction to invertebrates
34 Diversity of Life Origin & evolution of vertebrates

General Biology II: The structure and function of biomacromolecules; basics of metabolism; tour of the cell; membrane structure and function; basic energetics of cellular processes; respiration, photosynthesis; cell cycle, from gene to protein; structure and growth of vascular plants, resource acquisition and transport, soil and plant nutrition.

Specifically the following Campbell chapters will be covered:
3 Biochemistry Chemistry of water
4 Biochemistry Carbon: the basis of molecular diversity
5 Biochemistry Biological macromolecules and lipids
7 Cell biology Cell structure and function
8 Cell biology Cell membranes
10 Cell biology Respirion: introduction to metabolism
10 Cell biology Cell respiration
11 Cell biology Photosynthetic processes
16 Genetics Nucleic acids and inheritance
17 Genetics Expression of genes
18 Genetics Control of gene expression
19 Genetics DNA Technology
35 Plant structure&function Plant Structure and Growth
36 Plant structure&function Transport in vascular plants
37 Plant structure&function Plant nutrition
38 Plant structure&function Reproduction of flowering plants
39 Plant structure&function Plants signal and behavior

Abstract
Basic knowledge of enzymology, in particular the structure, kinetics and chemistry of enzyme-catalysed reaction in vitro and in vivo. Biochemistry of metabolism: Those completing the course are able to describe and understand fundamental cellular metabolic processes.

Objective
Based on the biology and chemistry courses in the 1. and 2. semester more detailed biochemical knowledge about enzymology, membrane biochemistry, and central metabolism will be presented.

Content
Introduction, basics, composition of cells, biochemical units, repetition of relevant organic chemistry
Structure and function of proteins
Lipids an biological membranes
Enzymes and enzyme kinetics
Catalytic strategies
Metabolism: Basic concepts and design. Repetition of basic thermodynamics
Glycolysis
The citric acid cycle
Oxidative phosphorylation

Lecture notes
by Laurence A. Moran (Author), Robert A Horton (Author), Gray Scrimgeour (Author), Marc Perry (Author)

Literature
by Laurence A. Moran (Author), Robert A Horton (Author), Gray Scrimgeour (Author), Marc Perry (Author)

Prerequisites / notice
Basic knowledge in biology and chemistry is a precondition.
Consumer Behaviour I

Abstract
Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior.

Objective
Students will be able to,
- explain the decision-making processes underlying the purchasing process
- describe the factors that have an influence on consumer behavior
- develop strategies to influence purchasing behavior

Competencies

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<th>Competencies</th>
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<th>Concepts and Theories</th>
<th>assessed</th>
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<td>Social Competencies</td>
<td>Customer Orientation</td>
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<td>Personal Competencies</td>
<td>Sensitivity to Diversity</td>
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Food Science and Nutrition Master - Key for Type

<table>
<thead>
<tr>
<th>Key for Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Key for Hours

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<tr>
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<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### 3. Semester

#### Basic Courses II

#### Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>402-0063-00L</td>
<td>Physics II</td>
<td>O</td>
<td>5 credits</td>
<td>3V+1U</td>
<td>A. Vaterlaus</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Introduction to the way physicists think and work with the help of concept questions, demonstration experiments and problem solving. Wherever possible, applications from thermodynamics, electricity and magnetism are taught from the areas of the degree programmes.</td>
<td></td>
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<tr>
<td><strong>Objective</strong></td>
<td>Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve them.</td>
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</tr>
<tr>
<td><strong>Content</strong></td>
<td>Thermodynamics with first and second law, phase transformations, transport phenomena. Introduction to electricity and magnetism, as well as waves and modern physics.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>A script will be distributed</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
| **Literature** | Friedhelm Kuypers  
Physik für Ingenieure und Naturwissenschaftler  
Band 2 Elektrizität, Optik, Wellen  
Wiley-VCH, 2012  
ISBN 3527411445, 9783527411443  
(4. Auflage 2022) |
| **Competencies** | Subject-specific Competencies: Concepts and Theories assessed  
Techniques and Technologies assessed  
Method-specific Competencies: Analytical Competencies fostered  
Decision-making fostered  
Problem-solving assessed  
Social Competencies: Communication fostered  
Personal Competencies: Self-direction and Self-management fostered |

| 701-0071-00L | Mathematics III: Systems Analysis | O    | 4 credits | 2V+1U | C. Brunner, R. Knutti, H. Wernli |
| **Abstract** | The objective of the systems analysis course is to deepen and illustrate the mathematical concepts on the basis of a series of very concrete examples. Topics covered include: linear box models with one or several variables, non-linear box models with one or several variables, time-discrete models, and continuous models in time and space. |
| **Objective** | Learning and applying of concepts (models) and quantitative methods to address concrete problems of environmental relevance.  
Understanding and applying the systems-analytic approach, i.e., Recognizing the core of the problem - simplification - quantitative approach - prediction. |
| **Content** |  
https://iac.ethz.ch/edu/courses/bachelor/vorbereitung/systemanalyse.html |
| **Lecture notes** | Overhead slides will be made available through the course website. |
| **Competencies** | Subject-specific Competencies: Concepts and Theories assessed  
Techniques and Technologies assessed  
Method-specific Competencies: Analytical Competencies assessed  
Problem-solving assessed  
Social Competencies: Communication fostered  
Personal Competencies: Creative Thinking fostered |

| 752-4001-00L | Microbiology | O    | 2 credits | 2V  | M. Schuppler, M. La Fortezza, M. Pilhofer, S. Robinson |
| **Abstract** | Some parts of the lecture will be taught in English.  
Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.  |
| **Objective** | Teaching of basic knowledge in microbiology.  |
| **Content** | Der Schwerpunkt liegt auf den Themen: Bakterielle Zellbiologie, Molekulare Genetik, Wachstumsphysiologie, Biochemische Diversität, Phylogenie und Taxonomie, Prokaryotische Vielfalt, Interaktion zwischen Menschen und Mikroorganismen sowie Biotechnologie.  |
| **Lecture notes** | Wird von den jeweiligen Dozenten ausgegeben.  |
| **Literature** | Die Behandlung der Themen erfolgt auf der Basis des Lehrbuchs Brock, Biology of Microorganisms |
| **Competencies** | Subject-specific Competencies: Concepts and Theories assessed  
Techniques and Technologies assessed |

| 752-0100-00L | Biochemistry | O    | 2 credits | 2V  | C. Frei |
| **Abstract** | Basic knowledge of enzymology, in particular the structure, kinetics and chemistry of enzyme-catalysed reaction in vitro and in vivo. Biochemistry of metabolism: Those completing the course are able to describe and understand fundamental cellular metabolic processes.  
Students are able to describe the structure of proteins/enzymes and are able to explain biochemical functions depending on their 3D structures.  
Students are able to assess and propose hypothesis how proteins change during evolution.  
Connections between several metabolic pathways are known and students can evaluate how one pathway is influence by the activity of another pathway |
| **Objective** | |

Data: 15.06.2024 12:39  
Autumn Semester 2024  
Page 1550 of 2653
Introduction, basics, composition of cells, biochemical units, repetition of relevant organic chemistry
Structure and function of proteins
Enzymes and enzyme kinetics
Catalytic strategies
Metabolism: Basic concepts and design. Repetition of basic thermodynamics
Glycolysis, fermentation
The citric acid cycle
Oxidative phosphorylation and ATP physiology

Lecture notes
Horton et al. (Pearson) serves as lecture notes.

Prerequisites / notice
Basic knowledge in biology and chemistry is a prerequisite.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Decision-making assessed
Problem-solving assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered

752-6305-00L
Physiology and Anatomy I
2 credits
2V
D. Burdakov, D. Peleg-Raibstein

Abstract
Imparts a basic understanding of physiology in mammals, focusing on the fundamental general principles of organ operation in health and disease. This is fostered by discussing all subjects from a functional point of view. A major topic of the lecture is food intake and digestion with its correlated neural and endocrine processes.

Objective
After this course the students are able to describe, explain, and apply basic principles of systems physiology and the mechanisms of the function of the major organ systems.

701-0225-00L
Organic Chemistry
2 credits
2V+1U
K. McNeill

Abstract
Basics of Organic Chemistry.

Reaction mechanisms in organic chemistry: substitutions, additions, eliminations, condensations, rearrangements, electrophilic aromatic substitution

Objective
Students will be able to:
• Recall basic organic chemistry reactions, including substitution, elimination and addition reactions occurring at sp2- and sp3-hybridized carbon centers,
• Explain the relative favorability of certain organic chemical structures or certain organic chemical reactions.
• Apply their understanding of reaction mechanism principles to explain observations.
• Differentiate the most reactive sites in a given organic chemical.
• Propose reaction mechanisms to new chemical transformations.

Content
Descriptive chemistry of functional groups (alkyl halides, alkenes, aromatic systems, carbonyls).

Reaction mechanisms (substitutions, additions, eliminations, condensations, electrophilic aromatic substitution).

Literature
Carsten Schmuck, Basisbuch Organische Chemie, Pearson

Previous knowledge
Der Stoff der Basischemie wird vorausgesetzt.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Mediation and Digital Technologies fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking assessed
Self-awareness and Self-reflection fostered

Mathematics IV: Statistics
4 credits
2V+1U
N. Meinshausen

Abstract
Introduction to basic methods and fundamental concepts of statistics and probability theory for practitioners in natural sciences. The concepts will be illustrated with some real data examples and applied using the statistical software R.

Objective
Capacity to learn from data; good practice when dealing with data and recognizing possible fraud in statistics; basic knowledge about the laws of randomness and stochastic thinking (thinking in probabilities); application of simple methods in inferential statistics (e.g., several hypothesis tests will be introduced), i.e. also using the statistical software R. The lecture will be held in German.

Content

Lecture notes
Ausführliches Skript zur Vorlesung ist erhältlich.

Literature
The course will introduce students to the biological, physical and engineering basis of food and its role for society. It will center around 3 case examples in which students will be introduced to basic concepts integrating several key disciplines of food science. Each example will be comprised of significant active learning content and practice in scientific communication. T

Objective
1. Gain an introductory knowledge of the multi-disciplinary topics comprising Food Science.
2. Understand how the multiple disciplines of food science interrelate in an applied context via guided learning of selected examples of foods and human health.
3. Be prepared to make informed decisions about future steps in the food science education and career.
4. Be able to write a well-structured paragraph

Additional Courses

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0000-02L</td>
<td>Laboratory Course in Physics for Students in Food Sciences</td>
<td>O</td>
<td>2</td>
<td>4P</td>
<td>A. Bland, A. Eggenberger, A. Müller</td>
</tr>
</tbody>
</table>

**Abstract**

The central aim is to provide an individual experience of the physical phenomena and the basic principles of the experiment. By conducting simple physical experiments the student will learn how to properly use physical instruments and how to evaluate the results correctly.

**Objective**

Laboratory work forms an important part of the education in natural sciences. The overhead topic in this lab course is the confrontation of fundamental problems of any experiment. Using the example of simple tasks, the following aspects should be considered in particular:

- the practical structure of the experiment and the knowledge of the measuring methods
- the use and handling of measuring instruments
- the correct evaluation and assessment of the observations
- deepening the knowledge in some areas of elementary physics
- physics as a personal experience

**Content**

Lab safety; error calculation and report writing; 6 selected experiments on a variety of topics. Selection of experiments may vary between courses.

**Lecture notes**

Manuals for the experiments in the physics lab; additional material is provided on the course website

**Competencies**

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Critical Thinking
- Integrity and Work Ethics

**752-4003-00L Practical Course in Microbiology**

**Abstract**

Basic principles of the handling of microorganisms (MO) - Detection of MO in the environment - Morphology and diagnostics of MO - Morphology and physiology of fungi - Antimicrobial agents - Microbial genetics - Bacterial physiology and interactions - Microbial pest control

**Objective**

The students are familiar with the laboratory work with microorganisms. Specific emphasis is put on the isolation and maintenance of pure cultures and the required hygiene measures. The students know the clinical and ecological importance of microorganisms.

**Content**

In an introductory part students are made familiar with the handling and cultivation of microorganisms (MO). Afterwards, the students detect MO in the environment and use MO for the conservation of food. This part is then followed by a practical introduction on routine diagnostics of MO and experiments with antimicrobial agents. On simple experiments, the students experience the interaction of MO with higher organisms - the common topic of all research groups at the Institute of Microbiology. Some simple experiments demonstrate the importance of MO in molecular genetics. The course ends with a short introduction into the fungi and an example of applied microbiology i.e. an experiment on microbial pest control.

**Lecture notes**

A detailed script of approx. 100 pp. and other relevant documents are available at Moodle at latest 1 week before the beginning of the practical course.

**Literature**

Recommended literature (facultative):
- Allgemeine Mikrobiologie by Georg Fuchs and Hans G. Schlegel, Thieme-Verlag, 9. Auflage 2014
- Taschenlehrbuch Biologie: Mikrobiologie by Katharina Munk, Thieme Verlag, 2008
- 2015

**Prerequisites / notice**

Performance of the students in this practical course is controlled by:

1. Attendance of all 7 course days
2. Handing in of written reports to selected experiments (in groups of 2 students)
3. Preparation of a poster to a selected topic of Microbiology (in groups of 4 students)

Participating doctoral students who collect credit points during their thesis are examined in a 30-minute oral exam at the end of the course.
Basics of Food Science

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<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-1000-00L</td>
<td>Food Chemistry I</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>L. Nyström, S. Boulos, M. Erzinger</td>
</tr>
</tbody>
</table>

Abstract
Descriptive chemistry of food constituents (focus on proteins, lipids, carbohydrates).
Reactions which affect the colour, flavour, texture, and the nutritional value of food raw materials and food products during processing, storage and preparation in a positive or in a negative way (introduction to lipid oxidation, Maillard reaction).

Objective
Recognize chemical structures of the main ingredients and be able to draw them themselves
Being able to recognize functional groups and assess their properties
Understand chemical reactions and be able to estimate their influence on the quality of a food product
Being able to explain the Maillard reaction and lipid oxidation

Content
Descriptive chemistry of food constituents (focus on proteins, lipids, carbohydrates).
Reactions which affect the colour, flavour, texture, and the nutritional value of food raw materials and food products during processing, storage and preparation in a positive or in a negative way (introduction to lipid oxidation, Maillard reaction).

Links to food analysis, food processing, and nutrition.

Competencies
Subject-specific Competencies
Concepts and Theories fostered
Techniques and Technologies fostered
Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management assessed
Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed

5. Semester

Basics of Food Science

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<tr>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>752-5001-00L</td>
<td>Food Biotechnology</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>N. Bokulich, A. Greppi, B. Pugin</td>
</tr>
</tbody>
</table>

Abstract
Biotechnology is the use of living organisms (or their products) to produce valuable substances or to perform specific services. In this course, you will learn about diverse applications of biotechnology in food and ingredient production, with a focus on microbial biotechnologies.

Objective
In this course you will explore the roles and potential of biotechnology in food production past, present, and future, with a focus on microbial biotechnologies. At the end of this course, you will be able to identify the microorganisms and biotechnologies currently implemented in food and food ingredient production and independently evaluate the potential of biotechnological solutions to current and future food challenges.

Content
The course will cover diverse topics in modern food biotechnology, including:
* food fermentation (arguably the world's oldest biotechnology)
* the taxonomy and metabolism of microorganisms used in food production
* microbial and fermentation kinetics
* bioreactors for food and ingredient production
* biopreservation
* molecular diagnostics
* safety and regulation of biotechnological ingredients in food production.
At the end of this course, you will be able to identify beneficial/detrimental bacteria associated with food products, execute basic bioinformatic analysis (DNA-based) to identify them, explain the main production (upstream) and purification (downstream) processes of food-relevant microorganisms and ingredients, calculate microbial kinetic parameters, connect key metabolic features with specific application in the food industry (e.g. biopreservation), and understand the general legislation (EU/CH) regarding the use of microorganisms in food.

Literature
A list of references will be given at the beginning of the course for the different topics presented during the course.
### Introduction to Nutritional Science

**W 3 credits 2V**  
I. Herter-Aeberli, K. Giller, C. Wolfrum

**Abstract**  
This course introduces basic concepts of micro- and macronutrient nutrition. Micronutrients studied include fat-soluble and water-soluble vitamins, minerals and trace elements. Macronutrients include proteins, fats, and carbohydrates. Special attention is given to nutrient digestion, bioavailability, metabolism and excretion with some focus on energy metabolism.

**Objective**  
To introduce the students to both macro- and micronutrients in relation to food and metabolism.

**Content**  
The course is divided into two parts: Micronutrients and macronutrients. The micronutrient part includes fat-soluble vitamins, water-soluble vitamins, minerals and trace elements. The macronutrient part introduces basic nutritional aspects of proteins, fats, carbohydrates and energy metabolism. The nutrients are described in relation to digestion, absorption and metabolism. Special aspects of homeostasis and homeorhesis are emphasized.

**Lecture notes**  
There is no script. Powerpoint presentations will be made available.

**Literature**  
Elmadfa I & Leitzmann C: Ernährung des Menschen  
UTB Ulmer, Stuttgart, 4. überarb. Ausgabe 2004  

Garrow JS and James WPT: Human Nutrition and Dietetics  
Churchill Livingstone, Edinburgh, 11th rev. ed. 2005  

### Food Microbiology I

**W 3 credits 2V**  
M. Loessner, A. Harms

**Abstract**  
This lecture is the first part of a one-year course. It offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts and molds present in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.

**Objective**  
The lecture offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts, molds and protozoa in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms. The focus of this first part of the two part lecture (Food Micro II is offered in the FS) will be on the organisms, but also on the factors which determine spoilage and foodborne disease.

**Content**  
1. History of Food Microbiology  
2. Overview of Microorganisms in Foods  
3. Microbial Spoilage of Foods  
4. Foodborne Disease

**Lecture notes**  
Electronic copies of the presentation slides (PDF) and additional material will be made available for download.

**Literature**  
Recommendations will be given in the first lecture.
Food Biotechnology (only for Students on the 2016 regulation who did not follow the course Lebensmittel-Verfahrenstechnik I)

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<tbody>
<tr>
<td>752-5001-01L</td>
<td>Food Biotechnology</td>
<td>W</td>
<td>4</td>
<td>2V+1A</td>
<td>N. Bokulich, A. Greppi, B. Pugin</td>
</tr>
</tbody>
</table>

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Self-presentation and Social Influence: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Food Science General Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>551-0317-00L</td>
<td>Immunology I</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>M. Kopf, A. Oxenius</td>
</tr>
</tbody>
</table>

Abstract
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Objective
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Content
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Lecture notes
Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"

Literature
- Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020

Prerequisites / notice
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Consumer Behaviour I

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>752-2120-00L</td>
<td>Consumer Behaviour I</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>M. Siegrist, A. Bearth, A. Berthold</td>
</tr>
</tbody>
</table>

Abstract
Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior

- explain the decision-making processes underlying the purchasing process
- describe the factors that have an influence on consumer behavior
- develop strategies to influence purchasing behavior

Food Chemistry II

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>752-1003-00L</td>
<td>Food Chemistry II</td>
<td>W+</td>
<td>3</td>
<td>2V</td>
<td>L. Nyström, S. Boulos, M. Erzinger</td>
</tr>
</tbody>
</table>

Abstract
Descriptive chemistry of food constituents (focus on structure-function relationships). Reactions which affect the colour, flavour, texture, and the nutritional value of food raw materials and food products during processing, storage and preparation in a positive or in a negative way (lipid oxidation, Maillard reaction, enzymatic browning).
Objective

Be able to draw chemical structures of the main ingredients, recognize functional groups in the structures and explain their properties.

Understand foods as complex systems and be able to make connections between chemical structures, chemical reactions and their influence on quality.

Recognize chemical reactions of lipid oxidation, Maillard reaction and enzymatic reactions and be able to formulate them themselves.

Content

Descriptive chemistry of food constituents (focus on structure-function relationships).

Reactions which affect the colour, flavour, texture, and the nutritional value of food raw materials and food products during processing, storage and preparation in a positive or in a negative way (lipid oxidation, Maillard reaction, enzymatic browning).

Links to food analysis, food processing, and nutrition.

Topics:
- Lipid oxidation, Maillard reaction, structural proteins/enzymes
- Food as complex systems
- Chemical reactions and reaction mechanisms
- Selected (possibly changing) food chemistry topics (e.g. sweeteners, polysaccharides, from olive to margarine, etc.)

The lectures Food Chemistry I and Food Chemistry II constitute a unit.

Lecture notes

The lectures are supplemented with handouts.

Literature


Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Social Competencies
Communication fostered

Fostered

Critical Thinking

Creative Thinking

Analytical Competencies

752-1103-00L Food Analysis II

W+ 3 credits 2V T. Gude

Abstract

To get acquainted with the principles and applications of mass spectrometry in food analytics.

Objective

The fundamentals of chemistry and their application to mass spectrometric techniques should be achieved.

Simple MS spectra can be interpreted.

The effects of the interpretation can be assessed

Content

Main focus: Mass spectrometry, applications of mass spectrometry (MS).

Lecture notes

The lectures are supplemented with handouts.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Graded

Personal Competencies
Critical Thinking assessed

752-3001-00L Food Process Engineering II

W+ 3 credits 3G S. Gstöhl

Abstract

To procure students with the basics of mechanical process engineering with main focus on mechanical unit operations used in the food industry.

Objective

Training in mechanical unit operations and understanding of the related impact on food structure and properties.

Content

Darstellung von Partikelgrössenverteilungen, Trennen, Zerkleinern, Agglomerieren, Beschreibung von Haufwerken, Haftkräfte, Kapillarphänomene, Sedimentation, Fest Flüssig Trennung

Es werden Übungen durchgeführt

Lecture notes

Script (ca. 100 pages, 80 figures), Lecturing slides

- F. Löffler, Grundlagen der mechanischen Verfahrenstechnik

Prerequisites / notice

Voraussetzungen: Vorlesung in VTI, sowie physikalische und mathematische Grundkenntnisse

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking assessed

752-2000-00L Food Materials Science

W+ 4 credits 3G R. Mezzenga, G. Nyström, M. Radiom

Abstract

Principles of soft condensed matter applied to food polymers, surfactants and colloids

Objective

Students will be able to:
- Describe the fundamental physical principles ruling the self-assembly, aggregation, processing and structure-properties relationship in food systems constituted by polysaccharides (polymers), proteins (colloids) and lipids (surfactants).
- Assess and recommend the best set of parameters controlling structure in foods
- Integrate physical and chemical principles to optimize food properties to meet specific requirements of defined food products

Competencies

Subject-specific Competencies
Concepts and Theories assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

752-6307-00L Food, Habits and Health

W 3 credits 2V D. Burdakov, D. Peleg-Raibstein

Abstract

Imparts an advanced understanding of physiology, focusing on the link between nutrition and function of the mammalian organism. This is fostered by discussing all subjects from a viewpoint of health and disease. A major topic of the lectures is the link between nutrition and brain function, including mental health and neurodegenerative disorders.
Objective

At the end of the course, the students are able to describe, explain, and apply the biological and nutritional principles of physiology including specific examples relating to brain functions.

Lecture notes

Handouts for each topic will be made available on Moodle.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Communication fostered
Negotiation fostered

Social Competencies

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered

Lecture notes

Handouts for each topic will be made available on Moodle.

Abstract

The course prepares students for the basic methods of scientific work. Documentation and communication of scientific projects is one of the focal points of any scientific work. They take place at different times of a project and therefore have many forms and methodologies. The lecture takes up these steps and teaches the necessary methodical tools.

Objective

Students know the basics of scientific working and can apply them to their work.

Students know the basics and the conventions of scientific writing in natural sciences (German and English) and can apply them in their own texts.

Students are able to find relevant literature in catalogs and subject databases and to assess their quality.

Students create a scientific poster in small groups.

Content

- Literature (scientific publishing, sources and their quality), literature research, databases
- Writing scientific reports in German and English
- Practical statistics with examples and exercises
- Create graphics and tables
- Creation of a poster
- Assessment, processing, reduction, and storage of data
- Ethics in research (plagiarism, acknowledgements)
- Other relevant topics

Prerequisites / notice

keine

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Method-specific Competencies
Analytical Competencies fostered
Decision-making fostered
Problem-solving fostered
Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Personal Competencies
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered

Abstract

The course Accounting for Managers offers an introduction to financial and managerial accounting, especially for students who aspire for a career in business and management with a science or engineering background.

Objective

After attending the class, you should be able to:
- understand the accounting system, the reporting process, and be able to prepare financial statements
- feel comfortable reading and using the information presented in companies’ annual reports
- understand cost concepts and conduct cost analyses
- become familiar with several classic decisions using managerial accounting information
- comment on the current events related to these topics

Content

Accounting plays a critical role in the effective functioning of the financial market as well as the long-term success of a company. This course intends to provide an introduction to accounting for those who wish to pursue a career in business, and need the skills and knowledge to understand, analyze, and interpret accounting information to make informed decisions. The course is divided into two parts. In the first part, we focus on financial reporting and start with the basic accounting concepts and the accounting cycle, to learn how the financial system is set up in a company and how financial statements are prepared. We then delve deeper into each major account, and discuss how revenues and expenses are recognized, and how assets, liabilities, and equities are reported. In the second part, we focus on managerial accounting for internal managerial/operational decisions including fundamental topics such as cost behavior, cost estimation, CVP analyses, and relevant costing. We then cover budgeting and standard costing, which are important parts of accounting system in companies.

Prerequisites / notice

This course is a prerequisite for the course Financial Management.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Food Science Laboratory Practice

Number Title Type ECTS Hours Lecturers
752-4007-00L Experimental Food Microbiology ■ W 3 credits 4P M. Schuppler

Registration only after having attended the course Lebensmittel-Mikrobiologie I (752-4005-00L).

Abstract

Teaching of basic experimental knowledge for detection and identification of relevant microorganisms in food. Various practical experiments were accompanied by theoretic introductions to the different topics. The students become acquainted with state-of-the-art methods with main focus on modern molecular techniques for the rapid detection of food borne pathogens.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1557 of 2653
Objective

Fachliche Lernziele

Die Studierenden
- setzen im Studium erworbenes und im Rahmen der Lehrveranstaltung neu erarbeitetes Wissen ein, um zu beurteilen, welche Mikroorganismen in welchen Lebensmitteln relevant sind.
- können entscheiden, welche Verfahren zum Nachweis welcher Mikroorganismen geeignet sind.

Überfachliche Lernziele

Die Studierenden
- evaluiert und bewerten ihre Ergebnisse vor dem Hintergrund der verwendeten Methoden.
- dokumentieren ihre Tätigkeiten in einem Laborjournal in übersichtlicher Form und diskutieren die erhaltenen Ergebnisse kritisch.

Content

Grundtechniken für die mikrobiologische Untersuchung von Lebensmitteln, Qualitätssicherung, Anwendung von antimikrobiellen Wirkstoffen, Nachweismethoden für die wichtigsten pathogenen Keime aus Lebensmitteln und einzelnen Keimen aus fermentierten oder probiotischen Lebensmitteln mit klassischen Methoden (u.a. Anreicherungssysteme, ELISA, Enzysysteme) und Methoden der Molekularbiologie (PCR, Hybridisierung, in situ-Nachweis), Durchführung von Gentransfermethoden mit Mikroorganismen (Konjugation, Transformation) und Bakteriophagen in Lebensmitteln

Method-specific Competencies

Techniques and Technologies

Social Competencies

Communication

Analytical Competencies

Cooperation and Teamwork

Analytical Competencies

Critical Thinking

Prerequisites / notice

Important information!

During the course we will work with the food-borne pathogen Listeria monocytogenes. Listeria monocytogenes represents a particular threat in case of pregnancy. Due to biosafety reasons participation is not allowed in case of pregnancy.

Credit value

2 PECTS

References are given in the manuscript.

Wird am Praktikumsanfang abgegeben.

Lecture notes

All information and the program will be sent to enrolled students prior to the start of the laboratory course by e-mail. The scripts for this course on the page of the course catalogue in learning materials are available online and can be viewed after login.

Literature

- Krämer: "Lebensmittel-Mikrobiologie" (Ulm; UTB)
- Süssmuth et al.: "Mikrobiologisch-Biochemisches Praktikum" (Thieme)
- Süssmuth et al.: "Mikrobiologisch-Biochemisches Praktikum" (Thieme)
- Wird am Praktikumsanfang abgegeben.

Prerequisites

Prerequisite: Attendance of the course 752-2001-00L

W. R. Studart

R. Nicolosi Libanori, G. Panzarasa,
M. Steinacher

Food Technology Laboratory Course

W  2 credits  4P  H. Adelmann

752-2002-00L

Food Science General Courses can be accounted as electives as well.


electives as well.

Food Science General Courses can be accounted as electives as well.

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<tr>
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<th>Hours</th>
<th>Lecturers</th>
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Elective

A list with possible electives will be published separately.

Autumn Semester 2024
This course is divided into two main blocks. The first block focuses on the primary molecular adaptations of living organisms, while the second block covers the fundamental microstructural design principles present in biological materials.

**Block I: Molecular Adaptations of Living Organisms and Creation of Adaptive Bio-inspired Materials**

- Temporal regulation in biological and bio-inspired molecular systems;
- Autonomous molecular structures and out-of-equilibrium systems;
- Molecular motion and work generation mechanisms in biological and bio-inspired systems;
- Sensing, adaptation, and communication in biological and bio-inspired material systems;

**Block II: Principles of Microstructural Design in Biological Materials and Their Synthetically Engineered Counterparts**

- Fundamentals of engineering in biological and bio-inspired materials;
- Replicating biological design principles in synthetic materials (structural, optical, surface properties, etc.);
- Bio-inspired design and systems (mechanical actuation and bio-inspiration in the built environment).

**Lecture notes**

Copies of the slides will be made available for download before each lecture.

**Literature**

The course is mainly based on the references listed below. Additional references will be provided during the lectures.


**Competencies**

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Concepts &amp; Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptability &amp; Flexibility</td>
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<td>Techniques &amp; Technologies</td>
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<td>Decision-making</td>
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<td>Media &amp; Digital Technologies</td>
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<td>assessed</td>
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<td>Problem-solving</td>
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<td>Project Management</td>
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**Literature**

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The lecture explores current challenges of corporate sustainability and prepares students to become champions for sustainable business practices. The module combines asynchronous videos, live sessions, with a group work phase between weeks 5-10 of semester during which students deep-dive into one of 10 sustainability challenges.

**Objective**

Students:
- assess the limits and the potential of corporate sustainability for sustainable development
- develop competencies that are useful in the context of corporate sustainability and beyond (analytical competency, critical thinking, problem solving)
- recognize and realize opportunities through team work for corporate sustainability in a business environment
- present strategic recommendations in teams

**Content**

Corporate Sustainability is the flagship course of the Group for Sustainability and Technology at D-MTEC. In this course, students learn about key concepts in corporate sustainability and develop skills to implement them in the real world. The course prepares students for making well-informed sustainability decisions in their future careers.

The course uses constructive alignment to bring the various innovative teaching and learning elements (e.g., case-based experiential learning, reflective thinking and blended learning with videos and quizzes) into a coherent transformational journey. Students can now flexibly, efficiently, and effectively acquire the conceptual foundations that are essential for a substantial understanding of corporate sustainability.

http://www.sustec.ethz.ch/teaching/lectures/corporate-sustainability.html

**Literature**

Recommendations will be distributed via Moodle, and are available from the start of the course.

**Lecture notes**

Presentation slides will be available on Moodle after lectures.

**Prerequisites**

TEACHING FORMAT/ ATTENDANCE: The course includes several mandatory sessions that participants must attend to successfully earn credit points. It is not possible to take the class purely online.

**Competencies**

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**Credits and Exam**

After passing a written test at the end of the course (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test). Visiting students (e.g., from the University of Zurich, exchange students) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory. Students who obtain a grade of < 4.0 for the test will have a second chance (see table below). Students who did not participate in the test on 18 December 2023 will not have access to the repeat test unless they submit compelling and documented (e.g., medical, other exam in parallel at ETH) reasons for why they were unable to participate in the first test. It covers all contents of the lectures and the reading assignments. Visiting students (e.g., from the University of Zurich or other universities) are subject to the same conditions. Registration for the course in the mystudies system of ETH is compulsory. No separate registration for the exam is required, registration for the course as well as credits will be made available via the Moodle platform for this course a few days after the respective lecture for students who are unable to attend in person. All electronic correspondence will take place via the ETH mystudies system and Moodle, so please make sure you are properly registered there with a functioning email address/account.

Autumn Semester 2024
Projects are not only the base of work in modern enterprises, but also the primary type of cooperation with customers. Students of ETH will be assessed on their Subject-specific Competencies, Communication, Adaptability and Flexibility, and Creative Thinking.

Project planning (aims, appointments, capacities, efforts and costs), project organization, scheduling and risk analysis, project execution, supervision and control, project evaluation, termination and documentation, conflict management, multinational project management, and support as well as agile project management methods such as SCRUM are fostered.

The lecture slides and other additional material are available for download from Moodle a week before each class. The course gives a detailed introduction on various aspects of professional project management out of theory and practice. Established concepts and methods for project organization, planning, execution and evaluation are introduced and major challenges discussed. The course includes an introduction to specialized project management software as well as agile project management concepts.

Projects are not only the base of work in modern enterprises, but also the primary type of cooperation with customers. Students of ETH will often work in or manage projects in the course of their career. Good project management knowledge is not only a guarantee for individual, but also for company-wide success.

The goal of this course is to give a detailed introduction into project management. The students should learn to plan and execute a project. The course offers an introduction to the theory and practice of supply chain management. Students will learn how to develop supply chain strategies and supply networks based on firms' competitive strategies and marketing priorities. The wide range of topics involved in supply chain management makes the field very open to innovation and further development. In the course of the lecture, students have the chance to learn and discuss both overall trends and practical insights on development. The course will familiarize students with modern supply chain management theory and practice to develop and manage supply chains.

The course offers an introduction to the theory and practice of supply chain management. Students will learn how to develop supply chain strategies and supply networks based on firms' competitive strategies and marketing priorities.

Students are familiar with current developments and trends in supply chain practices

Students are able to explain elements of a supply chain structure and their importance for supply chain strategy

Students can describe and evaluate fundamental logistics and supply chain concepts

Students can differentiate supply chain network designs and their applicability in specific company and sector settings

Students are able to apply the tools and methods used to optimize a supply chain structure

The course offers an introduction to the theory and practice of supply chain management. Students will learn how to develop supply chain strategies and supply networks based on firms' competitive strategies and marketing priorities.

The wide range of topics involved in supply chain management makes the field very open to innovation and further development. In the course of the lecture, students have the chance to learn and discuss both overall trends and practical insights on development. The course will familiarize students with modern supply chain management theory and practice to develop and manage supply chains. Starting with the corporate strategy, firms align their supply chain strategy. They have to manage trade-offs, such as efficiency and responsiveness. Understanding a supply chain's role within a firm and the implications of supply chain strategies for firm performance are the foundations of the course.

Starting with the corporate strategy, firms align their supply chain strategy. They have to manage trade-offs, such as efficiency and responsiveness. Understanding a supply chain's role within a firm and the implications of supply chain strategies for firm performance are the foundations of the course.

Building on the foundations, students get familiarized with the development of a supportive supply chain structure. This structure is in its core made up by logistical elements, such as facilities, inventory management and transportation. At the same time, supply chain management is inevitably cross-functional. As such, information and information infrastructure, sourcing decisions and pricing are further drivers to define a supply chain structure. Students will learn important elements in supply chain structure, including for example forecasting methods and network design modeling and optimization. Case study assignments and practical exercises within lectures allow students to gain hands-on experience and enhance their knowledge.

The wide range of topics involved in supply chain management makes the field very open to innovation and further development. In the course of the lecture, students have the chance to learn and discuss both overall trends and practical insights on development. The course further encourages student involvement within lectures, in exchange with peers and with guest speakers. Case study assignments and tools for self-assessment help students to learn actively and continuously throughout the course.

All organizational matters will be handled by the teaching assistant Yan Zou (yanzou@ethz.ch). Please use the SSCM Class Forum on Moodle as a first point of contact.

https://moodle-app2.let.ethz.ch/course/view.php?id=20606
The following textbook is recommended:


The following textbook is supplementary:


Prerequisites / Notice

Students should install MS Excel and the Excel Solver before class, as it is used for within-class exercises. Students without the program and add-in installed may nevertheless participate within groups during the exercises.

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701-0703-00L Environmental Ethics (University of Zurich)

W 3 credits 2V University lecturers

Abstract

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: 07/SMEEE266

Please register at:
https://www.uzh.ch/cmsssl/de/studies/application/chmobility.html

after you received your logon information you can enrol to courses at:
https://studentservices.uzh.ch/uzh/application#/Login

Mind the enrolment deadlines at UZH:

Objective

On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

376-1581-00L Cancer: Fundamentals, Origin and Therapy

W 2 credits 2G H. Nägeli

Abstract


Objective

Students are able to describe selected chemicals, biological and molecular processes that occur in cells spontaneously or after physical or chemical exposure and resulting in a tumor. They are able to list important cancer-inducing agents and explain the respective mechanism of action. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies.

Content

The lecture deals with problems of tumor epidemiology (causes, mortality, incidence). Cancer is delineated as a multi-step process. Classes of chemical compounds that induce cancer are discussed as well as the reactive metabolites that may be built from. Covalent binding to DNA is discussed and different types of mutations resulting thereof. A selection of proto-oncogenes and tumor suppressor genes is presented. Their function will be discussed as well as the changes which are found in these genes in tumor cells, starting from single nucleotide exchanges up to large deletions.

The reason for genetic predisposition to cancer will be discussed as well as cancer relevant aspects of cell cycle regulation. The role of tumor microenvironments and phenomena like angiogenesis and metastasis are presented as well as the mechanisms that protect the genome from mutagenic damage. Further subjects address old and new strategies of cancer treatment. Personalised cancer treatment.

Lecture notes

Handouts with reproductions of all presented transparencies will be distributed.

Literature


additional information is given during the lecture

Prerequisites / Notice

The lecture requires an active participation of the students. All students will participate in individual or group work focussing on specific subject of the lecture. Students will have ample time for preparation during lecture time.
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| 376-1661-00L | Ethics of Life Sciences and Biotechnology | W+ | 3 credits | 2V | A. Blasimme, E. Vayena |

**Abstract**

This semester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their technological application. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences.

**Objective**

This course is tailored to students who want to become familiar with the analysis of ethical issues in all the different domains of life sciences and biotechnology. The course aims at equipping students with the necessary knowledge and analytic skills to understand, discuss and address the ethical aspects of science and technology in the domain of human health. The specific learning objectives of this course are:

A. Identify ethical issues in life sciences and biotechnology.
B. Analyze and critically discuss ethical issues in life sciences and biotechnology.
C. Become aware of relevant legal and public policy frameworks.
D. Distinguish different ethical approaches and argumentative strategies in applied ethics.
E. Recognize how ethical issues relate to different accounts of technology and innovation.
F. Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
G. Autonomously anticipate ethical issues.
H. Propose and communicate solutions to ethical challenges and dilemmas.

**Content**

The course starts off with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain of applied ethics. The students will also be introduced to current theoretical accounts of technology and will start to appreciate the relevance of ethics especially with respect to new and emerging technologies. Usable analytic tools will also be provided, thus enabling the students to engage with the discipline in a practical way from the very onset of the semester.

The course will continue with thematic sessions covering a broad variety of topics all of which are relevant to the different study tracks offered by the department. In particular, the course will cover the following domains: digital health technologies and medical AI; food, nutrition and healthy longevity; biomedical engineering; genetics; neuroscience and Neurotechnologies; medical robotics; disability and rehabilitation; environmental ethics. The course will also include sessions on cross-cutting ethically relevant aspects of health sciences and technologies, namely: access to innovation, translational research, and the relation between science and public policy.

All the topics of the course will be illustrated and interactively discussed through many case studies, offering the students the opportunity to prepare and present them, and to use them in individual as well as group exercises. Throughout the course, the students will have multiple opportunities to experiment with ethical argumentation and to practice their evolving skills.

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**Abstract**

First identification with Pharmaceutical Sciences; motivation for profiling in the Natural Sciences, which are focused on within the first two years as a preparation for the specialized studies; sensitization for the duties and the responsibilities of a person with a federal diploma in Pharmacy; information about job opportunities.

**Objective**

First identification with Pharmaceutical Sciences; motivation for profiling in the Natural Sciences as a preparation for the specialized studies; sensitization for the duties and the responsibilities of a person with a federal diploma in Pharmacy; information about job opportunities.

**Content**

Introduction to Pharmaceutical Sciences by selected milestones of research and development. Overview on research activities at the Institute of Pharmaceutical Sciences that is focused on drug delivery and development (from concepts to prototypes). Sensitization for communication skills and information management. Demonstration of job opportunities in community pharmacies, in the hospital, in industry, and in the public sector by experts in the different fields.
### Bachelor Studies (Programme Regulations 2024)

#### 1st semester

#### First Year Examination Block 1

<table>
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<tr>
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<td>401-0251-00L</td>
<td>Mathematics I</td>
<td>O</td>
<td>6</td>
<td>4V+2U</td>
<td>A. Cannas da Silva</td>
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<tr>
<td>Abstract</td>
<td>This course covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems - notably through ordinary differential equations.</td>
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<td>The goal of Mathematics I and II is to provide the mathematical foundations relevant for this paradigm. Differential equations are by far the most important tool for modelling and are therefore a main focus of both of these courses.</td>
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<td>2. Linear Algebra and Complex Numbers: systems of linear equations, Gauss-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, complex roots, fundamental theorem of algebra.</td>
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<td>3. Ordinary Differential Equations: separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.</td>
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<td></td>
<td>- Bretscher, O.: Linear Algebra with Applications (Pearson Prentice Hall).</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: familiarity with the basic notions from Calculus, in particular those of function and derivative.</td>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Die Grundlagen des Welternährungssystem werden anhand von Fallbeispielen aus der Forschung entlang der Wertschöpfungskette vermittelt.</td>
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<tr>
<td>Objective</td>
<td>Mit Besuch dieser Lehrveranstaltung soll Verständnis geschaffen werden, was ein Welternährungssystem ist, wo aktuell die grossen Herausforderungen liegen, was Elemente und Einflussfaktoren auf die Ernährungssicherheit sind, welche Wechselwirkungen zwischen diesen Elementen und Einflussfaktoren bestehen, und welche potentiellen Lösungsstrategien sich für spezifische Herausforderungen ableiten lassen.</td>
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<tr>
<td>Lecture notes</td>
<td>Skripte und zusätzliches Lernmaterial werden auf Moodle verfügbar gemacht.</td>
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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>351-1158-00L</td>
<td>Economics</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>U. Renold, T. Bolli, P. McDonald, F. Pusterla, A. Zubovic</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course introduces basic economic concepts and theories. Beginning with microeconomics, the course starts with the topics of supply and demand, markets, and behavioral economics before moving on to the key macroeconomic concepts of national accounts, the labor market, trade, and monetary policy.</td>
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Data: 15.06.2024 12:39       Autumn Semester 2024       Page 1564 of 2653
Objective
After successful completion of the course you will be able to:

- Describe the basic micro- and macroeconomic problems and theories.
- Introduce economic reasoning appropriately to a given topic.
- Evaluate economic measures.

Content
Households, firms, supply and demand: How are household preferences and consumption patterns formed? How does a household react to price changes? How are goods prices formed? At what prices are companies willing to offer goods? How do we make economic decisions?

Markets: What is "perfect competition" and how does a competitive market work? Are monopolies always a bad thing? How can the state influence the market?

Market failure: What happens when prices give wrong signals?

Labour market: How do supply and demand work in the labour market? What influences unemployment?

Foreign trade: Why do countries trade with each other? What are the consequences for the domestic market?

Money and inflation: What exactly is money? How does money creation work and what happens when there is too much (or too little) money on the market?

Students will be asked to apply these concepts to issues in their own field of study and to current issues in society. This goal will be achieved through participation in exercises, class discussions and reading material from current media. By the end of the course, students should be able to apply economic analysis confidently and independently.
Lecture notes: no script

Literature:

Prerequisites / notice
The lecture is the first in a series of two lectures given over two semesters for students with biology as a basic subject.

529-2001-02L Chemistry I O 4 credits 2V+2U J. Cvengros, J. E. E. Buschmann, P. Funck, R. Verel

Abstract
General Chemistry I: Chemical bond and molecular structure, chemical thermodynamics, chemical equilibrium.

In the course "Chemistry I", the competencies of process understanding, system understanding, modeling, concept development and data analysis & interpretation are taught, applied and examined.

Objective
Introduction to general and inorganic chemistry. Basics of the composition and the change of the material world. Introduction to the thermodynamically controlled physico-chemical processes. Macroscopic phenomena and their explanation through atomic and molecular properties. Using the theories to solve qualitatively and quantitatively chemical and ecologically relevant problems.

Content
1. Stoichiometry
   Amount of substance and mass. Composition of chemical compounds. Reaction equation. Ideal gas law.
2. Atoms
   Elementary particles and atoms. Electron configuration of the elements. Periodic system.
4. Basics of chemical thermodynamics
   System and surroundings. Description of state and change of state of chemical systems.
5. First law of thermodynamics
6. Second law of thermodynamics
   Entropy. Change of entropy in chemical systems and universe. Reaction entropy.
7. Gibbs energy and chemical potential.
8. Chemical equilibrium
   Law of mass action. Reaction quotient and equilibrium constant. Phase transition equilibrium.
9. Acids and bases
10. Dissolution and precipitation
    Heterogeneous equilibrium. Dissolution and solubility product. Carbon dioxide-carbonic acid-carbonate equilibrium.

Lecture notes
Online-Skript mit durchgerechneten Beispielen.

Literature

Weiterführende Literatur:

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered

Personal Competencies
- Adaptable and Flexibility fostered
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

Additional First Year Courses

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>252-0839-00L</td>
<td>Informatics</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>M. Dahinden, L. E. Fässler</td>
</tr>
</tbody>
</table>

Abstract
Students learn to apply selected concepts and tools from computer science for working on interdisciplinary projects. The following topics are covered: modeling and simulations, managing data with lists, tables and relational databases, introduction to programming.

Objective
The students learn to...
- choose and apply appropriate tools from computer science,
- process and analyze real-world data from their subject of study,
- handle the complexity of real-world data,
- query databases and understand and evaluate the corresponding database model,
- encode a problem into a program, test the program, and correct errors,
- implement models from the natural sciences as a simulation.

Content
1. Modeling and simulations
2. Data management with lists and tables
3. Data management with a relational database
4. Introduction to programming with Python 1 (variables & data types)
5. Introduction to programming with Python 2 (control structures & logic)
6. Introduction to programming with Python 3 (sequential data structures)

Lecture notes
All materials for the lecture are available at www.evim.ethz.ch

Literature
This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>fostered</th>
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<tbody>
<tr>
<td></td>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<td>Project Management</td>
<td>fostered</td>
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<td></td>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
<td>assessed</td>
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<td>Critical Thinking</td>
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<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<td>Self-direction and Self-management</td>
<td>fostered</td>
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</table>

**751-0801-00L Fundamentals of Microscopy and Plant Biology**

**Abstract**

**Objective**
Capability of preparing biological specimen, microscopy and documentation. Understanding the correlation between plant structure and function at the level of organs, tissues and cells. Awareness of the link between plant anatomy, systematics, physiology, ecology, and development.

**Content**

**Lecture notes**
Online in Moodle Course

**Literature**
For further reading (not obligatory):
Gerhard Wanner: Mikroskopisch-Botanisches Praktikum, Georg Thieme Verlag, Stuttgart.

**Prerequisites / notice**
Groups of a maximum of 20 students.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>fostered</th>
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<tbody>
<tr>
<td></td>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<td>Self-direction and Self-management</td>
<td>fostered</td>
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</table>

**Science in Perspective**

**Recommended Science in Perspective (Type B) for D-HEST**

see Science in Perspective: Type A: Enhancement of Reflection Capability

**Language Courses**
see Science in Perspective: Language Courses ETH/UZH

**Bachelor's Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>752-0220-20L</td>
<td>Bachelor's Thesis</td>
<td>O</td>
<td>15</td>
<td>32D</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

**Abstract**
The Bachelor Thesis completes the Bachelor programme and consists of a scientific project carried out independently under the tutorship of a lecturer at D-HEST.

**Objective**
The Bachelor Thesis aims at fostering the student's ability to independent, structured and scientific working and at deepening their knowledge in a specific field.

**Food Science and Nutrition Bachelor - Key for Type**

| O | Compulsory | E- | Recommended, not eligible for credits |
| W+| Eligible for credits and recommended | Z | Courses outside the curriculum |
| W | Eligible for credits | Dr | Suitable for doctorate |

**Key for Hours**

| V | lecture |
| G | lecture with exercise |
| U | exercise |
| S | seminar |
| K | colloquium |
| P | practical/laboratory course |
| A | independent project |
| D | diploma thesis |
| R | revision course / private study |

**ECTS**
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Management, Technology and Economics (General Courses)

In the section "general courses", lectures are listed which are offered by the D-MTEC as service lectures for students not belonging to D-MTEC.

## General Courses

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>351-0778-00L</td>
<td>Discovering Management</td>
<td>Z</td>
<td>3 credits</td>
<td>3G</td>
<td>B. Clarysse, S. Bruzoni, V. Hoffmann, T. Netland</td>
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<tr>
<td></td>
<td>Does not take place this semester.</td>
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<td></td>
<td>Entry level course in management for BSc, MSc and PHD students at all levels not belonging to D-MTEC. This course can be complemented with Discovering Management (Exercises) 351-0778-01.</td>
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<tr>
<td>Abstract</td>
<td>Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.</td>
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<tr>
<td>Objective</td>
<td>The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship. In particular, the aims of the course are to: (1) broaden understanding of management principles and frameworks, (2) advance insights into the sources of corporate and entrepreneurial success, (3) develop skills to apply this knowledge to real-life managerial problems. The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.</td>
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<tr>
<td>Content</td>
<td>The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts. The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case. The theory sessions will follow a &quot;lecture-style&quot; approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching. Through small group work, you will develop analyses of each of the cases. The theory sessions will be assessed via a multiple choice exam.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
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<td>Method-specific Competencies</td>
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<td>Self-presentation and Social Influence</td>
<td>fostered</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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<tr>
<td>351-0778-01L</td>
<td>Discovering Management (Pitch)</td>
<td>Z</td>
<td>1 credit</td>
<td>1U</td>
<td>B. Clarysse, L. P. T. Vandeweghe</td>
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<tr>
<td></td>
<td>Does not take place this semester.</td>
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<td></td>
<td>Complementary exercises for the module Discovering Management.</td>
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<tr>
<td>Prerequisite: Participation and successful completion of the module Discovering Management (351-0778-00L) is mandatory.</td>
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<tr>
<td>Abstract</td>
<td>This course is offered complementary to the basis course 351-0778-00L, &quot;Discovering Management&quot;. The course offers an additional exercise.</td>
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<tr>
<td>Objective</td>
<td>The general objective of Discovering Management (Exercises) is to complement the course &quot;Discovering Management&quot; with one larger additional exercise. Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.</td>
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<tr>
<td>Content</td>
<td>The exercise consists of delivering and submitting a &quot;pitch&quot; with a clear recommendation for one of the selected cases amongst those seen in Discovering Management, using your insights from Discovering Management, and an extra session on pitching. Students have the option to either do this alone or in a group of two students.</td>
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<tr>
<td>Literature</td>
<td>All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. Students following this course should also be enrolled for course 351-0778-00L, &quot;Discovering Management&quot;.</td>
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<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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</tr>
<tr>
<td>351-1109-00L</td>
<td>Introduction to Microeconomics</td>
<td>Z</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Wörter, M. Beck</td>
</tr>
<tr>
<td></td>
<td>GESS (Science in Perspective):</td>
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</tbody>
</table>

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This course is only for students enrolled in a Bachelor's degree programme.

Students enrolled in a Master's degree programme may attend "Principles of Microeconomics" (LE 363-0503-00L) instead.

Note for D-MAVT students: If you have already successfully completed "Principles of Microeconomics" (LE 363-0503-00L), then you will not be permitted to attend it again.

Abstract
The course introduces basic principles, problems and approaches of microeconomics. It describes economic decisions of households and firms, and their coordination through perfectly competitive markets.

Objective
Students acquire a deeper understanding of basic microeconomic models. They acquire the ability to apply these models in the interpretation of real world economic contexts.

Content
Market, budget constraint, preferences, utility function, utility maximisation, demand, technology, profit function, cost minimisation, cost functions, perfect competition, information and communication technologies

Lecture notes
Course material in e-learning environment https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php

Literature

Prerequisites / notice
This course "Einführung in die Mikroökonomie" (363-1109-00L) is intended for Bachelor students and LE 363-0503-00 "Principles of Microeconomics" for Master students.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management
Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation
Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

4 credits 3V O. Krebs, P. Egger, M. Köthenbürger

351-0511-00L Managerial Economics
Not for MSc students belonging to D-MTEC!

Abstract
"Managerial Economics" provides an introduction to the theories and methods from Economics and Management Science to analyze economic decision-making in the context of markets. The course targets students with no prior knowledge in Economics and Management.

Objective
The objective of this course is to provide an introduction to microeconomic thinking. Based on the fundamental principles of economic analysis (optimization and equilibrium), the focus lies on understanding key economic concepts relevant for understanding and analyzing economic behavior of firms and consumers in the context of markets. Market demand and supply are derived from the individual decision-making of economic agents and market outcomes under different assumptions about the market structure and market power (perfect competition, monopoly, oligopoly, game theory) are studied. This introductory course aims at providing essential knowledge from the fields of Economics and Management relevant for economic decision-making in the context of both the private and public sector.

Literature

Prerequisites / notice
The course targets both Bachelor and Master students. No prior knowledge in the areas of Economics and Management is required.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management
Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation
Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

3 credits 2V A. Fetz, M. Gysler

351-1034-00L Microeconomics
Not for students belonging to D-MTEC!

Abstract
Introduction to the economic decisions of households and firms, and their coordination through markets. Analysis of different market structures and of situations in which markets may lead to socially undesirable outcomes.

Objective
Understanding of basic microeconomic models. Ability to apply these models to real world economic situations.

Content
Economics as a science, division of labour and welfare (concept of comparative advantage), supply and demand (market equilibrium, elasticity), households (preferences, demand), firms (technology, cost analysis, profit maximisation, supply), perfect competition, monopoly and oligopoly, externalities, public goods, information, factor markets and income distribution

Lecture notes
via email

Literature
Mankiw, G. and Taylor M. (2023): Economics, Cengage Learning

Prerequisites / notice
Course macroeconomics in the spring term
### Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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### Abstract

This course introduces the students to the long-standing tradition of actively involving users of technology and other knowledge-intensive products in the development and production process, and through own cases they develop an entrepreneurial understanding of product development under distributed, user-centered, or open innovation strategies.

### Objective

The course includes both lectures and exercises alternately. The goal is to understand the opportunity of user innovation for management and develop strategies to harness the value of user-developed ideas and contributions for firms and other organizations.

The students actively participate in discussions during the lectures and contribute presentations of case studies during the exercises. The combination should allow to compare theory with practical cases from various industries.

The course presents and builds upon recent research and challenges the students to devise innovation strategies that take into account the availability of user expertise, free and public knowledge, and the interaction with communities that span beyond one organization.

Performance assessment will be: a written group essay based on the open/user innovation case that participants will research and present during the block seminar (including the slides). Each group will have to hand in a 15-20 page essay, details on the required format and the content will be distributed during the course. Active class participation is required.

Content

This course on user innovation extends courses on knowledge management and innovation as well as marketing. The students are introduced to the long-standing tradition of actively involving users of technology and other knowledge-intensive products in the development and production process, and through own cases they develop an entrepreneurial understanding of product development under distributed, user-centered, or open innovation strategies. Theoretical underpinnings taught in the course include models of innovation, the structuration of technology, and an introduction to entrepreneurship.

Lecture notes

The slides of the lectures are made available and updated continuously through Moodle.

Literature

Relevant literature for the course includes slides and reading assignments. Papers will be made available through a corresponding Moodle group.

### Competencies

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### Abstract

This course introduces basic economic concepts and theories. Beginning with microeconomics, the course starts with the topics of supply and demand, markets, and behavioral economics before moving on to the key macroeconomic concepts of national accounts, the labor market, trade, and monetary policy.

### Objective

After successful completion of the course you will be able to:

- Describe the basic micro- and macroeconomic problems and theories.
- Introduce economic reasoning appropriately to a given topic.
- Evaluate economic measures.
Content

Households, firms, supply and demand: How are household preferences and consumption patterns formed? How does a household react to price changes? How are goods prices formed? At what prices are companies willing to offer goods? How do we make economic decisions?

Markets: What is "perfect competition" and how does a competitive market work? Are monopolies always a bad thing? How can the state influence the market?

Market failure: What happens when prices give wrong signals?

Labour market: How do supply and demand work in the labour market? What influences unemployment?

National accounts: How big is the Swiss economy?

Foreign trade: Why do countries trade with each other? What are the consequences for the domestic market?

Money and inflation: What exactly is money? How does money creation work and what happens when there is too much (or too little) money on the market?

Students will be asked to apply these concepts to issues in their own field of study and to current issues in society. This goal will be achieved through participation in exercises, class discussions and reading material from current media. By the end of the course, students should be able to apply economic analysis confidently and independently.

Lecture notes

no script available

Literature


Prerequisites / notice

Sie brauchen keine Vorkenntnisse, um dem Kurs zu folgen.

Competencies

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351-1158-AAL Principles of Economics

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Students understand basic microeconomics and macroeconomics problems and theories. They are able to argue along economic principles and to judge policy measures.

Objective

Upon successful completion of the course, you will be able to:
- Describe the basic microeconomic and macroeconomic problems and theories.
- Make economic arguments to a given topic.
- Evaluate economic measures.

Content

Households, firms, supply and demand: How are household preferences and consumption behavior formed? How does a household react to price changes? How are goods prices formed? At what prices are firms willing to offer goods? How do we make economic decisions?

Markets: What is "perfect competition" and how does a competitive market work? Are monopolies always a bad thing? How do we make economic decisions?

Market failure: What happens when prices give wrong signals?

Labour market: How do supply and demand work in the labor market? What influences unemployment?

National Accounts: How big is the Swiss economy?

Foreign trade: Why do countries trade with each other? What are the consequences for the domestic market?

Money and inflation: What exactly is money? How does money creation work, and what happens when there is too much (or too little) money on the market?

Students will be asked to apply these concepts to issues in their own field of study and to current issues in society.

Literature


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Management, Technology and Economics (General Courses) - Key for Type

| Z | Courses outside the curriculum | O | Compulsory |
| Dr | Suitable for doctorate | W+ | Eligible for credits and recommended |
| E- | Recommended, not eligible for credits | W | Eligible for credits |

Key for Hours

V | lecture | P | practical/laboratory course |
G | lecture with exercise | A | independent project |
U | exercise | D | diploma thesis |
S | seminar | R | revision course / private study |
K | colloquium |

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Introduction to Management

After attending the class, you should be able to:

Objective

- understand the accounting system, the reporting process, and be able to prepare financial statements
- feel comfortable reading and using the information presented in companies’ annual reports
- understand cost concepts and conduct cost analyses
- become familiar with several classic decisions using managerial accounting information
- comment on the current events related to these topics

Content

Accounting plays a critical role in the effective functioning of the financial market as well as the long-term success of a company. This course intends to provide an introduction to accounting for those who wish to pursue a career in business, and need the skills and knowledge to understand, analyze, and interpret accounting information to make informed decisions. The course is divided into two parts. In the first part, we focus on financial reporting and start with the basic accounting concepts and the accounting cycle, to learn how the financial system is set up in a company and how financial statements are prepared. We then delve deeper into each major account, and discuss how revenues and expenses are recognized, and how assets, liabilities, and equities are reported. In the second part, we focus on managerial accounting for internal managerial/operational decisions including fundamental topics such as cost behavior, cost estimation, CVP analyses, and relevant costing. We then cover budgeting and standard costing, which are important parts of accounting system in companies.

Prerequisites / notice

This course is a prerequisite for the course Financial Management.

Competencies

Subject-specific Competencies: Concepts and Theories assessed
Techniques and Technologies assessed

General Management and Human Resource Management

Core Courses

Financial Management

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<td>Accounting for Managers</td>
<td>W+</td>
<td>3 credits</td>
<td>2V</td>
<td>H. Chen</td>
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Abstract

The course Accounting for Managers offers an introduction to financial and managerial accounting, especially for students who aspire for a career in business and management with a science or engineering background.

Objective

After attending the class, you should be able to:
- understand the accounting system, the reporting process, and be able to prepare financial statements
- feel comfortable reading and using the information presented in companies’ annual reports
- understand cost concepts and conduct cost analyses
- become familiar with several classic decisions using managerial accounting information
- comment on the current events related to these topics

Content

Accounting plays a critical role in the effective functioning of the financial market as well as the long-term success of a company. This course intends to provide an introduction to accounting for those who wish to pursue a career in business, and need the skills and knowledge to understand, analyze, and interpret accounting information to make informed decisions. The course is divided into two parts. In the first part, we focus on financial reporting and start with the basic accounting concepts and the accounting cycle, to learn how the financial system is set up in a company and how financial statements are prepared. We then delve deeper into each major account, and discuss how revenues and expenses are recognized, and how assets, liabilities, and equities are reported. In the second part, we focus on managerial accounting for internal managerial/operational decisions including fundamental topics such as cost behavior, cost estimation, CVP analyses, and relevant costing. We then cover budgeting and standard costing, which are important parts of accounting system in companies.

Prerequisites / notice

This course is a prerequisite for the course Financial Management.

Competencies

Subject-specific Competencies: Concepts and Theories assessed
Techniques and Technologies assessed

General Management and Human Resource Management

Core Courses

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<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>Z. Zagorac-Uremovic, D. Baschung, J. O'Neil</td>
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Abstract

This course is an introduction to general management. This course follows a systemic view of organizations and adopts the congruence model as a framework to analyze the critical, interconnected elements of organizations.

Objective

By the end of this course, students will understand management as a set of skills, processes, tools and methods that enable organizations to achieve their goals and to coordinate operations in order to meet evolving customers’ and societal needs. The students will achieve these goals by being able to:
- Analyze organizations as open systems, and describe their critical elements,
- Apply conceptual tools and methods that help to analyze or approach the critical elements,
- Compare different notions of organizational performance, and explain why they matter,
- Discuss the relationships that connect the critical elements of an organization on the basis of real cases,
- Explain how change, internally or externally initiated, impact such relationships

Content

This course is an introduction to general management. This course follows a ‘systemic’ view of organizations and adopts the congruence model as a framework to analyze the critical, interconnected elements of organizations: Input (i.e., from external environment), strategy, people, work, formal and informal structure of the organization, and its outputs. In this course we will introduce these critical elements and learn how managers can analyze and approach these elements by means of different conceptual tools and methods in order to achieve performance. We will furthermore discuss the relationships that connect the critical elements together by means of real-life cases, whereby the focus will be on the critical reflection of particular cases of fits and misfits between those elements and on the application of a selection of tools and methods.

Prerequisites / notice

The final exam is requested for all types of students (BSc, MSc, MAs, PhD, and Exchange students). It is not possible to retake the exam within the same term or academic year. We strongly recommend Exchange students to take it into consideration when selecting the courses to attend.

Competencies

Subject-specific Competencies: Concepts and Theories assessed

Literature

The content of the course will rely on different readings, cases and selected chapters of following book:

Selected readings from the book and additional learning materials will be available on the course Moodle:
https://moodle-app2.let.ethz.ch/course/view.php?id=20842

The content of the course will rely on different readings and on selected chapters of following book:

Selected readings from the book and additional learning materials will be available on the course Moodle:
https://moodle-app2.let.ethz.ch/course/view.php?id=20842

The content of the course will rely on different readings, cases and selected chapters of following book:

Selected readings from the book and additional learning materials will be available on the course Moodle:
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Selected readings from the book and additional learning materials will be available on the course Moodle:
https://moodle-app2.let.ethz.ch/course/view.php?id=20842
### Management of Digital Transformation

**Number:** 363-0421-00L  
**Title:** Management of Digital Transformation  
**Type:** W⁺  
**ECTS:** 3 credits  
**Hours:** 2G  
**Lecturers:** E. Fleisch

#### Abstract
This course provides an overview of Digital Transformation within organizations, the opportunities that come with it, but also the issues managers face transforming their organizations into the digital age. Increasingly, information technology (IT) is not only being used as a tool to improve processes but to also create and capture new customer value and to gain and maintain competitive advantage.

#### Objective
This course introduces the students the relevant subjects that form the digital transformation agenda of organizations' top-level management. After completing the 4 core learning blocks below, students will be able understand, analyze and critically question organization’s digital transformation processes while also learning the frameworks and tools used by organizations to digitally transform.

1. Digital transformation strategies  
2. Organizing the digital transformation  
3. Digital transformation and technology  
4. Digital transformation within industries

Throughout the course, students will learn from and discuss with guest lecturers their experiences of digital transformation.

#### Content
Digital Transformation has become a top management theme across all industries. It is part of the strategic agenda of management and supervisory boards with dedicated roles to drive forward its design and implementation.

The lecture introduces many of the relevant subjects that together form the digital transformation agenda of organizations' top-level management. It establishes the main themes, tools, and theoretical concepts. The lecture consists of 4 learning blocks, each with a focus on an area of Digital Transformation, and will feature guest lecturers from industry. The lecture is structured as follows:

##### Block 1: Strategy
- Digital Business Model Patterns  
- Platform Companies  
- Subscription Models  
- Lessons from Theory Toolbox

##### Block 2: Organizational
- Towards an Agile Organization

##### Block 3: Technology
- "Future-proof” Infrastructure

##### Block 4: Industry
- Digital Transformation in the Health Care Industry  
- Digital Transformation in the Automotive Industry

The course is divided into an onsite classroom part and an online self-learning part. All teaching materials will be available through the course page on Moodle.

#### Lecture notes
All lecture content is provided via the Moodle platform.

#### Literature
All relevant literature is provided via the Moodle platform.

#### Competencies

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### Production and Operations Management

**Number:** 363-0445-00L  
**Title:** Production and Operations Management  
**Type:** W⁺  
**ECTS:** 3 credits  
**Hours:** 2G  
**Lecturers:** T. Netland

#### Abstract
This core course provides insights into the basic theories, principles, concepts, and techniques used to design, analyze, and improve the operational capabilities of an organization.

#### Objective
This course provides students with a broad theoretical basis for understanding, designing, analyzing, and improving manufacturing operations. After completing this course:

1. Students can apply key concepts of POM to detail an operations strategy.  
2. Students can do simple forecasting of demand and plan the needed capacity to meet it.  
3. Students can conduct process mapping analysis, use it to design and improve processes and layouts, and elaborate on the limitations of the chosen method.  
4. Students can choose IT, OT, and automation technology for manufacturing applications.  
5. Students can design information flows, manage master data, and use it to plan and control a factory.  
6. Students can design material flows in and beyond factories.  
7. Students can design performance management systems.  
8. Students can select and use problem-solving tools to improve quality and productivity.  
9. Additional skills: Students acquire experience in teamwork.
The course covers the most fundamental strategic and tactical concepts in production and operations management (POM).

Production and Operations Management (POM) is at the heart of any business. It is concerned with the business processes that transform input into output and deliver products and services to customers. Factory management is an important part of POM, but it is much more than what takes place inside the production facilities of companies likeABB, BMW, LEGO, Nestlé, TESLA, and Toyota. Did you know that the largest portion of assets and employees in most organizations are engaged in the operations function? Although this course focuses on manufacturing, all types of organizations depend on their operational capabilities. With the ongoing globalization and digitization of manufacturing, POM has won a deserved status for providing a competitive advantage.

This course covers the following topics: Introduction to POM, Manufacturing strategy, Forecasting and capacity, Process design, Layout, Industry 4.0, Information flow, Material flow, Logistics/SCM

Performance management, Performance improvement, Quality management, and Maintenance.

This course is administered via Moodle. The course is designed around five elements:
2. Video lectures. Short video lectures presenting basic POM concepts.
3. Class lectures. Deep-dives with case examples on select topics.
4. FactoryVR group assignment. FactoryVR allows students to visit factories virtually.
5. Quizzes. A few quizzes during the semester help students check their progress and prepare for the written exam.

Suggested literature is provided in the syllabus.

The following textbook is supplementary:


All organizational matters will be handled by the teaching assistant Yan Zou (yanzou@ethz.ch). Please use the SSCM Class Forum on Moodle as a first point of contact.

The course material will be made available for download on Moodle:
https://moodle-app2.let.ethz.ch/course/view.php?id=20606

The course offers an introduction to the theory and practice of supply chain management. Students will learn how to develop supply chain strategies and supply chain networks based on firms competitive strategies and marketing priorities.

Starting with the corporate strategy, firms align their supply chain strategy. They have to manage trade-offs, such as efficiency and responsiveness. Understanding a supply chain’s role within a firm and the implications of supply chain strategies for firm performance are the foundations of the course.

Modern supply chains are not only essential to ensure functioning logistics but also help firms develop and maintain competitive advantage in globalized (supply) markets with numerous partners and competitors. While taking into account future opportunities and risks, effective supply chains ought to be aligned with and support the achievement of the firm’s corporate, business and product strategies. This course will familiarize students with modern supply chain management theory and practice to develop and manage supply chains.

The wide range of topics involved in supply chain management makes the field very open to innovation and further development. In the course of the lecture, students have the chance to learn and discuss both overall trends and practical insights on development. The course furthermore encourages student involvement within lectures, in exchange with peers and with guest speakers. Case study assignments and tools for self-assessment help students to learn actively and continuously throughout the course.

Building on the foundations, students get familiarized with the development of a supportive supply chain structure. This structure is in its core made up by logistical elements, such as facilities, inventory management and transportation. At the same time, supply chain management is inevitably cross-functional. As such, information and information infrastructure, sourcing decisions and pricing are further drivers to define a supply chain structure. Students will learn important elements in supply chain structure, including for example forecasting methods and network design modeling and optimization. Case study assignments and practical exercises within lectures allow students to gain hands-on experience and enhance their knowledge.

The content is structured as follows:
1. Students can explain the importance of supply chain management for a firm’s strategy and success
2. Students are able to apply the tools and methods used to optimize a supply chain structure
3. Students can differentiate supply chain network designs and their applicability in specific company and sector settings
4. Students can describe and evaluate fundamental logistics and supply chain concepts
5. Students are able to explain elements of a supply chain structure and their importance for supply chain strategy
6. Students are familiar with current developments and trends in supply chain practices

Starting with the corporate strategy, firms align their supply chain strategy. They have to manage trade-offs, such as efficiency and responsiveness. Understanding a supply chain’s role within a firm and the implications of supply chain strategies for firm performance are the foundations of the course.
Micro and Macroeconomics

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<tr>
<td>363-0565-00L</td>
<td>Principles of Macroeconomics</td>
<td>W+</td>
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<td>J.-E. Sturm</td>
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Abstract
This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

Objective
This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to every-day economic problems.

Content
This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

Lecture notes
The course Moodle page contains announcements, course information and lecture slides.

Literature

This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filippini).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies assessed
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Self-presentation and Social Influence fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

363-0503-00L Principles of Microeconomics

W+ 3 credits 2G M. Filippini

Abstract
The course introduces basic principles, problems and approaches of microeconomics. This provides the students with reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution.

Objective
The learning objectives of the course are:

1. Students must be able to discuss basic principles, problems and approaches in microeconomics. (2) Students can analyse and explain simple economic principles in a market using supply and demand graphs. (3) Students can contrast different market structures and describe firm and consumer behaviour. (4) Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole. (5) Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics. (6) Students can apply simple mathematical concepts on economic problems.
A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics, economics of non-renewable resources, economics of renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.

Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then allows for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture "Principles of Microeconomics" is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.

Topics covered by the course are:

- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade


Complementary:

GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.

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| Abstract | Relationship between economy and environment, market failures, external effects and public goods, contingent valuation, internalisation of externalities, economics of non-renewable resources, economics of renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems. |

| Objective | A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change. |

| Content | The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power. When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy. |

Introduction to Marketing

Number: 363-0403-00L
Title: Introduction to Marketing
Type: W+ 3 credits 2G
ECTS: 3 credits
Lecturers: F. von Wangenheim, P. Bachmann

Abstract:
This course provides an overview on essential perspectives of marketing and how marketing adds value to a business. It will teach concepts, frameworks and methods for marketing decision making. The course will also look at issues related to marketing implementation. Thereby, a particular focus will be on how data and data analytics can help to support marketers in their decision making.

Objective:
After taking the class, students will be able to:
1) Understand how marketing adds value to a business.
2) Provide an overview of key concepts in marketing that are applicable to any business.
3) Understand how consumers behave and how this impacts marketing.
4) Learn how analytics and quantitative methods can help to improve decision making in marketing.
5) Get to know the elements that shape a firm’s marketing strategy (segmentation, targeting, positioning) and marketing tactics (product, price, promotion, place).

Content:
The class will center on the importance of marketing as an activity that creates long-term value for the benefit of organizations and their customers. It will teach concepts, frameworks and methods for marketing decision making. Specifically, the course is aims to provide students with:

- an overview on the role of marketing within a business,
- details on strategic marketing management decisions and tools,
- a profound knowledge on the individual elements of the marketing mix (product, price, promotion, place),
- an awareness of specific contexts of marketing,
- first-hand experience on data-driven techniques to support marketers’ decision making.

Thus, this course will introduce key analytical tools to help solving respective managerial tasks. This is a lecture with integrated exercises. Access to a laptop is required for the exercises. The class might be thought in an in-person, remote or in a hybrid format. Students might also be taught via pre-recorded videos and assigned material for self-study.

Literature:

The course might comprise mandatory and supplemental reading material. Other literature may be assigned in class.

Method-specific Competencies

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies
Analytical Competencies

Competencies

Assessed

Assessed

Assessed

Assessed

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Assessed
**Abstract**

This course introduces central theories, frameworks, and tools for developing competitive strategies.

**Objective**

The Strategic Management course aims to impart relevant competencies in strategic management, both for professional and academic development. This course offers an introduction to the fundamentals of strategy and the most widely used concepts and methods in strategic management. The course is delivered through a combination of lectures on concepts and methods, as well as case studies where students work on solving strategic issues of the case companies. The course participants will also have the opportunity to engage with firm executives, gaining insights into the real-time strategic challenges that organizations encounter, thereby acquiring practical experience.

**Content**

- **23.09.2024**: Entering the field and course logistics
- **30.09.2024**: Industry dynamics I: Industry analysis + Guest Lecture 1
- **14.10.2024**: The resource-based theory of the firm + Cases
- **28.10.2024**: The knowledge-based theory of the firm + Cases
- **11.11.2024**: Industry dynamics II: Analysis of technology and innovation + Cases
- **25.11.2024**: Wrap-up + Cases + Guest Lecture 2

The Strategic Management course delivers a comprehensive learning experience by integrating lectures on fundamental theories and concepts with practical case studies. This approach allows course participants to develop a deep understanding of essential and contemporary issues in the field, while providing opportunities for the practical application of these theoretical insights to strategic challenges faced by businesses.

The course focuses on competitive strategy, which involves analyzing and establishing a firm's position within an industry to ensure its performance. This is achieved through exploring topics such as industry structure, industry evolution, and the analysis of a firm's resources and knowledge, as well as innovation.

To succeed in the course, course participants are expected to read and understand the required readings, which consist of publications covering the most important research in management and strategy.

To emphasize the relevance of Strategic Management in real-world situations, senior executives of Swiss companies will hold guest lectures to provide their insights on strategy in practice and current topics in the field.

For further questions and if you are unable to sign up through myStudies, please contact the course assistant: http://www.smi.ethz.ch/education/practicing-strategy.html

For more information please see: http://www.smi.ethz.ch/education/practicing-strategy.html
This course focuses on the sources of innovation (with a specific focus on digital technologies), the tools and techniques that organizations deploy to innovate routinely, and the strategic implications of technical change at different levels of analysis: individuals, firms and whole ecosystems.

This course intends to enable all students to:

- Acquire and understand the basic jargon, concepts and methods necessary to discuss, in a precise and concise manner, innovation processes and their outcomes at different levels of analysis
- Analyze the differences between individual and organizational decision processes and their innovative outcomes
- Evaluate critically the potential of different (digital) technologies to impact business organizations.

Organizations and people are faced with a fundamental decision: they have to allocate resources between well-known tasks that reliably generate positive results; or explore new ways of doing things, new technologies, products and services. The latter is a high risk choice. Its rewards can be high, but the chances of success are small. How do firms organize to take these decisions? What kind of management skills are necessary to take them? What kind of tools and methods are deployed to sustain managerial decision-making in highly volatile environments? These are the central questions on which this course focuses, relying on a combination of lectures, case-based discussion, and guest speakers.

This course focuses on the sources of innovation (with a specific focus on digital technologies), the tools and techniques that organizations deploy to innovate routinely, and the strategic implications of technical change at different levels of analysis: individuals, firms and whole ecosystems.

- Evaluate critically the potential of different (digital) technologies to impact business organizations.

The course content and methods are designed for students with some background in management and/or economics.

The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.

Weekly self-study tasks are used to apply the concepts introduced in the lectures.

We practice how to solve nonlinear models formally and numerically and how to interpret the results.

We start with a comparison of different modeling approaches, to highlight the problems and challenges of system modeling.

We focus on two sources of complexity: (a) nonlinear dynamics, which is captured in this course, "Economic Dynamics and Complexity" and (b) collective interactions, which is captured in the course "Agent-Based Modeling of Economic Systems" (in Spring).

Our approach to economic dynamics combines insights from different disciplines: macroeconomics studying business cycles and growth, system dynamics rooted general system theory and cybernetics, and nonlinear dynamics using applied mathematics.

We start with a comparison of different modeling approaches, to highlight the problems and challenges of system modeling.

The subsequent lectures then introduce different one- and two-dimensional nonlinear models with applications in economics, such as models of supply and demand, business cycles, growth and competition.

Emphasis is on the formal analysis of these models using methods from applied mathematics and tools for solving coupled differential equations.

Weekly self-study tasks are used to apply the concepts introduced in the lectures.

We practice how to solve nonlinear models formally and numerically and how to interpret the results.

The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.

Students should be familiar with nonlinear differential equations and should have basic programming skills. All necessary details to solve nonlinear models will be provided in the course. The course will not build on mathematical proofs, optimization, statistics, efficient numerical computation and other specialized skills.
The economic environment of today's companies is characterized by high cost pressure, declining margins, intensified international competition, rising customer requirements and increasingly strict regulations. Strategic and operational decisions at all management levels are becoming more and more complex due to the increasing amount of data, interrelationships, conditions and target criteria to be considered. Often it is no longer possible to solve operational tasks with experience and common sense alone and to adequately estimate the consequences of decisions without software support.

Quantitative methods and models of operations research and operations management offer decision support for complex problems. Mathematical optimization models are used to precisely formulate operational decision problems so that they can subsequently be analysed and optimized using suitable solution methods. A large number of quantitative real-world problems can be formulated and solved in this general framework. Applications of operations research comprise, for instance, decision problems in production planning, supply chain management, transportation networks, machine and workforce scheduling, blending of components, telecommunication network design, airline fleet assignment and revenue management.

This course offers an introduction to operations research, emphasizing basic methodologies and underlying mathematical structures. The following topics are covered in detail:
- Introduction to system modelling and operations research
- Linear models and the importance of linear programming
- Duality theory in linear programming and shadow prices
- Integer programming
- Dynamic optimization (under uncertainty) and applications in inventory management.

Lecture notes
A printed script will be made available.

Literature
Any standard textbook in Operations Research is a useful complement to the course.

Prerequisites / notice
Undergraduate calculus, linear algebra, probability and statistics are a prerequisite.

The course includes out-of-class assignments to give students some hands-on experience in conducting empirical research in management. Projects will focus on one particular aspect of empirical research, like the formulation of a research question or the design of a study. Assignments will be graded and need to be turned-in on time as they will be shown and discussed in class. Class participation is encouraged and can greatly improve students’ learning. In this spirit, students are expected to attend class regularly and come to class prepared.

This course offers an introduction to operations research, emphasizing basic methodologies and underlying mathematical structures. The following topics are covered in detail:
- Introduction to system modelling and operations research
- Linear models and the importance of linear programming
- Duality theory in linear programming and shadow prices
- Integer programming
- Dynamic optimization (under uncertainty) and applications in inventory management.

Lecture notes
A printed script will be made available.

Literature
Any standard textbook in Operations Research is a useful complement to the course.

Prerequisites / notice
Undergraduate calculus, linear algebra, probability and statistics are a prerequisite.
Abstract
The course introduces to the most common empirical methods for the analysis of issues in environmental, energy, and resource economics. The course includes computer laboratory sessions, and covers the following broad topics: demand models, discrete choice models, empirical methods in policy evaluation, field- and quasi-experiments.

Objective
At the end of the course, the students will be able to: understand the most common empirical methodologies used in environmental, energy, and resource economics; understand the problems the methodologies learnt in class aim to address; appreciate the importance of causal inference in empirical economics; read and understand the research papers in the literature; apply the empirical methods learnt in class using the software R.

Content
The course introduces students to empirical statistical methods that have wide application in environmental, energy, and resource economics and it is divided in four blocks. The first block is a quick review of the basic econometric methodology and concepts (OLS, standard errors, logit/probit models); the second block introduces demand models like the Almost Ideal Demand System, discrete choice models, and their evolutions; the third block explores causal inference in empirical economics and the main reduced-form econometric techniques used in policy evaluation, such as difference-in-differences, regression discontinuity and synthetic control; the fourth block introduces field experiments and instrumental variables, and their characteristics.

At the end of each block there will be a computer laboratory class in which the student will learn to apply the methodologies learnt in class using the statistical open-source software R. Throughout the course, students will have the chance to work on actual data used for analysis in economics papers.

The lectures will make use of current research papers in the literature to illustrate practical examples in which the methodologies learnt in class have been used. Students will be expected to read in advance the paper that will be explained during the lecture.

The evaluation policy has the aim to allow students to get practical experience on the econometric methodologies learnt in class. Thus, beyond a final open-book computer exercise exam (60% of the grade), the course includes short takehome computer exercises (40% of the grade).

As the course will be centered on econometric methods, it is recommended that students have taken 363-0570-00L Principles of Econometrics first, or have otherwise a solid knowledge of basic econometric methodologies as detailed in Part 1 of Wooldridge, Jeffrey M. (2018) Introductory Econometrics: A Modern Approach. Seventh ed. ISBN: 978-1-337-55886-0. Knowledge of statistical software R is helpful, but not required and will be taught in the computer laboratory sessions.

Prerequisites / notice
It is highly recommended to take 363-0570-00L Principles of Econometrics first.

Competencies
Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Problem-solving

Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-direction and Self-management

363-1136-00L Dynamic Macroeconomics, Innovation and Growth

Students who have successfully completed the course "Dynamic Macroeconomics" (364-0559-00L) or "Economics of Innovation and Growth" (363-0562-01L) can not register for this course.

Abstract
Introducing dynamic models and workhorses in macroeconomics, understanding the role of innovation and institutions for economic development and discussing policies to foster innovation and economic growth.

Objective
After the course, students will be familiar with dynamic general equilibrium theory and the basic workhorse models in macroeconomics. Participants will be able to apply the frameworks to interesting issues, such as innovation and growth. Moreover, students will understand how the world has developed over the last centuries and the proximate and fundamental causes of innovation and economic growth. Students will understand and apply the basic models of economic growth and will be able to identify policies to foster innovation and growth and to reduce the large wealth differences in the world. Finally, they will get an idea how digitization and artificial intelligence might drive economic growth.

Content
1. Introduction
2. The Solow Model
3. The Neoclassical Growth Model (with Mathematical Background)
4. Technological Progress and how the World has developed
5. Innovations and Growth (New Growth Theory)
6. Growth Policies and Fundamental Causes for Growth
7. Digitization and Artificial Intelligence

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Multinational firms have grown in importance in recent decades. Given that their affiliates are located in different countries, they face differences in tax provisions and how governments will respond to this behavior in its choice of tax systems. Different channels how multinational firms allocate taxable profits across countries will be analyzed: transfer pricing policies, internal financing decisions and agency problems and their relation to tax policy.

The course has two parts: The first part of the lecture contains a detailed treatment of the different channels multinational firms can use to strategically allocate profits to low-tax countries and how the tax avoidance decision might interfere with other decisions of the multinational firm. Building on this insight, we will discuss whether governments might strategically choose to adjust its tax provisions either to benefit from the multinational firm tax-saving behavior or to protect its tax base against the tax-planning behavior. In the second part of the course, we will discuss different papers that empirically analyze the validity of the different channels we have discussed in the first part. Students will be able to read and understand regression output tables. Additionally, students will be able to apply the estimation approaches in practice using STATA.

Literature
14. Current Literature on Digitization and Artificial Intelligence

Prerequisites / notice
Students who have successfully completed the course "Dynamic Macroeconomics" (364-0559-00L) or "Economics of Innovation and Growth" (363-0562-01L) can not register for this course.

Competencies
- Understanding how taxes influence decisions of multinational firms
- Develop thinking about the strategic use of differential tax systems for multinational firms
- Evaluate options for governments to respond to the tax planning behavior of multinational firms
- Using theoretical models and empirical analysis to uncover regularities in how multinational firms respond to taxes

Content
Multinational firms have grown in importance in recent decades. Given that their affiliates are located in different countries, they face various tax systems. This creates complexity with respect to the operation of a multinational firm, but also offers the option to benefit from differences across various tax provisions. Starting from this observation, the course looks at how multinational firms respond to the differences in tax provisions and how governments will respond to this behavior in its choice of tax systems. Different channels how multinational firms allocate taxable profits across countries will be analyzed: transfer pricing policies, internal financing decisions and investments. A particular emphasis will be put on how agency problems within multinational firms interact with tax avoidance behavior and how they are related to tax policy.

Afterwards, we will enter a discussion of the presented paper and clarify unaddressed issues.

Competencies
- Understanding how taxes influence decisions of multinational firms
- Develop thinking about the strategic use of differential tax systems for multinational firms
- Evaluate options for governments to respond to the tax planning behavior of multinational firms
- Using theoretical models and empirical analysis to uncover regularities in how multinational firms respond to taxes

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The course will tentatively cover the following subjects:
- review of ordinary least squares (OLS) estimation
- instrumental variable estimation and two-stage least squares estimation
- seemingly unrelated regression models
- simultaneous equation models
- maximum likelihood estimation
- binary response models
- count data models
- censored and truncated regression models
- sample selection models
- treatment effect models
- static linear panel data models (random effects and fixed effects estimation)

For the theoretical portions of the lectures, we will prepare slides for in-class discussion. The format of the course is in-person. Slides will be distributed electronically before each lecture.

For the applied portion of the lectures, we will provide STATA do files, log files, and data sets.

Problem sets will also be made available after every lecture. These problem sets will not be collected or graded, but students can use them in order to prepare for the final exam. Solutions will be made available in the following lecture.

While there is no required textbook for the course, we draw from the following texts, which are also recommended for the preparation of the exam:

Prior basic knowledge of matrix algebra and probability theory is strongly recommended.

Prerequisites

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Labor Economics

The course will tentatively cover the following subjects:
- linear probability models
- logit and probit models
- binary response models
- count data models
- dynamic panel data models
- treatment effect models
- sample selection models
- censored and truncated regression models
- seemingly unrelated regression models
- simultaneous equation models
- maximum likelihood estimation
- instrumental variable estimation
- minimum wage effects
- unemployment insurance
- unemployment
- minimum wage
- welfare
- wage compression
- wage dispersion
- wage inequality

The lectures will consist of both theoretical and practical components. In the theoretical part, we will discuss each estimation approach in detail. The lecture will present the assumptions, derivations, as well as the advantages and disadvantages of the estimation approach.

In the empirical part, we will look at simulation results using artificial data. Furthermore, we will investigate a particular research question using STATA.

The main aim of this course is to analyse the goals of monetary policy and to review the instruments available to central banks in order to pursue these goals. It will focus on the transmission mechanisms of monetary policy and the differences between monetary policy rules and discretionary policy. It will also make connections between theoretical economic concepts and current real world issues.

363-1021-00L Monetary Policy

W 3 credits 2V J.-E. Sturm, A. Rathke

The lecture provides an introduction to central issues in labor economics, including the determinants of labor supply, firms' demand for workers, minimum wages, unemployment, wage inequality, the effects of digital technologies on the labor market, and labor market discrimination. It presents research papers on these issues and discusses the empirical challenges related to their research designs.

In this course, students will get answers to a range of relevant questions about modern labor markets: Who works, how much, and why? Do people work less if they have a universal (guaranteed) income or pay higher taxes? How does a firm determine its employment? Does a minimum wage reduce the employment of workers it intends to help? How does unemployment arise? Did technological change (e.g., computers and robots) contribute to the rise in wage inequality in developed countries? How does generative artificial intelligence (AI) affect the labor market? Is there wage and hiring discrimination against women, men, and foreigners in the labor market, and if so, why? After presenting how modern labor economics conceptualizes these issues, the course discusses state-of-the-art empirical research papers that answer these questions. In this context, the course familiarizes students with modern data science methods that researchers apply to get causal answers to research questions. This introduction to modern applied economics does not require any prior background in economics or statistics.

The lecture targets students interested in the functioning of labor markets and the academic debate about specific labor market policies. A second target group is students that want to learn how modern empirical research in labor economics uses big data to analyze central issues in labor economics.

The performance will be assessed based on a written exam at the end of the semester.

363-1159-00L Labor Economics
Objective
This lecture will introduce the fundamentals of monetary economics and explain the working and impact of monetary policy. The main aim of this course is to describe and analyze the goals of monetary policy and to review the instruments available to central banks in order to pursue these goals. It will focus on the transmission mechanisms of monetary policy, the effectiveness of monetary policy actions, the differences between monetary policy rules and discretionary policy, as well as in institutional issues concerning central banks, transparency of monetary authorities and monetary policy in a monetary union framework. Moreover, we discuss the implementation of monetary policy in practice and the design of optimal policy.

Content
For the functioning of today's economy, central banks and their policies play an important role. Monetary policy is the policy adopted by the monetary authority of a country, the central bank. The central bank controls either the interest rate payable on very short-term borrowing or the money supply, often targeting inflation or the interest rate to ensure price stability and general trust in the currency. This monetary policy course looks into today's major questions related to policies of central banks. It provides insights into the monetary policy process using core economic principles and real-world examples.

Lecture notes
The course Moodle page contains announcements, course information and lecture slides.

Literature
The course will be based on chapters of:

Prerequisites / notice
Basic knowledge in international economics and a good background in macroeconomics.

Competencies

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363-1177-00L  Monetary Theory  W  3 credits  2G  H. J. van Buggenum

Abstract
We cover the three most important models of monetary theory that are used for the conduct of monetary policy. The models are covered from both a theoretical perspective - in terms of the model and their intuition - and a practical perspective, in terms of how the models can be solved numerically and how they can be used to understand monetary-policy issues.

Objective
After taking this course, students will be able to:
- Understand why intrinsically useless assets such as banknotes have value, i.e., understand the role of assets (money in particular) as a means of payment.
- Understand why nominal assets can be of real importance, i.e., understand the role of money as a unit of account.
- Understand inflation and interest-rate dynamics, and how these relate to real economic activity and expectations.
- Understand and apply models that are used for the conduct of monetary policy.
- Solve dynamic macro models with a computer, for instance with Python, Matlab and Dynare.
- Apply the theory to some empirically relevant issues for monetary policy, including: the 2008-2009 financial crisis; the zero-lower bound on nominal interest rates; and large supply and demand shocks.

Content
The course is aimed at students who:
- are interested in economics in general and monetary economics in specific;
- are interested in how mathematical models can be used to capture real-world phenomena, particularly those related to money, inflation, and interest rates.
- command over good mathematical skills;
- command over good knowledge of microeconomics and macroeconomics, for instance from core courses in the Master program;
- Students who fulfill these requirements will benefit from the course in the following dimensions:
  - they will gain a deeper understanding of phenomena related to money, interest-rates and inflation, which are key elements to understand how real-world economies operate;
  - they will be able to understand models that are used by researchers and central banks to study and design monetary policy;
  - they will gain an understanding of how these models can be solved and simulated with a computer;
  - they will learn how to relate monetary theory to empirically relevant and topical issues, such as unconventional monetary policy (quantitative easing), high inflation, the zero lower bound on nominal interest rates, and financial crises.

The course consists of weekly meetings that take the form of lectures and tutorials. The provisional agenda is as follows:

Week 1-2: Cash-in-advance model; a model with a transactional role for money.
- Session 1: Lecture
- Session 2: Tutorial

Week 3-6: New-Keynesian model; the workhorse framework for monetary policy.
- Session 3: Lecture; the benchmark 3-equation model.
- Session 4: Tutorial; solving the model with the computer.
- Session 5: Lecture; monetary policy and the zero-lower bound.
- Session 6: Tutorial; monetary policy and the zero-lower bound.

Week 6-10: New-Monetarist model; a model with a role for assets as means of payment.
- Session 7: Lecture; the benchmark model.
- Session 8: Tutorial; self-fulfilling inflation dynamics.
- Session 9: Lecture; a model of monetary policy in the interbank market.
- Session 10: Tutorial; stabilization policy in the interbank market.
The course introduces students to the economics of population ageing with a focus on pensions and individual retirement behaviour. This course provides an overview of the economics of ageing and focuses on pensions and retirement decisions. It introduces participants to the state-of-art knowledge, theories, and econometric methods to conduct research in the related areas.

Objective

The course aims to provide an understanding of the economics of ageing, with a focus on pensions and retirement. After completing the course, participants will be able to:

- Understand the basic economic aspects related to demography, social insurance and retirement.
- Describe the ongoing demographic transitions in developed and developing countries.
- Understand the basic structure of pension systems.
- Discuss the risks and merits of different pension systems and reform options.
- Understand the typical research designs and methods for policy evaluation relevant to retirement.
- Understand the theoretical framework to analyse individual consumption and savings behaviours over their life cycle.
- Understand key behaviour issues relevant to retirement decisions.
- Identify research questions related to population ageing.

Content

The course introduces students to the economics of population ageing with a focus on pensions and individual retirement behaviour. The course has three parts.

The first part provides an overview of the causes and economic consequences of population ageing. Topics include:
- Measurements of ageing, and current situations of population ageing around the world.
- Mortality, fertility, and their determinants.
- Mortality compression, healthy life expectancy, health costs, and gender gap.
- Design of pension, health, and long-term care insurance systems.

The second part discusses pension systems and relevant policies. Topics include:
- Impact of pension and retirement policies on the labour market, health, long-term care, wealth and savings.
- Pension reform options and their consequences.
- Gender inequality and inter-generational fairness.
- Financial risks in pension funds and variable annuities.

The third part of the course focuses on household financial planning for retirement. Topics include:
- Empirical evidence about consumption and savings in retirement.
- Retirement savings puzzle, annuity puzzle, and demand for long-term care insurance.
- The life-cycle framework to analyse how individuals should plan for their savings, investment, insurance, and other retirement-related decisions.
- Behaviour issues that could affect retirement-related decisions, such as inertia and default, peer effect, framing, hyperbolic discounting, mental accounting, and loss aversion.
- Role of financial literacy.
- Typical experimental designs and econometric methods to examine issues in retirement planning.

References will be given on a topic-by-topic basis during the course.

Literature

- Introduction to monetary policy, inflation, and the business cycle (Gali)

363-1178-00L Population Ageing and Pension Economics W 3 credits 2V C. Wan

Abstract

Population ageing puts pressure on the sustainability of public insurance systems and increases the individual responsibility for retirement security. This course provides an overview of the economics of ageing and focuses on pensions and retirement decisions. It introduces participants to the state-of-art knowledge, theories, and econometric methods to conduct research in the related areas.

Objective

The course aims to provide an understanding of the economics of ageing, with a focus on pensions and retirement. After completing the course, participants will be able to:

- Understand the basic economic aspects related to demography, social insurance and retirement.
- Describe the ongoing demographic transitions in developed and developing countries.
- Understand the basic structure of pension systems.
- Discuss the risks and merits of different pension systems and reform options.
- Understand the typical research designs and methods for policy evaluation relevant to retirement.
- Understand the theoretical framework to analyse individual consumption and savings behaviours over their life cycle.
- Understand key behaviour issues relevant to retirement decisions.
- Identify research questions related to population ageing.

Content

The course introduces students to the economics of population ageing with a focus on pensions and individual retirement behaviour. The course has three parts.

The first part provides an overview of the causes and economic consequences of population ageing. Topics include:
- Measurements of ageing, and current situations of population ageing around the world.
- Mortality, fertility, and their determinants.
- Mortality compression, healthy life expectancy, health costs, and gender gap.
- Design of pension, health, and long-term care insurance systems.

The second part discusses pension systems and relevant policies. Topics include:
- Impact of pension and retirement policies on the labour market, health, long-term care, wealth and savings.
- Pension reform options and their consequences.
- Gender inequality and inter-generational fairness.
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- Empirical evidence about consumption and savings in retirement.
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- Role of financial literacy.
- Typical experimental designs and econometric methods to examine issues in retirement planning.

References will be given on a topic-by-topic basis during the course.

Literature

- Introduction to monetary policy, inflation, and the business cycle (Gali)

363-1161-00L Time Series Econometrics and Macroeconomic Forecasting W 3 credits 2V S. Sarfaraz

Abstract

This course introduces the methods for analyzing and forecasting macroeconomic activity using multivariate time series analysis. We will study econometric models that central banks, government agencies and other research institutions use to analyze and forecasts macroeconomic variables.

Objective

How will the overall economy develop during the next quarters and years? What is the impact of the exchange rate on economic activity and inflation? How should we derive macroeconomic scenarios under alternative assumptions about the evolution of key variables like oil prices, exchange rates or the world economic activity? What are the effects of changes in monetary policy, fiscal policy or COVID-19 on economic activity? After completing this course, students will be able to tackle these and related questions using multivariate time series methods as applied by researchers and professional forecasters.
The course covers the following topics:

- Vector autoregressive (VAR) models
- Identification of macroeconomic shocks
- Conditional forecasting (macroeconomic scenario analysis)
- State space models
- Macroeconometrics and Big Data

During computer exercises, we utilize the time series models to study real world examples using R.

Prerequisites:

- Principles of Macroeconomics
- Principles of Econometrics

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| Social Competencies              | Communication                 | fostered              |          |
|                                  | Cooperation and Teamwork      | assessed              |          |
|                                  | Customer Orientation          | fostered              |          |
|                                  | Leadership and Responsibility | fostered              |          |

| Personal Competencies            | Adaptability and Flexibility  | fostered              |          |
|                                  | Creative Thinking             | assessed              |          |
|                                  | Critical Thinking             | assessed              |          |
|                                  | Self-awareness and Self-reflection | fostered          |          |
|                                  | Self-direction and Self-management | fostered              |          |

**363-1047-00L Urban Systems and Transportation**

**Abstract**

This course is an introduction to urban and regional economics. It focuses on the formation and development of urban systems, and highlights how transport infrastructure investments can affect the location, size and composition of such systems.

**Objective**

The main objective of this course is to provide students with some basic tools to analyze the fundamental economic forces at play in urban systems (i.e., agglomeration and congestion forces), and the role of transport networks in shaping the structure of these systems. Why do urban areas grow or decline? How do transport networks affect the location of individuals and firms? Does the location of a firm determine its productivity? Can transport infrastructure investments reduce economic disparities? These are some of the questions that students should be able to answer after having completed the course.

**Content**

The course is organized in four parts. I start with the key observation that economic activity (both in terms of population density and productivity) is unevenly distributed in space. For instance, the share of the population living in urban centers is increasing globally, from 16% in 1900 and 50% in 2000 to about 68% by the year 2050 (UN, World Economic Prospects, 2014). The goal of the first part is then to understand the economic forces at play behind these trends, looking at the effects within and across urban areas. I will also discuss how natural or man-made geographical characteristics (e.g., rivers, mountains, borders, etc.) affect the development of such urban systems.

In the second part, I discuss the planning and pricing of transport networks, moving from simple local models to more complex transport models at a global scale. The key aspects include: the first and second best road pricing, the public provision of transport networks and the demographic effects of transport networks.

In the third part, I combine the previous two parts and analyze the interaction between urban systems and transportation. Thereby, the main focus is to understand the economic mechanisms that can lead to a general equilibrium of all actors involved. However, as the study of the historical development of urban systems and transport networks provides interesting insights, I will discuss how their interaction in the past shapes today’s economic geography.

Finally, I broaden the scope of the course and explore related topics. There will be a particular emphasis on the relation between urban systems and fiscal federalism as well as environmental policies. Both aspects are important determinants of the contemporary developments of urban systems, and as such deserve our attention.

**Lecture notes**
Course slides will be made available to students prior to each class.

**Literature**
Course slides will be made available to students.

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**363-1180-00L Methodological Foundations of Economics**

**Abstract**

A tremendous share of how our societies function is governed by economics. Yet, economic research is rarely unanimous, often challenged and always hard to navigate. Taking a journey through commonly employed methods and their underlying assumptions, students will learn how to critically assess academic knowledge on concrete questions. A large share of the course will be devoted to case studies.

**Objective**

1. Have a solid understanding of the different methodologies employed in economics, know their strengths and limitations.
2. Select among methodologies employed in economics in function of a specific applied need.
3. Identify core assumptions in economic research papers and assess the scope of their results.
4. Forming an opinion on an applied economic topic based on academic work with the right critical distance.
Economic models rely on assumptions which are wrong. In economics, theoretical but also empirical studies often contradict each other, even among the most celebrated contributions. Behind its methods borrowed to natural sciences, economics rely on strong postulates and on different schools of thought. How should we handle contradictions, idealizing hypotheses or results too good to be true? What do we actually learn about the social world through economic research?

In this course, we will face those questions from both a theoretical and a practical perspective.

On the theoretical side, our approach will be an epistemological one. We will reflect on the methodological foundations of economics and the type of knowledge it aims to produce. We will dig into some of its most central concepts: the quest for causality, equilibrium reasonings, and the revealed preferences approach. While conceptual, our journey will take us through the formal foundations of econometrics, decision theory, and game theory.

On the practical side, the aim is to equip students with the necessary tools to effectively navigate existing economic research to obtain answers to real-world questions. After this course students will be able to form a critical opinion on topical matters, such as “should public debt be canceled in developing countries?” or “are the Paris agreements good news for the climate?”, without being experts on these questions.

Overall this course can be seen as an epistemological introduction to economics as well as methodological training for using academic knowledge in real life. It is thus intended for a general audience interested in economics, without specific previous training needed.

Lectures will be structured around a theoretical introduction and a paper’s discussion by the teacher, followed by a group discussion on other papers. Students are expected to prepare this discussion in groups and will be graded according to their participation. An additional evaluation will take place through a final exam.

**Literature**

- Game theory and economic modeling, (1990) David Kreps
- A model of competing narratives, (2020) Kfir Eliaz and Ran Spiegler
- A Course in Game Theory, (1994) Osborne and Rubinstein
- Between Mathematical Formalism, Normative Choice Rules, and the Behavioural Sciences: The Emergence of Rational Choice Theories in the late 1940s and early 1950s, (2017) Catherine Herfeld

**Competencies**

**Subject-specific Competencies**

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

**Social Competencies**

- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**

- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed
Asset Liability Management and Treasury Risks fostered

The objective of this course is to introduce students to the formal analysis of politics, via economic models.

After completing this course:
- Students will be able to analyze economic models of politics and interpret the results.
- Students will be able to evaluate economic models of politics.
- Students will be able to interpret real-world political phenomena in terms of economic models.
- Students will be able to develop and create new insights for politics using economic models.

This course will introduce students to a variety of foundational economic models of politics and policy making. This includes—but is not limited to—models of electoral competition, political agency, legislative bargaining, and the interaction between political and market outcomes (e.g., via market and business regulations).

The course material will mainly be theoretical and mathematical (primarily using game theory). Real-world examples and empirical research will be discussed to help motivate and evaluate the theoretical material. Most of the content will focus on the United States, for which rich theoretical and empirical literatures exist. However, the key tools, ideas, and insights can be applied more generally and beyond the United States.

The course assumes basic mathematical competencies (e.g., familiarity with algebra, multi-variable calculus, and probability). We will not assume prior knowledge of game theory—the course will introduce game theoretic concept as they are required. However, having previously taken an introductory course in game theory will be an advantage (e.g., D-MTEC courses such as: 363-0558-00L “Introduction to Game Theory: Strategic and Cooperative Thinking” or the recent edition of 363-0515-00L “Decisions, Markets, and Games”).

The course material primarily draws from the following textbook:

Other useful resources:

Prerequisites / notice
There are no formal admission requirements. It is expected that students have a basic level of mathematical competence. It will be beneficial if students have taken an undergraduate level course in microeconomics or game theory.

Literature
The course material primarily draws from the following textbook:

Other useful resources:

Methods
- Students will be able to develop and create new insights for politics using economic models.
- Students will be able to interpret real-world political phenomena in terms of economic models.
- Students will be able to evaluate economic models of politics.
- Students will be able to interpret real-world political phenomena in terms of economic models.
- Students will be able to develop and create new insights for politics using economic models.

Social Competencies
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

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Abstract
Asset Liability Management (ALM) is key to the financial success of any corporation. The goal is to develop a comprehensive understanding of the nature of corporate balance sheet and off-balance sheet positions and related profits and losses, including identification and mitigation of undue risks taken. This course is geared towards preparing students to apply these concepts in practical settings.

Objective
The main learning objectives of this course are:
- develop a comprehensive understanding of the nature of corporate balance sheet and off-balance sheet positions and their respective contribution to profits and losses
- measure and assess exposures to risk factors such as interest and FX rates, equity and commodity prices, as well as liquidity events
- trading and hedging to mitigate undue risks incurred

Content
The course is organized around a series of case studies. We will first discuss and develop an understanding of the fundamentals on different aspects of the management and risk management of the balance sheet. Using real life case studies each concept will then be directly applied and tested. In-class discussions, presentations and one written assignment are used to facilitate active and interactive learning in a stimulating environment. During the case studies students will frequently work in small groups. Therefore, the number of participants is limited to 40.

The course focuses on the application of finance concepts to the financial management of corporations and is geared towards preparing students to apply these concepts in practical settings. Executives of all sectors are expected to have a sound understanding of the content covered. As such, the course is not exclusively targeted at students who are considering a career in the financial services sector. It also recommended for students who want to work in the finance, treasury or risk area of corporates. It is also suitable for students who want to work for a consultancy firm.
"Corporate Finance" is an introductory course that presents those fundamental principles of finance that find direct application in the financial decisions of modern corporations. The course is structured in three parts: (i) Corporate Finance and Corporate Governance, (ii) Investment Decisions/Valuation, (iii) Financial Policy.

Upon successful conclusion of the course, students will:

1) know what corporate finance and corporate governance are about;
2) be able to price a wide array of corporate securities, assets, and projects, e.g., stocks, bonds, and options;
3) master three valuation approaches (discounted cash-flow valuation, relative valuation, and real-options valuation) and know about their applicability, their strengths, and their weaknesses;
4) know how to finance firms at different stages of their lifecycle;
5) be familiar with terms, acronyms, and concepts in the world of finance;
6) know how to relate real-world corporate events (past and current) to concepts learnt in class;
7) have increased their appeal as future manager, employee or entrepreneur by relevant knowledge in the field of finance in general and corporate finance in particular.

Part I: Corporate Finance and Corporate Governance
- Corporations and their characteristics (e.g., centralized management, limited liability, free transferability of economic claims, legal personality)
- Corporate finance and its goals (e.g., shareholder-value approach vs. stakeholder-value approach)
- Corporate governance problems and possible solutions (e.g., over-investment, under-investment, self-dealing, monetary incentives, board of directors, the market of corporate control, leverage, product-market competition)

Part II: Investment Decisions/Valuation
- Discounting and compounding
- Present value tools (e.g., perpetuities, growing perpetuities, annuities, growing annuities)
- Bond pricing and interest rates (e.g., types of bonds, term structure of interest rates, yield-to-maturity, duration concepts, forward rates, "riding the yield curve")
- Risk and return (e.g., moments of stock returns, modern portfolio theory, capital market line, systematic risk vs. unsystematic risk)
- CAPM in practice (e.g., computation of the risk free interest rate, beta, and the market risk premium; security market line)
- DCF Analysis: Cost of capital and cash flow estimation
- Relative valuation (e.g., earnings multiples, book multiples, sales multiples, fundamental drivers of multiples)
- Real options (e.g., option to abandon, option to delay, option to expand)

Part III: Financial Policy
- Corporate financing (e.g., instruments, internal vs. external financing, equity financing vs. debt financing, crowdfunding, M&M and beyond)
- Payout policy (e.g., dividends, par value reductions, share buybacks, M&M and beyond)

For the exam, only the material provided will be relevant. However, interested students may refer to the following textbook for an alternative, or a complementary, reading:

Objective
After taking this course, students will be able to
- Understand the fundamentals of emerging technologies like supervised learning, unsupervised learning, reinforcement learning or quantum computing.
- Understand recent technological developments in financial services and how they drive transformation, e.g. see applications from fraud detection, credit risk assessment, portfolio optimization.
- Reflect about the challenges of implementing machine learning in finance, e.g. data quality and availability, regulatory compliance, model interpretability and transparency, cybersecurity risks.
- Understand the importance of continued research and development in machine learning in finance.

Content
Overall, emerging technologies are transforming the finance and insurance industries by improving efficiency, reducing costs, enhancing customer experiences, and facilitating innovation. Hence, the financial manager of the future is commanding a wide set of skills ranging from a profound understanding of technological advances and a sensible understanding of the impact on workflows and business models.

Students with an interest in finance, banking and insurance are invited to take the course without explicit theoretical knowledge in financial economics. As the course will cover topics like machine learning, cyber security, quantum computing, an understanding of these technologies is welcomed, however not mandatory.

The course will also go beyond technological advances and will also cover management-related contents. Invited guest speakers will contribute to the sessions. In addition, separate networking sessions will provide entry opportunities into finance and banking. Selected guest speakers will cover different application from the field of finance and insurance, e.g.
- Fraud detection: Machine learning algorithms can be trained to identify unusual patterns in financial transactions, helping to detect fraudulent activities.
- Credit scoring: Machine learning can be used to develop more accurate credit scoring models, taking into account a wider range of data points than traditional models.
- Investment analysis: Machine learning can be used to analyze market trends, identify potential investment opportunities, and develop predictive models for asset prices.
- Risk management: Machine learning can be used to model and forecast risk, helping financial institutions to manage and mitigate risk more effectively.

The course is divided in sections, each covering different areas and technologies. Students are asked to solve a short in-class exam and one out of two group exercises cases.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies fostered
- Project Management assessed

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Self-direction and Self-management fostered

Human and Entrepreneurial Behaviour

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>363-1082-00L</td>
<td>Enabling Entrepreneurship: From Science to Startup</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>R. De Cock</td>
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</table>

Students should provide a brief overview (unto 1 page) of their business ideas that they would like to commercialise through the course. If they do not have an idea, they are required to provide a motivation letter stating why they would like to do this elective. If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

The total number of students will be limited to 50.

The students should submit the necessary information until 25 September 2024 and apply to Robin De Cock: Robin.DeCock@uantwerpen.be.

Abstract
This elective is relevant for students who have developed a technology and are keen to evaluate the steps in starting a startup. This is also relevant for students who would like to start a startup but do not have a technology, but are clear on a specific market and the impact they would like to create.

Objective
Students have technology competence or an idea that they would like to convert into a startup. They are now in the process of evaluating the steps necessary to do so. In summary:

1. Students want to become entrepreneurs.
2. The students can be from business or science & technology.
3. The course will enable the students to identify the relevance of their technology or idea from the market relevance perspective and thereby create a business case to take it to market.
4. The students will have exposure to investors and entrepreneurs (with a focus on ETH spin-offs) through the course, to gain insight to commercialise their idea.
The students would cover the following topics, as the build their idea into a business case:

1. Technology excellence: this assumes that the student has achieved a certain degree of competence in the area of technology that he or she expects to bring to the market
2. Market need and market relevance: The student would then be expected to identify the possible markets that may find the technology of relevance. Market relevance implies the process of identification of how relevant the market perceives the technology, and whether this can sustain over a longer period of time
3. IP and IP strategy: Intellectual property, whether in the form of a patent or a trade secret, implies the secret ingredient that enables the student to achieve certain results that competitors are unable to copy. This enables the student (and subsequently the startup) to hold on to the market that they create with customers
4. Team including future capabilities required: a startup requires multiple people with complementary capabilities. They also need to be motivated while at the same time protecting the interests of the startup
5. Financials: There is a need of funding to achieve milestones. This includes funding for salaries and running of the company
6. Investors and funding options: There are multiple funding options for a startup. They all come with different advantages and limitations. It's important for a startup to recognise its needs and find the investors that fit these needs and are best aligned with the vision of the founders
7. Preparation of business case: The students will finally prepare the business case that can help them to articulate the link of the technology with the market need and its willingness to pay
8. Legal overview, company forms and shareholders' agreements (including pitfalls)

The seminar includes talks from invited investors, entrepreneurs and legal experts regarding the importance of the various elements being covered in content, workshops and teamwork. There is a particular emphasis on market validation on each step of the journey, to ensure relevance.

Lecture notes
Since the course will revolve around the ideas of the students, the notes will be for the sole purpose of providing guidance to the students to help convert their technologies or ideas into business cases for the purpose of forming startups. Theoretical subject matter will be kept to a minimum and is not the focus of the course.

Literature
Book
Sethi, A. “From Science to Startup”
ISBN 978-3-319-30422-9

Prerequisites / notice
This course is relevant for those students who aspire to become entrepreneurs.

Students applying for this course are requested to submit a 1 page business idea or, in case they don't have a business idea, a brief motivation letter stating why they would like to do this course.

If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

Competencies
Subject-specific Competencies
Concepts and Theories fostered
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving fostered
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility assessed
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

363-0311-00L Psychological Aspects of Risk Management and Technology
W 3 credits 2V
N. Bienefeld-Seall, G. Grote, R. Schneider, M. Zumbühl

Abstract
Using uncertainty management by organizations and individuals as conceptual framework, risk management and risk implications of new technologies are treated. Three components of risk management (risk identification/evaluation, risk mitigation, risk communication) and underlying psychological and organizational processes are discussed, using company case studies to promote in-depth understanding.

Objective
- You know how risk and risk management is defined and applied in different industries
- You know the challenges of decision making under risk and uncertainty and its effects on organisations
- Know about and (partially) apply some risk management tools
- Gain some more in-depth knowledge in a selected field within risk management through the semester project (e.g. transport systems, IT, insurance)

This course consists of three main elements:

A) Attendance of lectures that provide the theoretical foundations of “Psychological Aspects of Risk Management and Technology” together with reading assignments for each lecture.

B) Attendance of guest lectures that provide a rich source of practical insights and enable the transfer of theory into practice by discussing real-life cases with experts from various industries.

C) Furthermore, this course enables you to apply what you have learned in the classroom into practice by participating in a group assignment in which you gain insights into various risk industries (e.g., aviation, healthcare, insurance) and topics (e.g., risks in cyber-attacks, mountaineering, autonomous vehicles). These projects help students understand key aspects through in-depth application of the course material on real-life topics. Each group project will be mentored and graded by one of the lecturers (70% of course grade). To round off the course at the end of the year, you will have the opportunity to present your group’s findings to the lecturers and to your peers (30% of course grade).
The course is organized into fourteen sessions. Sessions comprise a mixture of (guest) lectures, case discussions, and presentations. Through class discussion we will further deepen understanding of the topics and themes of the class. For each session you are required to prepare by reading the assigned literature or case material provided on the Moodle e-learning platform. Topics covered include:

- Elements of risk management:
  - Risk identification and evaluation
  - Risk mitigation
  - Risk communication

- Psychological and organizational concepts relevant in risk management
  - Decision-making under uncertainty
  - Risk perception
  - Resilient organizational processes for managing uncertainty

- Case studies on different elements of risk management (e.g., rule-making, training, managing project risks, automation)

- Group projects related to company case studies

Lecture notes
There is no script, but slides will be made available before the lectures.

Literature
There are texts for each of the course topics made available before the lectures.

Prerequisites / notice
The course is restricted to 40 participants who will work closely with the lecturers on case studies prepared by the lecturers on topics relevant in their own companies (SWICA, SWISS, University Hospital Zurich).

Competencies

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<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td>Problem-solving</td>
<td>fostered</td>
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<td>Project Management</td>
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<td>Social Competencies</td>
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<td>Self-direction and Self-management</td>
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363-0790-00L Technology Entrepreneurship W 2 credits 2V F. Hacklin

Abstract
Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding. This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are success factors in the creation of new firms, including founding, financing and growing a venture.

Objective
This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures. A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases.

Content
Weekly sessions - recorded.
10+ sessions carried out by guest lecturers: experts in the broad field of technology entrepreneurship (e.g., serial entrepreneurs, venture capitalists, (E)MBA professors, company builders, patent experts, scale-up executives, …). Final session: multiple choice semester assignment (100% of grade).

Typical lecture format (2h):
15': Introduction
60': Guest testimonial
15': Discussion related to topic (in groups)
10': Plenary discussion
20': Q&A with (guest) lecturer

Lecture notes
Lecture slides and case material

Competencies

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<td>Personal Competencies</td>
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363-0301-00L Work Design and Organizational Change W 3 credits 2G G. Grote

Abstract
Good work design is crucial for individual and company effectiveness and a core element to be considered in organizational change. Meaning of work, organization-technology interaction, and uncertainty management are discussed with respect to work design and sustainable organizational change. As course project, students learn and apply a method for analyzing and designing work in business settings.

Objective
- Know effects of work design on competence, motivation, and well-being
- Understand links between design of individual jobs and work processes
- Know basic processes involved in systematic organizational change
- Understand the interaction between organization and technology and its impact on organizational change
- Understand relevance of work design for company performance and strategy
- Know and apply methods for analyzing and designing work
Content
The course is organized in a highly interactive fashion, where discussion in class is as important as the input by the lecturer. Understanding the dynamics in organizations is helped enormously by concrete examples, which will be provided by the lecturer, by talks by guest lecturers, and also the students themselves based on their prior experience from working in various roles (as employees, volunteers, student assistants etc.). Through class discussion we aim to deepen the understanding of the themes covered in the course. The current changes in organizations brought about by Covid-19 will also be an important example which allows to illustrate and discuss many of the key concepts of the course.

Specifically, the course will cover the following topics:
- Work design: From Adam Smith to job crafting
- Effects of work design on performance and well-being
- Approaches to analyzing and designing work
- Modes of organizational change and change methods
- Balancing stability and flexibility in organizations as design criterion
- The organization-technology interaction and its impact on work design and organizational change
- Example Flexible working arrangements (e.g. home office)
- Strategic choices for work design

All through the course, students will be guided to work on their projects also, with about 25% of class time devoted to the projects. In the final session, students will present the main results of their projects and discuss main insights also across projects.

Literature
A list of required readings will be provided at the beginning of the course.

Prerequisites / notice
The course includes the completion of a course project to be conducted in groups of four students. The project entails applying a particular method for analyzing and designing work processes and is carried out by means of interviews and observations in companies chosen by the students.

Competencies
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<th>Subject-specific Competencies</th>
<th>Competencies</th>
<th>Type</th>
<th>ECTS</th>
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<td>W</td>
<td>3</td>
<td>1G</td>
<td>M. Wörter</td>
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<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
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Method-specific Competencies
| Analytical Competencies      | assessed     |      |      |       |           |
| Decision-making              | fostered     |      |      |       |           |
| Problem-solving              | fostered     |      |      |       |           |
| Project Management           | assessed     |      |      |       |           |

Social Competencies
| Communication                | assessed     |      |      |       |           |
| Cooperation and Teamwork     | assessed     |      |      |       |           |
| Self-presentation and Social Influence | fostered |      |      |       |           |

Personal Competencies
| Adaptability and Flexibility | assessed     |      |      |       |           |
| Creative Thinking             | fostered     |      |      |       |           |
| Critical Thinking             | assessed     |      |      |       |           |
| Integrity and Work Ethics     | fostered     |      |      |       |           |
| Self-awareness and Self-reflection | fostered |      |      |       |           |
| Self-direction and Self-management | assessed |      |      |       |           |

Natural Resources

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tr>
<td>363-1036-00L</td>
<td>Empirical Innovation Economics</td>
<td>W</td>
<td>3</td>
<td>1G</td>
<td>M. Wörter</td>
</tr>
</tbody>
</table>

Abstract
The course focuses on important factors that drive the innovation performance of firms, like innovation capabilities, the use of digital technologies, environmental and innovation policy and it shows how innovation activities relate to firm performance and to the technological dynamics of industries. We also discuss the implications of the findings for effective economic policy-making.

Objective
The course provides students with the basic skills to understand and assess empirically the technological activities of firms and their technological dynamics of industries. In addition, the aim is to promote the understanding of the essential criteria for innovation policy-making.

Content
The course consists of two parts. Part I provides an introduction into important topics in the field of the economics of innovation. Part II consists of empirical exercises based on various firm-level data sets, e.g., the KOF Innovation data, data about the digitization of firms, data about environmentally friendly innovations, or patent data. In part I, we will learn about ... a) market conditions that encourage firms to invest in R&D (Research and Development) and develop new products and processes. ... b) the role of competition and market structure for the R&D activities of companies. ... c) how digital and environmentally friendly technologies diffuse among firms. ... d) how the R&D activities of firms are affected by economic crises and how firms finance their R&D activities. ... e) how we can measure the returns to R&D activities. ... f) how environmental policies and innovation policies affect the technological activities of a firm. In part II we will use the KOF Innovation Survey data, patent data, data on digitization of firms, or other longitudinal data sources, to investigate empirically the technological activities of firms in relation to the topics introduced in part I.

Lecture notes
Will be provided in the course and in the e-learning environment: https://moodle-app2.let.ethz.ch/course/view.php?id=15120

Literature
Literature will be presented in the course. For an introduction into the economics of innovation see G.M. Peter Swann, The Economics of Innovation - an Introduction, Edward Elgar, 2009.

Prerequisites / notice
Course is directed to advanced Master-Students and PhD Students with an interest in empirical studies.
### 363-1106-00L The Economics of Climate Change

**W** 3 credits  2G  A. Goussebaïle

**Abstract**
After an introduction to the issue of climate change, we will see the policy instruments that can be used to mitigate it. We will then discuss the optimal level of these policies. Finally, we will analyze the political constraints that limit their implementation.

**Objective**
Students will acquire a general understanding of the problem faced by the society with climate change, as well as the ways and the obstacles to deal with it. From a technical point of view, this course intends to teach participants the main tools used in economic sciences to discuss the problem of climate change, understand its key determinants, advise policy makers and understand the constraints of the latter.

**Content**
The introductory part will explain why climate change represents a main issue for our societies. We will see the anthropogenic causes (i.e. greenhouse gas (GHG) emissions), the physical mechanism and the economic consequences of climate change. Then, we will introduce economic science modeling with the notion of externality to explain the excessive GHG emissions and characterize the societal challenge raised by climate change.

The second part of the course will present the different policy instruments for reducing GHG emissions (emission taxes, abatement subsidies, cap-and-trade system, standards). We will compare their performance and their distributional effects with regard to several aspects, with a special focus on the impact of uncertainty.

The third part of the course will focus on the level at which climate policies should be implemented, which depends on the cost of GHG emission abatement and the benefit of climate change mitigation. We will analyze the main drivers of the optimal emission abatement level, in particular discounting. We will also detail the economic models developed to evaluate the optimal abatement, namely Integrated Assessment Models.

The last part of the course will address the reasons why policy makers have only weakly implemented climate change policies up to now. We will discuss the difficulties of finding an international agreement for GHG emission reduction in a world with a large number of countries. We will also see why the time delay between GHG emissions and climate change may make society and policy makers reluctant to implement significant climate change policies.

**Lecture notes**
Lecture Notes of the course will be sent by email to officially subscribed students.

**Literature**
The main reference of the course is the set of lecture notes; students will also be encouraged to read some influential academic articles dealing with the issues under study.

**Prerequisites / notice**
Elementary knowledge of economic theory is a plus but not a prerequisite.

### 363-1194-00L An Introduction to Experiments in Consumer Behavior

**W** 3 credits  2G  U. Bernardic

**Abstract**
Designed for master students, this course offers insights and practical experience in behavioral economics and marketing experiments. It includes: 1) Mastering experiment design (RCT, A/B testing, conjoint analysis), programming, and implementation of experiment through focused lectures. 2) Selecting a seminal experiment, replicating it, and presenting a poster on the key findings.

**Objective**
After taking a course, students will be able to:
- design a simple (online) experiment with an open-source program, hands-on preregistration/replication
- recruit participants
- basic data analysis and analytical skills (in R)
- present (a poster) and discussion skills
- collaboratively work in groups
The course is especially suitable for master students who plan to conduct empirical research for their master thesis, or students who wish to get hands-on experiences with experimental methods. The objective is to provide students with the theoretical foundations for designing, implementing, conducting, and analyzing experiments, and hands-on experiences on empirical methods in behavioral economics or marketing (consumer behavior focus). After a brief recap of the counterfactual approach to causal inference and experimental designs, the course will cover the theoretical and practical aspects of designing and conducting survey experiments. The course will be divided in two stages. In stage 1 (theoretical part), students will learn how to design, plan, program, and run an experiment by attending to lectures. In stage 2 (practical part), students will work in a group, and choose one experiment in the area of behavioral economics or marketing, conduct a replication of that experiment using the techniques acquired in stage 1, and make and present a poster on the results of the replication. Performance in both, the theoretical and the practical part contribute equally to the final grade. In more detail, 50% of the final grade will be based on regular assignments that have to be submitted online prior to class (25%), and active participation during the weekly meetings (25%). The 50% of the grade will be based on the quality of the conducted research project (experimental design, data collection, statistical analysis) and the final presentation on the last day of class. Upon completion of this course, students will be equipped with a robust set of skills. They will learn to design simple online experiments using open-source programs, emphasizing hands-on preregistration and replication methods. Students will also acquire the competence to recruit participants effectively, and hands-on experiences with basic data analysis and analytical skills, utilizing R, a powerful tool for statistical computing and graphics. Essential to the dissemination of research, students will enhance their ability to present findings and engage in scholarly discussions through poster presentations. Furthermore, this course emphasizes the importance of teamwork, preparing students to collaboratively work in groups, an essential skill in both academic and professional settings.

### Competencies

#### Subject-specific Competencies

- Concepts and Theories: fostered
- Techniques and Technologies: assessed

#### Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: fostered
- Project Management: assessed

#### Social Competencies

- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

#### Personal Competencies

- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

### Supply Chain and Information Systems

#### Developing Digital Biomarkers

**Number**: 363-1163-00L  
**Title**: Supply Chain and Information Systems  
**Type**: W  
**ECTS**: 3 credits  
**Hours**: 2V  
**Lecturers**: F. Da Conceição Barata

**Abstract**

The course gives an introduction to digital biomarkers and provides students with the foundations to develop their own digital biomarkers. More specifically, the course will cover fundamental topics such as designing observational studies, collecting, and exploring data generated by consumer-centric devices, and applying analytical methods to predict health-related outcomes.

**Objective**

The widespread use of mobile technologies (e.g., wearable sensors, mobile applications, social media, and location-tracking technologies) has the potential to meet the health monitoring needs of the world’s aging population and the ever-growing number of chronic patients. However, this premise is based on the application of Machine Learning algorithms that allow us to use this data in many different ways. In this course we will analyze systematic ways to collect data, review the most relevant methods and applications in healthcare, discuss the main challenges they present and apply the newly gained knowledge in practical assignments.

The course has four core learning objectives. Students should:

- understand the anatomy of digital biomarkers
- understand the potential and applications of digital biomarkers
- be able to critically reflect and assess existing digital biomarkers
- be able to design and implement a digital biomarker

**Content**

The course will consist of four topic clusters that will allow the discussion of the most relevant digital biomarker applications in healthcare:

1) Digital Biomarkers: From biological to digital biomarkers. How are they motivated, defined and how can they be leveraged for monitoring? Prognostic vs. diagnostic vs. predictive biomarkers. Passive sensing vs. active sensing. Digital biomarker vs. Digital therapeutics.

2) Consumer-centric device data: Today, vast amount of physiological, environmental, and behavioral observations can be collected with consumer centric devices. To derive clinical meaningful information from this data is, however, difficult. We will analyze strategies for extracting knowledge from those measurements.

3) Methodology: In the last decade, neural networks (also known as "deep learning") have helped push the boundaries of the state-of-the-art in a myriad of domains. They have also uncovered a number of different problems. We will discuss advantages and disadvantage as well as alternative methods for their application to digital biomarker data.

4) Applications: Digital biomarkers are still an emerging subfield, but given that longitudinal in digital biomarker data are arguably easy to acquire in large quantities, it is expected that many relevant Machine Learning applications will emerge in the near future. We will review and discuss current applications and challenges.
The globalization of the world leads to an increasingly faster pace in business transformation. Enterprises have to adapt faster and even faster to the environmental changes in a global economy to remain competitive and to make sure they stay in business. In today's information age, this does not only mean to adapt business strategy and business processes but also to adapt information systems to the new circumstances. The fast adaptation through large scale corporate transformation projects that change strategy, business processes and information systems typically takes years in very complex large scale projects. Many projects fail because of insufficient alignment between decision makers in business and IT. Unclear understanding of the overall project scope, undefined roles and responsibilities, unclear project processes, quality problems and resistance to change are some typical problems found in such projects. The lecture is subdivided into following modules:

Corporate development introduction and motivation, Parallelization of corporate development and complexity reduction, Planning process and project portfolio management in corporate development, Management of large scale projects, integration of strategy, processes and information systems, Quality management in large scale projects, Project management in large scale projects, Change management within projects. The lecture is accompanied by four case studies that are used to exemplify the contents of the lecture by applying the concepts to real situations in corporate life.

### Systems Design and Risks

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tr>
<td>363-1017-00L</td>
<td>Risk and Insurance Economics</td>
<td>W</td>
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Abstract

The course covers the economics of risk and insurance, in particular the following topics will be discussed:
1) individual decision making under risk
2) models of insurance demand, risk sharing, insurance supply
3) information issues in insurance markets
4) advanced topics in microeconomics and behavioral economics
5) the macroeconomic role of insurers and insurance regulation

Objective

The course introduces students to basic microeconomic models of risk attitudes and highlight the role insurance can – or cannot – play for individuals facing risks.

Content

Everyday, we take decisions involving risks. These decisions are driven by our perception of and our appetite for risk. Insurance plays a significant role in people’s risk-management strategies.

In the first part of this lecture, we discuss a normative decision concept, Expected Utility theory, and compare it with empirically observed behaviour.

Students then learn about the rationale for individuals to purchase insurance, and for companies to offer it. We derive the optimal level of insurance demand and discuss how it depends on our model’s underlying assumptions.

We then discuss the consequences of information asymmetries in insurance markets and the consequences for insurance supply.

Finally, we discuss refinements in decision theory that help account for observed behaviours that don’t fit with the basic models of microeconomic theory. For example, we’ll explore how behavioural economics can be leveraged by the insurance industry.

Literature

Main literature:
- Handbook of the Economics of Risk and Uncertainty, Volume 1;

Further readings:

References will be given on a topic-by-topic basis during the course.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Personal Competencies
Critical Thinking assessed
Self-direction and Self-management fostered

Technology and Innovation

Number Title Type ECTS Hours Lecturers
363-0861-00L Alliance Advantage - Exploring the Value Creation Potential of Collaborations W 3 credits 2G C. G. C. Marx

Abstract

Alliances within innovation ecosystems are essential for developing new business models that address the increasing complexity of technologies and systems, as well as the intensifying global competition. Organizations are compelled to prioritize selected partnerships for value creation. We will emphasize the role of alliances and collaborations in driving innovation within these ecosystems.

Objective

Learning outcomes professional competence

The students
- learn and understand the management basics of inter-firm collaboration and organizational networks (strategy considerations incl. collaborative business models; cultural aspects including both corporate culture and international aspects, risk management, communication, etc.)
- realize the value creation potentials of alliances (added value)
- understand underlying theoretical models (mainly from the institutional economics, focusing on transaction cost and principal agent theory)
- identify and understand specific forms of collaboration (strategic alliances, joint ventures, Networks, etc.)
- apply tools hands on in real companies (planned in collaboration with companies)

Learning outcomes methodological competence

- Writing academic papers
- Developing structured documentation of interviews (in form of a presentation)
- Transferring theory directly into practical application
- Contributing to the learning journey

Learning outcomes social competence

- Improving communication skills as basics for collaboration
- Developing and applying team work skills
- Work together with industrial partners
- Coping with conflicts resolution in teams
The ever-increasing complexity of technologies and systems, coupled with heightened competitive pressure and the need to shorten time-to-market, drives organizations to concentrate on their core competencies. Collaborating with external partners presents a crucial value creation opportunity, significantly impacting daily management activities. This lecture aims to provide a comprehensive understanding of the unique management requirements for successful cooperation.

**Content:**
- Introduction to the theory and management of inter-firm collaboration and networks.
- Examination of the formation, management, and evolution of collaborations and networks.
- Exemplary collaborations in marketing, development, and manufacturing.
- Special forms of collaborations: innovation ecosystems, strategic alliances, joint ventures and mergers & acquisitions.

**Learning Journey:**
- Week 1: Introductory day providing an overview of the theoretical framework, explaining the course concept, case studies and intro to the first assignment.
- Weeks 2-5: First assignment focusing on key aspects of the framework: Networked Business Strategies; Culture and People Orientation; Leadership, Interaction and Communication; Resilience, Risk and Trust; Agile Structures and Processes; Collaborative Skills Development. This assignment will build the foundational knowledge necessary for the second part of the seminar.
- Mid-Semester: Presentation of the first assignment results, supplemented with additional input using a case study, preparation for the second assignment.
- Second Assignment: Analysis of real alliance projects within partner companies, i.e. preparing and conducting an interview, summarizing the interview into a presentation.
- Final day: Best practice exchange session to conclude the course.

This structured approach ensures a thorough understanding of inter-firm collaboration management, equipping participants with the necessary skills to navigate and leverage these partnerships effectively.

**Lecture notes**
- Lecture slides
- Current course material
- Harvard Case Studies

**Literature**
A list with recommended publications will be distributed in the lecture.

**Classic Books:**
- HBR Collaborating Effectively ISBN 978-1-4221-6264-4
- HBR on Mergers and Acquisitions: ISBN 1-57851-555-6

**Prerequisites / notice**
The number of students participating in the lecture is limited to 30.

**Competencies**

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**363-1051-00L Cases in Technology Marketing**

**W 3 credits 1G**

**F. von Wangenheim, D. Mane**

**Number of participants limited to 20.**

**Students have to apply for this course by sending a CV and an one-page motivation letter until 31.8.2024 to Theresa Schachner: tschachner@ethz.ch. Additionally please enroll via myStudies. Places will be assigned on the basis of your motivation letter.**

**Abstract**
The seminar “Cases in Technology Marketing” introduces students to key concepts and tools in technology marketing and familiarizes them subsequently with the challenges that (marketing) managers face in technology intensive markets by using real life cases.

**Objective**
1. Understanding and applying common business tools and frameworks
2. Understanding current challenges of managers in technology-intensive markets
3. Defining and analyzing comprehensive business problems using the example of a leading Swiss manufacturing company (Bühler AG)
4. Developing and evaluating different alternative case solutions
5. Making decisions on case solutions, justifying and defending them
6. Transferring case solutions into practice by formulating specific instructions for the management
7. Creation of novel, innovative ideas that help the company to gain a competitive edge
8. Cooperation in teams and coordination of team tasks
9. Adequate communication to and eye-level discussions with C-level managers

**Data: 15.06.2024 12:39**

**Autumn Semester 2024**

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The seminar “Cases in Technology Marketing” introduces students to key concepts and tools in technology marketing and familiarizes them subsequently with the challenges that (marketing) managers face in technology-intensive markets by using real-life cases. Students will have to work in groups and together solve past, current and future managerial problems in the form of cases. The team member composition will rotate for each case, enabling students to foster their teamwork abilities besides the application of theoretical concepts to the applied case questions. The students will have to present their case solutions to the lecturer and a top executive of a leading Swiss company (details see below). Also, they will be enabled to compare their solutions with what has actually been done or is yet to be done.

The three case studies presented in this course cover real managerial issues of the Swiss manufacturer Bühler AG (www.buhlergroup.com). A Bühler top executive will present the cases and discuss the students’ presentations and solutions. As such, the course allows for in-depth discussions of the real-life case situation with the C-level manager and hereby enables students to transfer their learnings from theoretical considerations to the applied field. The course will be rounded off with a day visit to the Bühler facilities in Uzwil, Switzerland, where students will have the chance to further connect with management and discuss the acquired key concepts, tools, and case study insights on-site.

Prerequisites / notice
In addition to course enrolment, students have to apply for this course by sending a CV and a short motivation letter until 31.08.2023 to Dr. Theresa Schachner: tschachner@ethz.ch.

Competencies

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<td>Self-direction and Self-management</td>
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363-0393-00L Corporate Strategy

Due to didactic considerations, the number of participants for this course is limited to 45.

Please register through myStudies to enroll for the course. Slots are assigned on a first-come first-serve basis (in the order of the registration date on myStudies). We will confirm your registration by e-mail. If you have any inquiries about the course, please contact the course assistant.

Abstract
This course focuses on the challenges in managing multi-business corporations, and covers topics related to the vertical and horizontal scope of business activities.

Objective
The course is a combination of lectures about concepts/methods, guest lectures, case studies, and individual assignments.

Content
Large- and medium-sized corporations play a central role in the economic activity of most developed and developing countries. Many of these organizations perform multiple business activities in multiple markets. In the face of increasing international competition, globalization, technological development, deregulation, and the emergence of new markets and industries, operating such a portfolio of business activities poses important managerial challenges forcing corporations to continuously re-consider their vertical and horizontal scope and boundaries.

The course Corporate Strategy draws from a wide range of theories and methods to develop an understanding of the conceptual frameworks, debates, and developments concerning decisions associated with the management of multi-business corporations. We will cover the key questions driving a firm’s corporate strategy, including:
- In what markets to compete with which businesses?
- Which activities should be performed by the firm and which should be outsourced (i.e. “make” or “buy” decisions)?
- What are the most appropriate approaches to growth and divestiture?
- How do institutional forces impact corporate strategy?

Specifically, we will examine how organisations manage their portfolio of business activities and markets to achieve competitive advantage through vertical integration, cooperative strategies such as strategic alliances and joint ventures, corporate diversification, mergers and acquisitions, divestitures, and globalization/international strategies, and strategic renewal.

The course homepage can be found at: http://www.smi.ethz.ch/education/corporate-strategy.html

Prerequisites / notice
Having participated in the course Strategic Management by Prof. Georg von Krogh/Dr. Stephan Herting is an advantage but not a requirement.

363-1028-00L Entrepreneurial Leadership

Limited number of participants.

Students apply for this course via the official website no later than 18.08.2024 (https://www.mtec.ethz.ch/studies/special-programmes/els.html). Once your application is confirmed, registration in
Abstract
This seminar provides master and PhD students at MTEC with the challenging opportunity of a real case on strategy, innovation and leadership in close collaboration with the senior management of a leading company: UBS.

Objective
The general objective of the course is to enable MTEC students to develop leadership skills by dealing with real-world business problems, thinking critically about the concepts discussed in their study programs and learning how to apply these concepts to provide practical implications. It provides students with coaching and mentoring from senior leaders in the company and professors from D-MTEC to bridge the gap between theory and practice.

Content
This seminar provides ambitious ETH students and doctoral candidates with a rewarding learning opportunity: a real case study of strategy and innovation in close collaboration with the top management of an outstanding company: UBS.

What you can expect:
You will work in teams on specific high priority assignments that flow from the company. Delving into the assignments you will both contribute to solving strategic issues and have an impact on their implementation at the company.

To gain insight into the company and its culture you will receive briefings from senior management, conduct interviews with experts and run workshops with your case managers. In the final presentations you will pitch your findings to key stakeholders and top management representatives and receive valuable feedback.

Furthermore you will be coached and supported by MTEC professors on the topics of project scoping, problem definition and solving, process improvement, strategy and board presentation.

The course is directed and organized by PD. Dr. Zeynep Erden and Dr. Isabel Spicker as part of the MTEC Leadership Development Programme.

What we expect from you:
You are an ambitious ETH student or doctoral candidate who is looking for a rewarding learning opportunity and is eager to go the extra mile. You will work on a real case study of strategy, technology and innovation in close collaboration with the senior management of an outstanding company. The recommendations that you formulate in collaboration with members of your team as well as with internal and external experts will be discussed at the partner and director levels. This demands a deep understanding of the company’s leadership culture.

In this endeavour, you are coached and supported by
- Stefano Brusoni, Chair of Technology and Innovation Management
- Georg von Krogh, Chair of Strategic Management and Innovation
- Oliver von Dzengelevski, Chair of Production and Operations Management
- Zeynep Erden, Lecturer, D-MTEC
- Isabel Spicker, D-MTEC

Literature
Literature and readings will be announced in the coaching sessions.

Prerequisites / notice
Please apply for this course via the official website (https://mtec.ethz.ch/studies/programme-elements/special-programmes/els.html). Apply no later than August 18, 2024.

The number of participants is limited to 18. ECTS: 4
Participants receive a certificate.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Industry and Competitive Analysis

Abstract
Industry and Competitive Analysis (ICA) is an essential part of any strategic management process. It contains a very practical set of methods to quickly gain a good grasp of an industry. The purpose of ICA is to understand factors that influence the financial performance of an industry and firms within that industry, thereby enabling firms to develop effective competitive strategies.

Objective
Goals of the course
- Students will develop an in-depth understanding of how the structure of an industry impacts both industry-level and firm-level performance
- Students will develop practical skills in analyzing industries and firms within them
- Students will gain a broad understanding of the impact of digitalization on various industries and develop an in-depth understanding of (at least) one chosen industry
- Students will improve the analytical skills needed to successfully compete in the digital age

363-0404-00L Industry and Competitive Analysis

ECTS: 3

W: 3 credits
3G: P. Tinguely
Industry and Competitive Analysis (ICA) is an essential part of any strategic management process in firms and other organizations. It contains a very practical set of methods to quickly gain a good grasp of an industry, be it pharmaceuticals, information and communication technology, professional services, or even the beer industry. The purpose of ICA is to understand factors that influence the performance of an industry and firms within that industry. Gaining such understanding supports firms in developing effective competitive strategies.

As the world witnesses tremendous development in digital technologies, many industries are in the midst of transitioning from analogue to digital business models. Digitalization is radically changing what firms produce and the way they organize their business activities. To adapt to these changes, practitioners and scholars alike need a more advanced set of analytical tools to understand the constantly-changing industries. That is why we have developed our course as ICA 2.0, which provides state-of-the-art tools to gain an updated picture of various industries before and after their digital transformation. In this course, we will study theoretical frameworks, examine evidence from empirical research, and benefit from experience shared by our guest speakers.

The course is organized into thirteen sessions that comprise a combination of (guests) lectures, case studies, and (tutored) group work. The schedule is subject to change, depending on the availability of the guest lecturers.

This course is built upon a management classic (Competitive Strategy: Techniques for Analyzing Industries and Competitors by Porter, 2004). We also draw from more recent research findings and practitioner-oriented strategy research. Students are expected to familiarize themselves with the assigned readings and develop a thorough understanding of the material before coming to class. For students wishing to explore the course content in greater depth, optional readings are proposed for each session. We will share the course literature and case material on the Moodle course page, which is accessible to students who have successfully enrolled to the course in myStudies.

Competitive strategy
- Chapter 2 of Porter (2004)

Industry Dynamics
- Chapter 3 of Porter (2004)

Opportunities & Feasibility Analyses

Strategic Groups & Advanced Analytics for ICA

ICA in the Digital Age I

ICA in the Digital Age II

Prerequisites / notice
Experience in statistical analysis with tools such as SPSS or equivalents is an advantage.

Note that class participation is important. Students should make sure that they can attend each weekly lecture prior to registration.

Exchange students can register by sending an e-mail to rudolfm@ethz.ch if facing problems with their registration in myStudies. Those registrations will be handled on a case-by-case basis.

Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Problem-solving: assessed
  - Project Management: assessed
- Social Competencies
  - Communication: assessed
  - Cooperation and Teamwork: assessed
- Personal Competencies
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Self-awareness and Self-reflection: assessed
  - Self-direction and Self-management: assessed

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1601 of 2653
Abstract
Students learn how to approach management research from various perspectives, how to evaluate empirical research, and how to develop their own research projects.

Objective
You will learn how to approach management research from various perspectives, how to evaluate empirical research, and how to develop your own research project. The successful completion of the course will help you to:
- Think critically and make compelling arguments about the strengths and weaknesses of published management research
- Find and review appropriate literature and previous research for your thesis
- Develop and frame interesting and relevant research questions and problem statements
- Design your research and choose an appropriate methodology for analysis (specific research methods and techniques are not discussed in this course)
- Structure your manuscript
- Plan and manage your thesis project

Content
This course combines lectures, group discussions and individual assignments.

Day 1: Course introduction, group analysis exercises and discussions, lectures on main topics.
Between course days 1 and 2: Individual and group work on assignments
Day 2: Assignment review and discussion, lectures on main topics, conclusion session.

Target audience:
The course is designed with two groups of students in mind: first, students who write their master thesis at the SMI chair and second, students who write their master thesis in the field of management at other MTEC chairs. For both groups, the focal topics of this course will arise frequently during the journey of writing their thesis, and the majority of topics are relevant for all students. However, we will provide some specific content (grading guidelines, thesis format) which might not be applicable for students tutored at other MTEC chairs.

Course topics:
1. Thesis topic and thesis proposal:
   - Choice of thesis topic, identification of research gap, formulation of research questions, writing of thesis proposal
2. Literature review:
   - Search and evaluation of academic literature, use of reference tools, writing of theoretical background chapter of thesis
3. Empirical research design:
   - Types of empirical research designs, choice of methodology, overview of data collection and analysis methods
4. Research output and report:
   - Writing of introduction, results and conclusion, thesis format and structure
5. Thesis assessment:
   - SMI grading criteria, MTEC guidelines

References:

363-1195-00L Crisis Management and Leadership ▲

Number of participants limited to 20.

Enrollment only with simultaneous submission of a short letter of motivation (max. 1 A4 page) plus CV. Students have to apply for this course by sending a CV and a one-page motivation letter until 31.08.2024 to David Baschung Link (mailto:dbaschun@ethz.ch). Additionally, please enroll via myStudies. Places will be assigned on the basis of your motivation letter.

Abstract
In this seminar you will learn how to quickly develop useful solutions in complex situations under time pressure and with incomplete information using a heuristic process as a person in charge (e.g. team leader).

Objective
After taking this course, students will be able to:
- develop useful solutions independently and in good time in situations with limited information and time constraints (personal competences, application);
- use heuristic procedures to reduce complex problems and make them solvable in an ad hoc context (methodological competences, application);
- develop and present concepts in groups and reflect on the interpersonal challenges in such contexts (social skills, application and understanding);
- bring in specialised knowledge from other courses in order to recognise the connections between business planning and scientific research (disciplinary skills, understanding);
- gain initial personal experience in the management and leadership of crises (experiential knowledge).
The aim of the seminar is to develop a real crisis case during a two-day block at a major international manufacturing company in the Lucerne area and to present the results to selected managers of the company. In the first part of the semester, you will learn the elements of a generic heuristic problem-solving procedure step by step in 4 double lessons. You will be taught the theoretical basis and then given a small business case, which you will solve in small groups using the newly learnt process steps until the following course. In the following week, you will reflect on the solutions together and receive feedback from the lecturer (without marks to encourage free learning). At the end of the preparation period, you will receive selected documents from a Swiss industrial company, which you will analyse to be ready for the visit to this company in the second part of the course.

In the second part, we visit an industrial company in Central Switzerland. Company representatives will present us with specific current challenges to which we will develop practical answers in small teams over the course of two days. This process is accompanied by team external coaches with relevant experience in leadership and management. Selected performances (oral and written) of these block days are graded, but the actual group work is ungraded to favour creative and innovative approaches. At the end of the two days, we present the proposed solutions to some of the company's executives. During the working days, you will also have time to get to know managers from the renowned family business in a relaxed atmosphere and expand your network accordingly (lunch, drinks reception, Q&A sessions).

To ensure learning success, the project outlined in the teamwork is further developed in writing in the remaining part of the semester and submitted as a term paper. This work is assessed and accounts for a total of 50% of the grade. At the end of the semester, achievements are recognised, and feedback is exchanged between lecturers and students.

**Lecture notes**
Will be made available from week to week via Moodle.

**Literature**

**Prerequisites / notice**
A maximum of 20 students to enable intensive support from the coaches and to ensure an immersive experience with the industry partner.

In addition to course enrolment, students have to apply for this course by sending a CV and a one-page motivation letter until 31.08.2024 to David Baschung Link (mailto:dbaschun@ethz.ch).

**Comptencies**
- **Subject-specific Competencies**
  - Concepts and Theories: fostered
  - Techniques and Technologies: fostered
- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: fostered
- **Social Competencies**
  - Communication: assessed
  - Cooperation and Teamwork: fostered
  - Customer Orientation: fostered
  - Leadership and Responsibility: assessed
  - Self-presentation and Social Influence: assessed
  - Sensitivity to Diversity: fostered
  - Negotiation: fostered
- **Personal Competencies**
  - Adaptability and Flexibility: fostered
  - Creative Thinking: assessed
  - Critical Thinking: fostered
  - Integrity and Work Ethics: fostered
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: assessed

**Abstract**
Students will learn about strategic foresight in the context of sustainable futures that incorporate principles of regeneration, resilience, and circularity. Foresight is an approach that scientists, government officials, and business executives use to explore and reflect on potential future challenges. The course will explore tools and techniques to advance our understanding of possible futures.

**Objective**
After completing the course, students will be able to:
- Discuss the value of foresight and how to use it.
- Execute activities to gather intelligence about future contexts.
- Organise and analyse drivers to explore the dynamics of change.
- Independently develop scenarios based on current best practices.
- Systematically analyse scenario implications and evaluate their relative value.

**Content**
The course is for Master (and PhD) students who want to develop their long-term thinking and leadership skills and are curious about sustainability and regeneration. Students will benefit from their own practice-oriented learning experience covering the foresight process and a deep dive into scenario-building methods and their concrete applications. The student number is limited; we select from a diverse group with interdisciplinary backgrounds.

This course is project-based and guided by the question: “Given that Switzerland will continue to experience significant climate change, what will sustainable energy/mobility/food production etc. scenarios for Switzerland look like, and how will we get there?” Students will work in groups to explore the different methods, building up a coherent understanding of Strategic Foresight applied to real-world contexts. The methods are analytical and creative, training students in openness and curiosity. The class requires hands-on engagement with the learning process. The lecturers will provide inputs and access to experts, and students will actively use the methods presented to develop realistic, valuable scenarios.

The case context will be sustainability linked to Swiss energy/mobility/food etc... Students will independently explore different aspects of this case and, in doing so, will meaningfully contribute to their learning and the ongoing work within ETH and the higher education sector about how universities may contribute to positive change in society. Students will develop their own scenarios in groups and present them at the end of the course. The course covers four phases of Strategic Foresight: (1) gathering intelligence about the future, (2) exploring dynamics of change, (3) describing what the future might be like, and (4) developing and testing strategies.
## Additional Courses

### Number
title | type | ects | hours | lecturers
---|---|---|---|---
363-0881-00L | Semester Project Small | W | 3 | 6A | Professors
363-0883-00L | Semester Project Large | W | 6 | 13A | Professors
363-0879-00L | Practical Training | O | 6 | external organisers
363-0600-00L | Master's Thesis | O | 30 | 57D | Professors
363-1063-00L | Academic Writing Course | O | 0 | 3G | R. Mihalka

### Abstract
The semester project (90 hours) is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

The semester project (180 hours) is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

The practical experience gained by the student completes the studies at the Swiss Federal Institute of Technology and prepares her/him for future activities in industry.

In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is supervised by the tutor and normally deals with a subject contained in the major fields. The research will be performed normally within a private company or at the ETH Zurich.

This course for MTEC MSc students focuses on developing students' English writing skills and their understanding of the disciplinary expectations for academic texts. The course is particularly designed to support students in writing their theses.

### Objective
The semester project (90 hours) is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

The semester project (180 hours) is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

The practical experience gained by the student completes the studies at the Swiss Federal Institute of Technology and prepares her/him for future activities in industry.

In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is supervised by the tutor and normally deals with a subject contained in the major fields. The research will be performed normally within a private company or at the ETH Zurich.

### Supplementary Courses
The students have to deepen their knowledge in the area(s) of engineering/natural sciences in consultation with the responsible professor (tutor). Core courses and electives of D-MTEC can not be used as supplementary courses.

### Industrial Internship
The students have to deepen their knowledge in the area(s) of engineering/natural sciences in consultation with the responsible professor (tutor). Core courses and electives of D-MTEC can not be used as supplementary courses.

### Master’s Thesis
Only students who fulfill the following criteria are allowed to begin with their master thesis:

- a. successful completion of the bachelor programme;
- b. fulfilling of any additional requirements necessary to gain admission to the master programme;
- c. internship fulfilled;
- d. academic writing course has been completed.

In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is supervised by the tutor and normally deals with a subject contained in the major fields. The research will be performed normally within a private company or at the ETH Zurich.

### Academic Writing Course
Compulsory for all MTEC MSc students. Attendance of the initial lecture is compulsory. Students who are unavailable at the time of the initial lecture need to take the course in another semester.

This course for MTEC MSc students focuses on developing students' English writing skills and their understanding of the disciplinary expectations for academic texts. The course is particularly designed to support students in writing their theses.
Objective

After the completion of the course, students are able to:
- understand the concept of plagiarism and cite their sources accurately and appropriately,
- plan the writing process efficiently,
- analyse model texts from the perspective of language use,
- plan, draft, and revise academic texts,
- provide peer review on others’ writing,
- write in a clear, precise, concise, and generally reader-friendly manner,
- use generative AI tools for writing without compromising their scientific integrity.

Content

Initial lecture: Writing at MSc level in D-MTEC, avoiding plagiarism, course overview

Workshop 1: The writing process
Workshop 2: Paragraph structure
Workshop 3: Methods
Workshop 4: Figures and tables
Workshop 5: Literature review
Workshop 6: Introduction
Workshop 7: Results, Discussion, Conclusion
Workshop 8: Abstract and Title

Lecture notes

Handouts and self-study materials are available on Moodle.

Prerequisites / notice

First-year students who participated in the lecture on plagiarism on the first day of studies will have a different schedule from other students. Please refer to the lecturer’s message for details, which will be sent out a week before the initial lecture.

Competencies

Method-specific Competencies
- Analytical Competencies
  - fostered
- Media and Digital Technologies
  - fostered
- Social Competencies
  - Communication
  - assessed
  - Cooperation and Teamwork
  - fostered
- Personal Competencies
  - Critical Thinking
  - fostered
  - Integrity and Work Ethics
  - fostered
  - Self-awareness and Self-reflection
  - fostered
  - Self-direction and Self-management
  - assessed

Management, Technology and Economics Master - Key for Type

O  Compulsory
W+  Eligible for credits and recommended
W  Eligible for credits
E-  Recommended, not eligible for credits
Z  Courses outside the curriculum
Dr  Suitable for doctorate

Key for Hours

V  lecture
G  lecture with exercise
U  exercise
S  seminar
K  colloquium
P  practical/laboratory course
A  independent project
D  diploma thesis
R  revision course / private study

ECTS  European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
At the end of the course, the student will be able to:

**Objective**

At the end of the course, the student will be able to:

- choose the appropriate material for mechanical engineering applications and to ensure their mechanical integrity.
- formalize and apply design criteria involving strength, local plasticity, and fatigue.
- derive the equations of motion using Lagrange’s equations, d’Alembert’s principle, and Hamilton’s principle.
- solve initial boundary value problems in solid mechanics, particularly including the finite element (FE) method for static and dynamic problems. To understand the structure of one-dimensional and multi-dimensional models, the students will learn different representations of the vibration behavior of engineering materials and the implications for the assessment of products’ function and mechanical damage.
- improve critical thinking and quantitative reasoning in order to learn and apply the theoretical foundation of the course to critical real-life problems.
- develop the technological competence to combine theory as well as analytical and computational simulation approaches to address structural problems.
- use materials selection software, 3D modeling, manufacturing or workshop tools, and materials testing equipment.
- apply manufacturing processes to a designed product.
- produce coherent and scientifically sound laboratory reports.
- provide leadership and teamwork spirit.

---

**Abstract**

The course offers an introduction to dynamics of engineering systems. The first part focuses on Newtonian dynamics and energy principles. The second part focuses on the free and forced response of single- and multi-degrees-of-freedom systems. Hands-on exercises, computer-based labs, and experimental demos will support the theoretical lectures.

**Content**

Day-by-day course content:

- Week 1
  - Day 1: Recap on Newtonian Dynamics for single particle
  - Day 2: Kinetics of systems of particles
  - Day 3: Kinetics of rigid bodies
  - Day 4: Analytical mechanics

- Week 2
  - Day 6: Mechanical Vibrations
  - Day 7: Elements of Structural Vibration - SDOF
  - Day 8: Elements of Vibration Theory - MDOF
  - Day 9: State Space Representations
  - Day 10: Transformations

**Lecture notes**

The material will be organized in lecture slides.

**Literature**

A specific list of books will be offered as useful-supplemental reading.

---

**Objective**

The students will be able to analyse mechanical problems, to formulate and apply design criteria involving strength, local plasticity, and fatigue. They will understand how mechanical theories are derived from basic principles as well as the role of phenomenological models. They will learn different representations of the vibration behavior of engineering materials and the implications for the assessment of products’ function and mechanical damage. They will know how to use advanced mathematical tools to solve engineering problems.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Problem-solving
- Social Competencies
  - Communication
- Personal Competencies
  - Creative Thinking
  - Critical Thinking

**Abstract**

This course introduces students to numerical methods commonly used in engineering with a focus on finite element (FE) analysis. Starting with finite differences and ending with static and dynamic FE problems, students will learn the fundamental concepts of finite elements as well as their implementation and application.

**Content**

Numerical methods and techniques for solving initial boundary value problems in engineering solid mechanics (heat conduction, static and dynamic mechanics problems of solids and structures). Finite difference methods, indirect and direct techniques, variational methods, mainly focus on the finite element (FE) method, FE analysis in small strain for applications in structural mechanics and solid mechanics.

**Lecture notes**

Typed lecture notes will be made available online.

---

**Objective**

To understand the concepts and application of numerical techniques for the solution of initial boundary value problems in solid and structural mechanics, particularly including the finite element (FE) method for static and dynamic problems. To understand the structure of FE codes and the right use of FE technology.
### Offered in the Autumn Semester.
Offered for the first time in HS 2024.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>173-0011-00L</td>
<td>Internship</td>
<td>O</td>
<td>5 credits</td>
<td>11P</td>
<td>to be announced</td>
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**Master’s Thesis**

Offered in the Autumn Semester.
Offered for the first time in HS 2024.

<table>
<thead>
<tr>
<th>Number</th>
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<td>173-0012-00L</td>
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<td>O</td>
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### MAS in Advanced Fundamentals of Mechatronics Engineering - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</table>

### Key for Hours

<table>
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</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
MAS in AI and Digital Technology

- Compulsory Modules
- Integration Modules and AI Project
- Master's Thesis

**Key for Hours**

<table>
<thead>
<tr>
<th>V</th>
<th>G</th>
<th>U</th>
<th>S</th>
<th>K</th>
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<tbody>
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<td>lecture with exercise</td>
<td>exercise</td>
<td>seminar</td>
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<td>diploma thesis</td>
<td>revision course / private study</td>
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**ECTS**
- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
MAS in Applied Technology

► Major in Applied Information Technology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>265-0100-00L</td>
<td>Foundations of Programming</td>
<td>O</td>
<td>2</td>
<td>2A</td>
<td>L. E. Fässler</td>
</tr>
<tr>
<td>Abstract</td>
<td>The initial module offers a practical introduction to some basic concepts and techniques for information processing as well as practical applications of them. The programming language are Python and SQL.</td>
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<tr>
<td>Objective</td>
<td>Participants learn...</td>
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<tr>
<td></td>
<td>- how to encode a problem into a program, test the program, and correct errors.</td>
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<tr>
<td></td>
<td>- to understand and improve existing code.</td>
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<tr>
<td></td>
<td>- deal with the complexity of real data.</td>
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<td></td>
<td>- store data in a suitable data structure.</td>
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<td></td>
<td>- query databases and understand and evaluate the corresponding database model.</td>
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<td></td>
<td>- to implement mathematical models as a simulation.</td>
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<tr>
<td>Content</td>
<td>The following programming concepts are introduced during this module:</td>
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<tr>
<td></td>
<td>1. Variables, data types</td>
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<td>2. Condition check, loops, logics</td>
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<td></td>
<td>3. Sequential data types</td>
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<td></td>
<td>4. Functions and Modules</td>
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<tr>
<td>Prerequisites / notice</td>
<td>No prior knowledge is required for this course. It is based on application-oriented learning. The students spend most of their time working through programming projects and discussing their results with teaching assistants. To learn the programming basics there are electronic tutorials available.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>fostered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Methodspecific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
</tr>
</tbody>
</table>

265-0101-00L Data Science: From Analytics to Learning O 4 credits 3V O. Akkus Ispir, E. Konukoglu

Abstract In this module, basic paradigms and techniques in working with data will be discussed, especially towards data security, managing data decentrally, and learning from data.

Objective Participants will understand some of the concepts in detail and see the mathematics behind them.

Content The module in particular covers cryptography and digital signatures, networking and distributed algorithms, distributed ledger technology, as well as machine learning (supervised and unsupervised learning). For each topic, there will be a hands-on and in-depth introduction that allows participants to gain a technical understanding of key ideas. This is supported by simple and concrete examples as well as programming assignments.

265-0102-00L Computer Vision Basics O 2 credits 2V E. Konukoglu

Abstract This module will cover basic theoretical knowledge on visual recognition systems of the last two decades, mostly focusing on the most recent advancements in deep learning and convolutional neural networks.

Objective Participants understand basic concepts of visual recognition and human-computer interaction systems.

Content The content starts with an introduction to neural networks and then focuses on how they are used for computer vision tasks. The theoretical knowledge will be supported with a practical session that will allow participants to gain hands-on experience with most commonly used tools and deepen their understanding of the key concepts with examples.

265-0104-00L Reinforcement Learning Basics W 2 credits 2V B. Grewe

265-0105-00L Ethics, Leadership & Communication in Data-Science W 2 credits 2V O. Akkus Ispir

► Major in Applied Manufacturing Technology

Offered only in the Spring Semester.

► Focus Courses Energy or Electronics and Digitization

Offered only in the Spring Semester.

► Major in CAS in Applied Technology: R&D and Innovation

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>247-0200-00L</td>
<td>Fundamentals of R&amp;D and Innovation</td>
<td>O</td>
<td>4</td>
<td>2G</td>
<td>U. Grossner, C. Ganz</td>
</tr>
</tbody>
</table>
### Abstract
This course provides an introduction to research & development, both as a general activity and as a dedicated function within a corporation. Participants will learn how to organize, conduct and manage individual R&D projects as well as groups of projects. Special emphasis will be given to scientific and technical reporting.

### Objective
The course provides the framework of organization, managing and reporting of R&D projects and innovation initiatives.

### Lecture notes
The module will be based on a self-study Polybook.

### Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Content</th>
<th>Objective</th>
<th>Abstract</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subject-specific Competencies</strong></td>
<td>Concepts and Theories, Techniques and Technologies</td>
<td>fostered</td>
<td>Innovation is more than a good idea; it involves bringing the idea to the market, resulting in a highly differentiating market position. Not only product, also ideas have a lifecycle, from conception through launch, scaling, maintenance, to phase out, and replacement by a new innovation. Each phase is facing particular challenges that will be explored.</td>
</tr>
<tr>
<td><strong>Method-specific Competencies</strong></td>
<td>Analytical Competencies, Decision-making, Problem-solving</td>
<td>fostered</td>
<td>In this module, participants will understand the diverse aspects of these phases and the impact on the organization and governance.</td>
</tr>
<tr>
<td><strong>Social Competencies</strong></td>
<td>Customer Orientation</td>
<td>fostered</td>
<td>The inner working of the R&amp;D organization by exploring roles and processes is investigated.</td>
</tr>
<tr>
<td><strong>Personal Competencies</strong></td>
<td>Creative Thinking, Critical Thinking</td>
<td>fostered</td>
<td>The aim of this course is to develop the participants' ability to articulate a coherent plan for R&amp;D activities linked to the business needs of a corporation, and to set the environment to enable an efficient R&amp;D organization.</td>
</tr>
</tbody>
</table>

### Offered Courses

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>247-0201-00L</td>
<td>Innovation – What Is and to What Purpose Do We Need It?</td>
<td>2</td>
<td>O</td>
<td>2G</td>
<td>U. Grossner, C. Ganz</td>
<td></td>
</tr>
<tr>
<td>247-0202-00L</td>
<td>R&amp;D: The Engine of Innovation</td>
<td>2</td>
<td>O</td>
<td>2G</td>
<td>U. Grossner, C. Ganz</td>
<td></td>
</tr>
<tr>
<td>247-0203-00L</td>
<td>The Innovation Ecosystem</td>
<td>2</td>
<td>O</td>
<td>2G</td>
<td>U. Grossner, C. Ganz</td>
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</tr>
</tbody>
</table>

### Experimental Project
Offered only in the Spring Semester.

### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
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<td>O</td>
<td>10</td>
<td>21D</td>
<td>Professors</td>
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</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1610 of 2653
Abstract
The topic of the independent Master's thesis should focus on a technical problem and can be related to a specific business case. The problem and technology evaluated are freely selectable, but must be approved in advance by the thesis supervisor.

Objective
The thesis should be integrative of the science and technology material and skills learned during the programme, particularly:

- Understand and apply the foundations of the area of science and technology relevant to the topic,
- Understand and describe the technical barriers to applying a technology successfully, and
- Respective documentation using precise and targeted technical language.

<table>
<thead>
<tr>
<th>Key for Hours</th>
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Special students and auditors need special permission from the lecturers.
## MAS in Architecture and Digital Fabrication

The MAS Digital Fabrication is a 1 year full-time programme and is structured as a series of teaching modules with an independent master thesis. Lessons within the modules are given in the form of lectures, practical workshops, and projects as the main modus for developing skills. Learning will be supported through one on one mentoring in studio, group critiques, symposia, and excursions.

### Module

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<thead>
<tr>
<th>Number</th>
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<tbody>
<tr>
<td>069-0001-00L</td>
<td>Digital Foundations</td>
<td>O</td>
<td>20 credits</td>
<td>2G</td>
<td>B. Dillenburger, F. Gramazio, M. Kohler</td>
</tr>
</tbody>
</table>

**Abstract**

Digital Foundations introduces students to information technology in architecture, to computational design and how robotic fabrication processes as well as 3D printing technologies are used to translate computational design models into physical objects and building components.

**Objective**

Students learn basic programming paradigms such as control structures and object oriented programming, the foundations of computational geometry and explore generative form-finding. Using Python as a main programming language within the frameworks of Processing, Rhino and Grasshopper, students learn to translate design thinking into computational algorithms. Furthermore, students learn about data preparation and toolpath creation for 3D printing (predominantly binder jet-printing and fused-deposition-modelling), and familiarise themselves with various mechatronic setups, materials and control-strategies of additive manufacturing. Students are taught the basic principles of working with industrial robotic arms in the field of architecture. Students practice different concepts of robotic control, which enables them to execute basic routines. They are able to write their own programmes and directly control the robotic set-up using UR-Script and custom Python modules. Through multiple exercises, students learn how to design and robotically build small-scale spatial structures exhibiting the potential of robotic fabrication processes. Additionally, they employ simple feedback loops for improving the accuracy of the fabrication process and as design-drivers.

---

**MAS in Architecture and Digital Fabrication - Key for Type**

<table>
<thead>
<tr>
<th>Key</th>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Suitable for doctorate</td>
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**Key for Hours**

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<td>lecture</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>independent project</td>
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<tr>
<td>U</td>
<td>exercise</td>
<td>diploma thesis</td>
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<td>S</td>
<td>seminar</td>
<td>revision course / private study</td>
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<td>K</td>
<td>colloquium</td>
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**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### MAS in Architecture, Real Estate, Construction

#### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tr>
<td>072-0001-00L</td>
<td>Construction Industry and Real Estate Market</td>
<td>O</td>
<td>3</td>
<td>7G</td>
<td>S. Menz</td>
</tr>
</tbody>
</table>

**Abstract**
In the first term of MAS ETH ARC, the students' knowledge of the construction sector and the real estate market will be reinforced and deepened, along for an informed interpretation of the stakeholders' decision making processes. It explores the topics of involved parties and perception of demand. Additionally, it will guide students in developing their research proposals and research questions.

**Objective**
The first term of MAS ETH ARC supports the students' expertise and personal skills and develops their reasoning and creative thinking skills. It compels the students to understand both ambitious projects and complex properties, to pursue long-term intentions, to carry out specific tasks, and to become aware of the consequences of their decisions. Over the course unit, students review and closely examine the expertise which they have gained so far. The course directs students to draw independent conclusions and to set forecasts as professionals. Ultimately, the knowledge and expertise which is gained throughout the unit will allow the students to fully realise their role as a professional in their field.

**Content**
In the first term of MAS ETH ARC, the students' knowledge of the construction sector and the real estate market will be reinforced and deepened, along for an informed interpretation of the stakeholders' decision making processes and interests. It also explores the topics of involved parties and perception of demand. Additionally, it will guide students in developing their research proposals and research questions.

Key words of the course unit
Project and property, design and building process, involved parties and services, interests, basic knowledge and terms, perception and dissociation, sustainable decisions, and life cycle

**MAS thesis**
Advising students on potential research, in light of students' interests, work and academic experience, and their professional aims.
Assisting students with determining the relevance of the study area. Discourse, developing the research objectives and devising the research questions. Public presentation of the initial objectives.

**Lecture notes**
Scripts, documents, studies, dates and addresses are stored on the server of the program.

**Literature**
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

<table>
<thead>
<tr>
<th>Number</th>
<th>Methodology</th>
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<tr>
<td>072-0003-00L</td>
<td>Methodology</td>
<td>O</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
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</table>

**Abstract**
In the fourth term of MAS ETH ARC, the students will guide through the process of methodology which is the ability to put their attitude into practice. Additionally, the course unit puts emphasis on the research findings and finalisation of the written work.

**Objective**
The fourth term of MAS ETH ARC supports the students' attitude and practice and methodology. It compels the students to analyse issues and carry out solutions. Ultimately, the knowledge and expertise which is gained throughout the unit will allow the students to fully realise their role as a professional in their field.

**Content**
In the fourth term of MAS ETH ARC, the students will guide through the process of methodology which is the ability to put their attitude into practice. Additionally, the course unit puts emphasis on the research findings and finalisation of the written work.

Key words of the course unit
Objectives, methodology, research, analysis and interpretation, academic writing, text understanding, publishing

**MAS thesis**
Advising students on potential research, in light of students' interests, work and academic experience, and their professional aims.
Assisting students with developing the research objectives and devising the research questions, illustrating the methodology, defining the contents, publicising their thesis. Public presentation of the objectives.

**Lecture notes**
Scripts, documents, studies, dates and addresses are stored on the server of the program.

**Literature**
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

### Major in Digitalisation

#### Core Courses

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<tr>
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<tr>
<td>072-0101-00L</td>
<td>Module 1: Foundations of Digitalisation</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
</tr>
</tbody>
</table>

**Abstract**
Key terms: Digital transformation is more than digitisation of existing processes and information

**Objective**
Independently of the building industry, Module 1 initially provides information about the characteristics of digitalisation through its principles and rules, enabling the participants to independently recognise the short-term and long-term changes that are resulting from it.

**Content**
The first module addresses the topic of digitalisation and digital transformation in a holistic sense. It is much more than converting documents into PDFs or using software. It is about transforming processes, resources and information into a consistent and efficient digital system to make life easier for employees and customers. This journey always involves change. From the perspective of other industries, we first build up a basic understanding and discuss the opportunities and risks.

How do the experiences of other industries help us? What can be derived from them? Why is BIM only a small part and why is the future of BIM not BIM?

**Lecture notes**
Scripts, documents, studies, dates and addresses are stored on the server of the program and accessible to students on the Miro Board.

**Literature**
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

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<tr>
<th>Number</th>
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<th>Type</th>
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<tr>
<td>072-0102-00L</td>
<td>Module 2: Collaboration</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
</tr>
</tbody>
</table>

**Abstract**
Key terms: "Behaviour for Collaboration" - Structural questions on collaboration and the patterns of behaviour.

**Objective**
In Module 2, we break from the theoretical idea of a purely technology-based, better collaboration and look at the situation realistically in order to be able to understand and develop new solutions and requirements.

**Content**
The usual approach towards digital transformation is to train people to use new technologies. In contrary, we ask for the specific challenges and problems people have with change. We learn to understand viewpoints of different partners within building projects and new solutions to specific problems.

**Lecture notes**
Scripts, documents, studies, dates and addresses are stored on the server of the program and accessible to students on the Miro Board.

**Literature**
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

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<tr>
<th>Number</th>
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<td>072-0103-00L</td>
<td>Module 3: Foundation of Automation</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
</tr>
</tbody>
</table>

**Abstract**
Key terms: Managed data, semantics and file formats

**Objective**
Module 3 we leave behind the negative images from the early days of automation. A gloomy and misanthropic image of automation - both a bliss and a curse. We get to know the positive sides and learn to apply them. How do we become a sustainable "Formula 1"?
What does it take to be able to work together in a digitally networked environment? How many "techie genes" are needed to work efficiently?

As a final module, new business models are discussed and explored. Examples will be used to explore patterns and interfaces and to understand the following terminologies, processes and competences. They are able to put them into practice.

We learn to consciously look at the topic of added value and digital transformation from different perspectives. Collision checking and quantity take-offs (QTO) are very useful. But they are only basics when it comes to real value creation.

### Module 4: Foundation of Value Creation

**Key terms:** Added value of digital transformation, distributed data management, digital twin, logistics and robotics.

**Objective**

Using specific examples, Module 4 illustrates the foundations and versatility of building information modeling (BIM), enabling participants to deal with the concepts, applications and mechanisms involved.

**Content**

"Highway to hell or highway to haven" - the question of a clear and simple roadmap is always at the heart of a digital transformation. "Value creation" is a central goal. Digitalisation is often seen as a strategy from the productivity gap. The fourth module shows how strategic goals can be developed in a roadmap and implemented in practice and how the individual shareholders and stakeholders participate.

We will analyse the topic on the basis of two concrete examples, familiarise ourselves with them and observe their further development as a result.

### Term Paper

The Term Paper is offered in spring semesters only.

### Major in Project Leadership

### Core Courses

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<td>1</td>
<td>2G</td>
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<td>- Organisational forms</td>
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<td>- Role and tasks</td>
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<td>- Attitude and practice</td>
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<td>1</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
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<tr>
<td>- Organisation charts</td>
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<td>- Project knowledge and process understanding</td>
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<td>- Structure of the project</td>
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<td>- Agile project management</td>
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<td>- Socio-economic viewpoint</td>
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<td>- Perception of demand</td>
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<td>072-0203-00L</td>
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<td>2G</td>
<td>A. Paulus, S. Menz</td>
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<tr>
<td>Objective</td>
<td>The students are able to understand the following terminologies, processes and competences. They are able to put them into practice.</td>
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<tr>
<td>- Phases and services</td>
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<td>- Due diligence and duty of loyalty</td>
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<td>- Duties and tasks, liability</td>
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<td>- Working packages</td>
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<tr>
<td>- Management and coordination</td>
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<tr>
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<td>Module 4: Guiding/Steering/Leading</td>
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<td>2G</td>
<td>A. Paulus, S. Menz</td>
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</table>
The importance of a life-cycle-oriented approach has arrived in the Swiss construction and real estate sector. Cumulative management

Our advanced studies' lectures are given in German. Please find an English written abstract and/or keywords in the field 'objective'.

Please find the teaching material, the further readings and Information on our server.

www.map.arch.ethz.ch/en

Key words: construction and real estate market, micro and macro environment

Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Module 3: Economic Interest

The students are able to understand the following terminologies, processes and competences. They are able to put them into practice.

Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

The total weight of all properties in Switzerland is estimated at around 1 billion tonnes. Every year around 10 million m³ of buildings are demolished and more than 60 million t of raw materials are used in new buildings. This module examines the cycle principle and its implications for selective decommissioning, disposal, landfilling, recycling and reuse, as well as the importance of the gray matter energy of materials.

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1615 of 2653
### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tr>
<td>072-0401-00L</td>
<td>Module 1: Market</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
</tr>
<tr>
<td>Abstract</td>
<td>Key terms: Market, purpose and business model</td>
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</tr>
<tr>
<td>Objective</td>
<td>The aim is to use a snapshot in time to interpret one’s own company and become able to assess opportunities and risks.</td>
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<tr>
<td>Content</td>
<td>The “company” module considers the role of organisations within the economic network of the markets and the nature of their identity. It presents the special aspects of planning offices as service providers, illustrates various types of company, and discusses companies’ lifecycle as they move from their founding to the period of planning for the succession. Both sector-specific development of management and organizational models and also the problems of obtaining access to international markets are also investigated. Alongside this, the foundations of a generally valid business model for service companies are described and key criteria are defined.</td>
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<tr>
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<td>Scripts, documents, studies, dates and addresses are stored on the server of the program.</td>
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<tr>
<td>072-0402-00L</td>
<td>Module 2: Acquisition</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
</tr>
<tr>
<td>Abstract</td>
<td>Key terms: Competence, communication and network</td>
<td></td>
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<tr>
<td>Objective</td>
<td>The aim is to become able to analyse and implement the processes and instruments used for acquisition in one’s own company.</td>
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<tr>
<td>Content</td>
<td>Acquisition represents a separate project in entrepreneurial activity, since all the activities involved in obtaining a commission fall under this term. The “acquisition” module focuses on imparting basic knowledge of networking and professional dialogue. Both of these tools require an assessment of one’s own situation with regard to competence, resources and customer relations. The conversation is a direct interaction; everyone involved is both an addressee and also basically an equal interlocutor. Networking can be learned: situational “small talk,” social competence and a healthy ability to communicate can be learned.</td>
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<tr>
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<td>Literature recommendations at <a href="http://www.bauprozess.arch.ethz.ch">www.bauprozess.arch.ethz.ch</a> and <a href="http://www.kompetenz.arch.ethz.ch">www.kompetenz.arch.ethz.ch</a></td>
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<tr>
<td>072-0403-00L</td>
<td>Module 3: Marketing</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
</tr>
<tr>
<td>Abstract</td>
<td>Key terms: Planning, positioning and identity</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The aim is to become familiar with the tools used in marketing and able to use them in specific situations.</td>
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</tr>
<tr>
<td>Content</td>
<td>Marketing means orienting company activities towards market demands. Communication between suppliers, clients and the competition plays the decisive role here. The “marketing” module illustrates the foundations of marketing planning for architects and engineers. The essential definitions are provided and the core tasks involved in marketing are described. On this basis, the way in which a marketing plan is developed is explained and strategic and operational marketing planning is described in detail. The topics of branding and the opportunities represented by press and public relations work for architects and planners round out the “marketing” module.</td>
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<tr>
<td>Literature</td>
<td>Scripts, documents, studies, dates and addresses are stored on the server of the program.</td>
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<tr>
<td>072-0404-00L</td>
<td>Module 4: Financial Management</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
</tr>
<tr>
<td>Abstract</td>
<td>Key terms: Cost accounting, budgeting and controlling</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Objective</td>
<td>The aim is to become able to analyse one’s own company’s financial resources in detail, interpret key parameters for the current situation and test them.</td>
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<tr>
<td>Content</td>
<td>Financial management means achieving the target company output with costs that are as low as possible, and in the longer term to create secure asset and capital structures. The tasks involved in financial management in a planning office include establishing a well-structured accounting department, careful cost accounting, sound budgeting and an effective controlling system. On the basis of a practical financial structure for architects and engineering offices, the “financial management” module presents the information needed to carry these tasks out in a professional and responsible way.</td>
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<tr>
<td>Literature</td>
<td>Scripts, documents, studies, dates and addresses are stored on the server of the program.</td>
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<tr>
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<td>Literature recommendations at <a href="http://www.bauprozess.arch.ethz.ch">www.bauprozess.arch.ethz.ch</a> and <a href="http://www.kompetenz.arch.ethz.ch">www.kompetenz.arch.ethz.ch</a></td>
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<tr>
<td>072-0405-00L</td>
<td>Module 5: Digitalisation</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus, S. Menz</td>
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<tr>
<td>Abstract</td>
<td>Key terms: Strategy, potentials and digital planning</td>
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<tr>
<td>Objective</td>
<td>The aim is to become familiar with the current practical work involved in IT in planning companies and be able both to analyze the specific challenges it implies and also to infer one’s own prospects for development in this context. In addition, thought needs to be given to the way in which the value creation provided by digitalisation influences one’s own company.</td>
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<tr>
<td>Content</td>
<td>IT refers to the one hand to information and data processing in a company, and on the other to the hardware and software components needed for the purpose. This “information technology” module focuses on potential strategies for company management in the IT field. The focus is not on the use of any individual programme, but on taking conscious decisions for or against IT components in one’s own company in order to obtain helpful support in one’s everyday work. The strengths, weaknesses, opportunities and risk of this strategy suggest possible potentials.</td>
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<tr>
<td>Literature</td>
<td>The participants will present their own theses on entrepreneurship and open them up for discussion in the plenary session.</td>
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<tr>
<td>Literature</td>
<td>Literature recommendations at <a href="http://www.bauprozess.arch.ethz.ch">www.bauprozess.arch.ethz.ch</a> and <a href="http://www.kompetenz.arch.ethz.ch">www.kompetenz.arch.ethz.ch</a></td>
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### Term Paper

The Term Paper is offered in spring semesters only.

### MAS in Architecture, Real Estate, Construction - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1616 of 2653
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<thead>
<tr>
<th>Key for Hours</th>
<th>Description</th>
<th>Key for Hours</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Field of Preservation

Core Courses and Seminars

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>079-0100-00L</td>
<td>Scientific questions of monument conservation practice</td>
<td>O</td>
<td>3</td>
<td>2S</td>
<td>S. M. Schlachetzki, S. Langenberg</td>
</tr>
</tbody>
</table>

Abstract
The seminar provides an introduction to the basics of working with heritage theory on a scientific basis. It imparts methodological knowledge, introduces participants to archive-based research, and enables them to critically evaluate the sources consulted. The subsequent communication of the results in the form of an expert's report is also part of the course.

Objective
The aim of the seminar is to qualify participants to apply methods of architectural and cultural studies in the evaluation of objects of the built environment. Participants are enabled to assess a selected building in the form of a heritage conservation expert's report.

Content
An essential basis for the responsible handling of the built heritage is the ability to recognize its characteristics and special features from an architectural-historical perspective and to objectively work out its historical testimonial value. This requires knowledge of scientific methods as well as the ability to undertake targeted research and critically evaluate source material in order to productively incorporate it into the analysis. The first part of the seminar is devoted to an introduction to academic work in the field of architecture and cultural studies. This lays the foundation for the second part which deals with the independent academic appraisal of an individual building.

Competencies

Subject-specific Competencies
- Concepts and Theories: fostered
- Method-specific Competencies
  - Analytical Competencies: fostered
  - Decision-making: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

079-0101-00L Seminar Texts on Preservation

Abstract
In the seminar, selected texts on architectural theory and monument preservation are read together and discussed in plenary. The focus is on selected writings from John Ruskin, Gottfried Semper and Friedrich Nietzsche to Alois Riegl and Adolf Loos to Walter Benjamin, Aleida Assmann and Peter Zumthor.

Objective
Skills in reading complex theoretical and literary writings on architecture and monument preservation are taught. With increasing practice, these enable participants to undertake an independent appropriation of architectural theory and monument preservation content.

Content
The writings on architectural theory and historic preservation discussed in the seminar provide an overview of the most important theories and concepts of historic preservation. Ruskin’s narrative of architectural historicity, Semper’s conception of “Bekleidung” and Nietzsche’s transformation of mythology are covered, as are Riegl’s notions of “Erinnerungswert” and “Gegenwartswert”. Loos’ writings on architecture, Benjamin’s notion of aura and Aleida Assmann’s memory space as well as Peter Zumthor’s atmosphere. Each text is discussed in terms of textual structure, conceptual history, visual language, relationship to poetry and literature, strategies of theory, etc. Identifying the levels and intersections that link a theory with other theories characterises one of the main tasks of our seminar.

Literature
Alois Riegl, Der moderne Denkmalkultus. Sein Wesen und seine Bedeutung, Wien / Leipzig 1903.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: fostered

063-0911-24L Future Monuments

Abstract
Heritage conservation is dedicated to the preservation and protection of historical buildings. In this lecture, students will learn about the theoretical positions on historic monuments and the basics of preservation in practice.

Objective
In addition to active participation in the discussions, students will be asked to engage with a topic or object of their own choice in order to be able to develop and comprehensively justify their own positions within the context of preservation. Our goal here is to foster students’ communication skills and the culture of discussion.

Content
The responsible reconstruction and further development of the existing building stock requires knowledge and an understanding of the theoretical positions conservation and the basics of preservation in practice. The core course of spring semester 2024 conveys this knowledge to students with the help of selected writings and discusses them in the context of various guest lectures.
Literature

READING LIST

Monographs and edited volumes:


Dehio, Georg, Kunsthistorische Aufsätze, München 1914


Franz, Birgit, Gerhard Vinken und Johanna Blokker (Hg.), Denkmal - Werte - Bewertung, Denkmalpflege im Spannungsfeld von Fachinstitutions und bürgerschaftlichem Engagement, Holzminden 2013 (Veröffentlichung des Arbeitskreises Theorie und Lehre der Denkmalpflege e.V., Band 23).

Huse, Norbert (Hg.), Denkmalpflege: Deutsche Texte aus drei Jahrhunderten, München 1984.

ICOMOS Deutschland/ Österreich/ Luxemburg/ Schweiz (Hg.), Monumenta I: Internationale Grundsätze und Richtlinien der Denkmalpflege, Stuttgart 2012.


Schmidt, Leo (Hg.), Einführung in die Denkmalpflege, Darmstadt 2008.


Wohlleben, Marion und Georg Mörsch, Georg Dehio und Alois Riegl - Konservieren, nicht restaurieren. Streitschriften zur Denkmalpflege um 1900, Basel 1988 (Bauwelt Fundamente 80)

Hassler, Uta, Langfriststabilität. Beiträge zur langfristigen Dynamik der gebauten Umwelt, Zürich 2011

Fundamentals and legal texts:

Stadt Zürich Hochbaudepartement, Amt für Städtebau, Denkmalpflege und Archäologie (Hg.), Schulhäuser der Stadt Zürich. Spezialinventar Archäologie und Denkmalpflege, September 2008

Stadt Zürich Hochbaudepartement, Amt für Städtebau (Hg.), Bauten, Gärten und Anlagen 1960 bis 1980, Inventarergänzung, August 2013


Denkmalpflegegesetzgebung in den Heimatkantonen der Kursteilnehmenden.

Die Kunstdenkmäler der Schweiz

INSA – Inventare der Heimatkantonen der Teilnehmenden
Analytical Competencies

Themes and Technologies

Decision-making

Problem-solving

Project Management

Social Competencies

Communication

Cooperation and Teamwork

Self-presentation and Social Influence

Sensitivity to Diversity

Negotiation

Personal Competencies

Adaptability and Flexibility

Creative Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

Title

Hours

ECTS

Concepts and Theories

assessed

Techniques and Technologies

fostered

Analytical Competencies

assessed

Decision-making

assessed

Problem-solving

fostered

Project Management

fostered

Communication

assessed

Cooperation and Teamwork

fostered

Self-presentation and Social Influence

fostered

Sensitivity to Diversity

assessed

Negotiation

assessed

Adaptability and Flexibility

fostered

Creative Thinking

assessed

Integrity and Work Ethics

fostered

Self-awareness and Self-reflection

fostered

Self-direction and Self-management

fostered

Preservation Law

O

2 credits

1G

S. Langenberg

The course elaborates the legal concept of “monument” in its important distinction from the respective scientific concept. It highlights its embeddedness and effect in public building law. Furthermore, it deals with legal protection instruments and procedures. In addition to elaborating the legal concept of monuments, the course familiarises participants with legal protection instruments and procedures. It is planned to involve the participants by means of practical examples. In order to get to know the formation of theory, its paths and detours, the most important terms and persons in the history of monument conservation are introduced. Based on various texts, the history of the protection of architectural monuments since antiquity is illuminated. Further focal points in the history of monument preservation were during the Enlightenment, the French Revolution and in the process of the formation of nation states. The discourse on the concept and practice of monument conservation as we understand it today was led by a number of conservators in the German-speaking world around 1900. War-related destruction and the incipient building boom in Europe led to modern debates on the theory of monuments, which are still relevant today. Dealing with monument values is not an end in itself; it can be essential for the preservation of the monument or for historical mediation. Critical positions on the tasks, goals or practices of heritage preservation can only be developed against the background of a knowledge of its historical approaches.

Theory and History of Preservation

O

2 credits

2V


To follow

Concepts and Theories

assessed

Analytical Competencies

assessed

Decision-making

fostered

Problem-solving

fostered

Project Management

fostered

Communication

fostered

Cooperation and Teamwork

fostered

Leadership and Responsibility

fostered

Self-presentation and Social Influence

fostered

Sensitivity to Diversity

fostered

Negotiation

fostered

Adaptability and Flexibility

fostered

Creative Thinking

assessed

Integrity and Work Ethics

fostered

Self-awareness and Self-reflection

assessed

Self-direction and Self-management

fostered
The Methods Seminar provides students with assistance in identifying topics and writing initial project outlines for the master's thesis. Individual plenary sessions highlight methods and strategies for designing research papers. In individual meetings, students are guided in setting up their work plan as well as in drafting a preliminary outline of their MAS thesis.

At the end of the semester, students will have significantly expanded their skills in scientific research, in writing project outlines, as well as their knowledge of scientific methods. The aim of the Seminar is the basic preparation for the following semester, in which the students are fully engaged in writing their master's theses.

Die Lehrveranstaltung findet am Freitag von 14:00 bis 16:00 Uhr am Institut für Denkmalpflege und historische Bauforschung statt.

Kursdaten:
22.9. HIL E 71.1
3.11. HIL E 71.1
1.12.
8.12.
15.12.

Subject-specific Competencies
- Concepts and Theories

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication

Personal Competencies
- Adaptability and Flexibility
- Sensitivity to Diversity
- Critical Thinking
- Self-awareness and Self-reflection

Digital Heritage

This course focuses on recent constructions built using innovative computational design and fabrication technologies, and the challenges associated with their repair, maintenance, and preservation.

With the help of input lectures and excursions in and around Zurich, participants will explore new types of materials, structural designs, construction processes and methods associated with recently completed buildings built using computational methods. They will learn to critically observe existing theories and methods of preservation and discuss in groups the relationship between today’s digitally fabricated objects and future challenges in the discipline of preservation.

Kursdaten:
079-0251-00L
Autumn Semester 2024
15.06.2024 12:39
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The past two decades witnessed significant advances in the areas of computational design and digital fabrication in architecture. These often include the use of advanced fabrication tools such as robotic arms and 3D printers which are computer-controlled via algorithmic scripts for the purpose of manufacturing geometrically complex building parts that are optimized in terms of materials and structural design. The prototypes and buildings which demonstrate such technologies often feature new and experimental composite materials, construction details, planning and fabrication processes. They are the result of unique interdisciplinary science and industry partnerships. The innovations embedded in such objects offer a preview to building methods which will become commonplace in the production of buildings in the future. As such, it is of critical importance to observe the performance of such novel constructions especially in terms of their durability and repairability, and to document the building processes to foresee the challenges associated with the preservation of the future building stock. Switzerland and especially Zurich has become an important innovation center in the field of digital fabrication in architecture. This course will discuss the role and relevance of digitally built architecture as heritage through excursions and input lectures. The discussion will be accompanied by a critical observation on the existing preservation theories and practices regarding innovations in architecture and construction.

### Major Courses and Cooperations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>079-0250-00L</td>
<td>Preservation in Switzerland</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>S. Langenberg</td>
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<tr>
<td>079-0252-00L</td>
<td>Development of the Existing Building Stock</td>
<td>O</td>
<td>2</td>
<td>1G</td>
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**Abstract**

Historic buildings and sites are not per se significant parts of cultural heritage. They only become so when certain values are associated with them. Monument values are as dynamic as the society that produces them. The lecture traces the historical development of monument recognition and preservation in Switzerland since 1798.

**Objective**

Students will be able to name the most important actors in Swiss heritage conservation and describe developments in the field. They know methodological approaches and can place them in their historical context. They can identify the necessary principles and instruments in different situations and use them in their professional environment.

**Content**

In the 20th century, the most important impulses for the theory and practice of restoration came from the Federal Commission for the Preservation of Monuments, whose theoretical discourse and work are traced in detail. However, the activities of the cantons, private-law organisations and universities are also examined within the course. The institutionalisation of monument preservation is analysed in the context of social developments, whereby the evolution of its self-image from a patriotic civic duty in the age of industrialisation to monument preservation as environmental protection in the sustainability discourse of the 21st century is also examined. In the second half of the semester, the theoretical foundations, actors and instruments that are relevant in Switzerland today will be presented and their interaction explained.

Central questions will be examined in greater depth using concrete case studies. Among others, the following will be discussed: the restoration of Chillon Castle from 1897; the mountain village restoration of Vrin in 1944; the restoration of the Augustinian Church in Zurich in 1958; the controversy surrounding the reconstruction of the Predigerchor in Zurich in 1987; the extension of the Stadtcasino Basel (2016-2020); the struggle for the preservation of medieval wooden buildings in the canton of Schwyz (2000-2021).

**Competencies**

PDfs of the lecture slides will be provided before the lecture. Furthermore, the audience will be granted access to recent journal articles.

**Abstract**

History of the construction site and its technology

**Objective**

Introduction to Construction History and the so-called “building archeology”: ability to perform a “close reading” of historic built fabric, based on an in-depth knowledge on historic production techniques, both in the workshop and on the construction site itself. The focus is on constructions in stone.

**Content**

This lecture series deals with the history of the production of buildings. This history draws heavily on pictorial and archival sources, but the lecture will always establish the link to traces observable on site. In that sense, the lecture is an introduction to the wide topic of “building archeology”. Among others, we will cover the following topics:

- construction materials, tools and tooling of construction elements
- material flow and economic boundary conditions of the construction site
- construction site technology and construction machinery (scaffolding, cranes, etc.)
- history of building production

The autumn semester is primarily dedicated to building with stone: from quarrying to dressing and lifting. We consider tools, construction site technology such as scaffolding, centring and other temporary works, cranes. We study all types of stone constructions, from foundations to walls to vaults, from concrete-like rubble stone through small dressed stone to huge monoliths.

The spring term lecture, conversely, is mostly dedicated to timber construction and to the evolution of structural concepts over time.

**Competencies**

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

**Additional Major Courses and Cooperations**

**Number** 063-0901-00L

**Title** Construction History: The Construction Site and Its Technology

**Type** O

**ECTS** 2 credits

**Hours** 2G

**Lecturers** S. Holzer

**Abstract**

History of the construction site and its technology

**Objective**

Introduction to Construction History and the so-called “building archeology”: ability to perform a “close reading” of historic built fabric, based on an in-depth knowledge on historic production techniques, both in the workshop and on the construction site itself. The focus is on constructions in stone.

**Content**

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- construction site technology and construction machinery (scaffolding, cranes, etc.)
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The spring term lecture, conversely, is mostly dedicated to timber construction and to the evolution of structural concepts over time.

**Lecture notes**

PDfs of the lecture slides will be provided before the lecture. Furthermore, the audience will be granted access to recent journal articles and book chapters providing in-depth insight into the topics covered by the lecture.

**Prerequisites / notice**

This lecture will NOT be given by Prof. Holzer in the fall term 2024 (sabbatical). Rather, students are asked to listen to the recordings from fall 2023 (video.ethz.ch) and to have a look at the slides from 2023. Both will provide all information necessary to pass the exam.

However, there will be biweekly lecture-hall events during which topics from last year’s lecture will be considered, questions answered, and some additional illustrative examples presented. This will include presentations by PhD students reporting from their ongoing research projects.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management
- Social Competencies
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
  - Negotiation
- Personal Competencies
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

**Data:** 15.06.2024 12:39

**Autumn Semester 2024**

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### Competencies

**Subject-specific Competencies**
- Concepts and Theories

**Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Social Competencies**
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Personal Competencies**
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Social influence
- Self-direction and Self-management

### Abstract

Surveying and measuring technologies in historical building archaeology. Case studies on building archaeology.

### Objective

Basic understanding of different surveying methods and first practical contacts with technical surveys instruments. Understanding of the procedures and aims of building archaeology.

### Content

From folding rule to laser scanner: surveying techniques and their possible applications.

The elective subject "Building Surveying and Building Archaeology" covers surveying and measurement methods ranging from simple hand measurements and tachymetry to laser scanning, terrestrial and drone-based photogrammetry (structure from motion) and other non-invasive assessment methods such as thermal imaging. The different methods and technologies will be presented on the basis of current or completed research projects and their practical applications will be discussed. Internal and external guest speakers will report on their latest research projects in the field of building research and construction history. In the course of the elective, students will also have the opportunity to try out the methods themselves and integrate them into a small concluding project of their own.

The course is composed of theoretical and practical parts in and outside the classroom.

### Literature

Will be announced in the course for the individual lectures.

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### Competencies

**Subject-specific Competencies**
- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Social Competencies**
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Personal Competencies**
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Social influence
- Self-direction and Self-management

---

### Abstract

Through joint reading seminars, visits, and lectures, current topics and concepts in preservation and construction heritage are discussed.

### Objective

Students explore specific questions in depth and discuss them within the group and with experts.
## Electives

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>052-0705-00L</td>
<td>Landscape Architecture I</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>A. Bucher</td>
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### Abstract

The Landscape Architecture I and II lecture series looks at the design of nature from the first cultural landscapes to today's complex cultural landscape formations. The lecture series not only analyzes the results of anthropogenic nature design, but also discusses its various causes, contexts and consequences.

### Objective

The course provides the basics and tools for an in-depth understanding of the discipline of landscape architecture and its far-reaching interconnections with architecture, urban planning, ecology and other spatial and nature-related sciences. The aim is to adopt landscape perspectives in planning and design processes and to critically reflect on one's own projects within a specific context.

Students learn about historical developments and their topicality and learn "from history". Design contexts are presented on the basis of examples. Students develop a basis for ways of thinking and action for current landscape architectural challenges.

### Content

The lectures in the fall semester course "History and Theory of Gardens and Landscape Architecture" provide an overview of the cultural history of nature, the landscape and the garden from its origins to the present day. An in-depth understanding of change as well as the design strategies and characteristics of the most important epochs and their current relevance will be discussed.

### Lecture notes

Handouts and a bibliography will be provided.

### Literature

Handouts and a bibliography will be provided.

### Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<td>Sensitivity to Diversity</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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</table>

### Prerequisites / notice

**General information on the examination:**

Bachelor students: The knowledge taught in the lecture and the exam-relevant literature provided by the lecturer serve as the basis for exam preparation. The course is designed as an annual program. As the written session exam tests knowledge from both the Landscape Architecture I and II lecture series, it is strongly recommended that you attend the course over two semesters. The examination topics will be announced shortly before the end of the semester. The lecturer will provide texts on the examination topics as pdf files for download. These serve to deepen understanding of the lecture.

Mobility students or students from other departments: Students who only attend the lecture for one semester complete the lecture with an end-of-semester oral examination. Here too, the lecturer provides literature relevant to the examination as a download. Students registered for the exam will receive further information on the exam procedure by email shortly before the end of the semester.

### 052-0901-00L

**Building History I**

**Abstract**

History of building from classical antiquity to modernity: building types, constructions, forms, with particular reference to functional issues such as flexibility of use, statics, durability. This is not a mere history lecture, but an important part of the basic introduction into construction.

**Objective**

Participants know the fundamentals of building history, including landmark monuments of each era, key historic constructions and forms. They are able to "read" a historic building and to relate it to building history. They are aware of the variety of historic building constructions.
Building history I covers the period from classical Greek antiquity to medieval architecture. The principal topics include construction issues such as Greek megalithic building, Roman mortar-and-rubble construction, and vaulting.

Within the Vitruvian and Albertian triad of firmitas, utilitas and venustas, we focus on the first two topics, whereas the last topic (deciphering the "meaning" of architecture) stands at the heart of the "architectural history" lectures. The present lecture contributes essentially to deepening knowledge about historic constructions, an indispensable precondition for building within existing fabric.

- buildings of Greek antiquity as examples of construction with huge stone blocks
- Roman buildings as examples of building with small materials, strict functional dispositions, and evolution of the art of vaulting
- late antique and early Christian buildings: discovering interior space, developing new paradigms for religious architecture, construction wide-span roofs
- early and high medieval construction, continuing antique traditions, revival of dressed stone and vaulting
- small buildings, notably rural housing
- the medieval monastery

Lecture notes
Please keep a tight record of manuscript notes yourself. pdfs of lecture slides will be on line before each lecture. Lecture notes for exam preparation are provided and should be used in conjunction with the pictures from the lecture slides.

The exam will be held at the end of the first year. It is a computer-based multiple choice test. It calls for precise knowledge of the examples presented in the lecture, including the specifics of the architecture and construction of the buildings. Terminology is in GERMAN.

Lectures
Due to professor Holzer's sabbatical, this lecture will be given by Dr. Jasmin Schäfer, in Fall Term 2024. However, the contents will be identical to the lecture delivered by professor Holzer in the Fall Term of 2023. This includes the topics, slides, lecture notes. Professor Holzer's lecture of Fall Term 2023 is available as a recording on video.ethz.ch. The lecture of Dr. Schäfer in Fall Term 2024 will NOT be recorded. Please refer to the recording of Fall Term 2023 under video.ethz.ch.

You may either listen to the fall 2023 recordings, to Dr. Schäfer's live lecture, or to both, to be prepared for the spring term of 2025 and the exam.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Method-specific Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Social Competencies
Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Mas in Preservation and Construction History - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
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<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Key for Hours

<table>
<thead>
<tr>
<th>V</th>
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<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

ECCTS
European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
## Module Digital Clinical Trials

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
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<tbody>
<tr>
<td>395-0100-01L</td>
<td>The Power of Study Design</td>
<td>O</td>
<td>3</td>
<td>3G</td>
<td>S. Goldhahn, A. Burden, D. Stekhoven, to be announced</td>
</tr>
<tr>
<td>395-0103-00L</td>
<td>Precision Medicine and AI</td>
<td>O</td>
<td>2</td>
<td>3G</td>
<td>A. Fontecedro-Curioni, A. Ghosh, S. Modica</td>
</tr>
</tbody>
</table>

**Abstract**

Precision Medicine is a new approach in health care aiming to deliver personalized prevention and treatment for human diseases, by taking into account individual differences in lifestyle, environment, and biology.

**Objective**

After taking this course, participants will be able

- to describe the goal of precision medicine;
- to explain different next-generation sequencing technologies;
- to illustrate how to make good use of public biological/clinical repositories;
- to demonstrate basic concepts of big data and machine learning;
- to explain how to genotype biological samples for a genetic disease;
- to describe examples of complicated ethical or clinical situations in personalized medicine.

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>395-0104-00L</td>
<td>Digital Measures</td>
<td>O</td>
<td>3</td>
<td>3G</td>
<td>J. Goldhahn, I. Clay</td>
</tr>
</tbody>
</table>

**Abstract**

Participants will learn all necessary steps to establish new digital measures for their own clinical research. They will get a comprehensive understanding of this new emerging field, will discuss the newest guidelines with authors from international societies, will have a chance to interact with digital pioneers, and will be enabled to develop a concept for their individual digital measure.

**Objective**

The course enables participants to...

1. describe why new methods are needed to generate evidence.
2. describe how new (digital) methods for generating evidence are established.
3. explain how the concept of patient-centredness is applied in the development of new methods for evidence generation.
4. analyse sources of bias in basic research.
5. analyse the conditions for the development and validation of new evidence generation tools.
6. understand the framework for the development of new methods for evidence generation and to analyse the advantages and disadvantages of different approaches.
7. develop their own concept for a new digital measure.

### Competencies

**Subject-specific Competencies**

- Concepts and Theories: assessed

**Method-specific Competencies**

- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: fostered

**Social Competencies**

- Communication: fostered

**Personal Competencies**

- Creative Thinking: fostered
- Critical Thinking: fostered

## Module Digital Health

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>375-0003-00L</td>
<td>Designing a Digital Biomarker (Group Project 2)</td>
<td>O</td>
<td>4</td>
<td>1G</td>
<td>M. Jovanova, T. Kowatsch</td>
</tr>
</tbody>
</table>

**Abstract**

The course introduces the concept of digital biomarkers. More specifically, the course will cover fundamental topics such as designing observational studies, collecting and exploring data generated by consumer-centric devices, and applying analytical methods to predict health-related outcomes.

**Objective**

The widespread use of mobile technologies (e.g., wearable sensors, mobile applications, social media, and location-tracking technologies) can meet the health monitoring needs of the world's aging population and the ever-growing number of chronic patients. However, this premise is based on applying information and communication technologies that allow us to monitor patient data in many different ways. In this course, we will analyze systematic ways to collect data, review the most appropriate methods and applications in healthcare, discuss the main challenges, and apply the newly gained knowledge in a project.

The course has four learning objectives, i.e., to

1. understand the concept of digital biomarkers in general
2. understand the various application areas of digital biomarkers
3. to critically reflect and assess existing digital biomarkers
4. to understand how to design a digital biomarker

**Content**

The course will cover the following topics:

1. Introduction to digital biomarkers
2. Design of digital biomarker studies
3. Exploration and assessment of digital biomarker candidates
4. Digital biomarker project and critical reflection
Literature


Prerequisites / notice
This module is assessed based on the participant's pass/fail status of the group project (including a presentation). The group project is ungraded.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies

- Communication
- Cooperation and Teamwork
- Customer Orientation
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Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Project 3

Designing a Just-in-time Adaptive Intervention (Group Project)

Objective

After this module, participants will be able to...

1. understand the importance of just-in-time adaptive interventions (JITAs), esp. for the prevention of NCDs
2. understand the design, implementation and evaluation of smartphone-based and chatbot-delivered JITAs
3. discuss opportunities and challenges of JITAs

Abstract

Today, we face the challenge of chronic conditions. Personal coaching approaches are neither scalable nor financially sustainable. The question arises therefore to which degree Digital Health Interventions (DHIs) are appropriate to address this challenge. In this CAS module, students will design, implement and evaluate a DHI, esp. a just-in-time adaptive intervention.

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"Can medical Alexas make us more healthy?" (The New York Times, April 2021); "Wearables as a tool for measuring therapeutic adherence in behavioral health" (npj Digital Medicine, May 2021); "Improving community healthcare screenings with smartphone-based AI technologies" (The Lancet Digital Health, May 2021); "Predictive analytics and tailored interventions improve clinical outcomes" (npj Digital Medicine, June 2021); "H1 2021 secured $14.7B in digital health funding, already surpassing all of 2020's funding" (Rock Health, 2021)

What are the implications and rationale behind the recent developments in the field of digital health?

Digital Health is the use of information and communication technology for the prevention and treatment of diseases in the everyday life of individuals. It is thus linked to topics such as digital health interventions, digital biomarkers, digital coaches and healthcare chatbots, telemedicine, mobile and wearable computing, self-tracking, personalized medicine, connected health, smart homes, or smart cars.

In the 20th century, healthcare systems specialized in acute care. In the 21st century, we now face the challenge of dealing with the specific characteristics of non-communicable diseases (NCDs). NCDs are now responsible for around 70% of all deaths worldwide and 85% of all deaths in Europe and are associated with an estimated economic loss of $7 trillion between 2011 and 2025. NCDs are characterized in particular by the fact that they require an intervention paradigm that focuses on prevention and lifestyle change. Lifestyle (e.g., diet, physical activity, tobacco, or alcohol consumption) can reduce the risk of suffering from a chronic condition or, if already present, can reduce its burden. A corresponding change in lifestyle is, however, only implemented by a fraction of those affected, partly because of missing or inadequate interventions or health literacy, partly due to socio-cultural influences. Individual personal coaching of these individuals is neither scalable nor financially sustainable.

To this end, the question arises on how to develop evidence–based digital health interventions (DHIs) that allow medical doctors and other caregivers to scale and tailor long-term treatments to individuals in need at sustainable costs. At the intersection of health economics, behavioral medicine, information systems research, and computer science, this CAS module has the objective to help participants interested in the multi-disciplinary field of digital health to better understand the need, design, implementation, and assessment of DHIs, esp. just-in-time adaptive interventions (JITAIs).

After this module, participants will be able to…

1. understand the importance of JITAIs, esp. for the prevention of NCDs
2. understand the design, implementation and evaluation of smartphone-based and chatbot-delivered JITAIs
3. discuss opportunities and challenges of JITAIs

The CAS module is structured in two parts and follows the concept of a blended treatment consisting of live sessions and complementary online material. In the live sessions, participants will learn relevant topics. Complementary learning material (e.g., video clips), multiple-choice questions, and exercises are provided via the online learning platform.

In the second part, participants work in teams and will use their knowledge from the first part of the module to develop a smartphone-based and chatbot-delivered JTAI with MobileCoach (www.mobile-coach.eu), an open-source software platform for the development of digital biomarker and digital health interventions. Each team will then present and discuss the resulting JTAI and evaluation results with their colleagues who will provide peer reviews. Additional live coaching sessions are offered to support the teams with the design and evaluation of their JITAIs, and with the preparation of the final group project presentations.

Prerequisites / notice / Competencies

This module is assessed based on the participant's pass/fail status of the group project (including a presentation). The group project is ungraded.

Subject-specific Competencies

Method-specific Competencies

Social Competencies

Personal Competencies

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

Content

Adaptability and Flexibility

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Communication

Cooperation and Teamwork

Customer Orientation

Leadership and Responsibility

Self-presentation and Social Influence

Sensitivity to Diversity

Negotiation

<table>
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Compulsory Elective Modules
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
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<tr>
<td>395-0200-00L</td>
<td>Regulatory World</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>J. Goldhahn, I. Clay, D. Schaffarczyk</td>
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</table>

**Abstract**
Participants will be introduced into regulations and landscape including all stakeholders. The different types of medicinal products are introduced including subsequent regulations. Participants apply the knowledge in different starting scenarios.

**Objective**
- understand the complexity of the regulatory landscape
- know the main characteristics of different medicinal products and subsequent regulatory pathways
- identify the different stakeholders and players in this landscape
- analyze different regulatory strategies using real-world cases

**Content**
- The regulatory landscape – a challenge for all players
- Different types of medicinal products - different regulatory pathways
- Health authorities – friend or foe?
- Different countries – different regulations
- Successful regulatory strategy – make or break for a medicinal product
- From idea to product – do it yourself

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<tr>
<th>Number</th>
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<tr>
<td>395-0201-00L</td>
<td>Regulatory Thinking</td>
<td>W</td>
<td>2</td>
<td>4G</td>
<td>D. Schaffarczyk, R. Abächerli, further lecturers</td>
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</table>

**Abstract**
Students gain an overview of how to transform a research idea into a finished healthtech product by confidently navigating different regulatory landscapes and developing compelling certification strategies for various healthtech products. Students learn how to use Regulatory Thinking to turn Regulatory Affairs into a business planning tool.

**Objective**
- Applying of regulatory thinking and translation of this method into practice.
- Getting an overview of applicable laws, different regulations, directives and guidelines in the healthtech sector: MD, IVD, SaMD, medicine, biotech, ATMP.
- Understanding the different roles and responsibilities of Certification Bodies (CB), Notified Bodies (NB), and other Regulators and/or Reimbursement Agencies, hereafter: Competent Authorities (CAs).
- Knowing how to address CAs, including communication and interaction
- Awareness of the importance of a quality management system (QMS) and knowing different systems, including, but not limited to ISO 13485:2016, GMP, GLP, GCP

**Content**
The journey of regulatory thinking - from medical devices (MDs), to in vitro diagnostics (IVDs), to software as a medical device (SaMD), to medicines and advanced therapeutic medicinal products (ATMPs): Commonalities, differences and the search for the lowest common denominator in terms of:
- Regulations/Directives/Laws/Guidelines
- Interaction with the regulatory authorities
- The principles of safety/efficacy/performance/transparency
- The requirements for the implementation of a QMS

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<tr>
<td>395-0202-00L</td>
<td>Intended Use / Indication</td>
<td>W</td>
<td>2</td>
<td>4G</td>
<td>D. Schaffarczyk, R. Abächerli, further lecturers</td>
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</table>

**Abstract**
From software as a medical device to medicinal products: The intended use of a healthtech product serves as strategic pivotal point from conception to reimbursement strategies: Understanding its importance defines advertising claims and ensures that the product meets the needs of patients.

**Objective**
Know and understand different definitions: medical need / public health assessment; personalized medicine, pharmacogenomics/ customized device.

Understand the importance of medical and stakeholder needs assessments in medicine / medtech / in-vitro diagnostics / software as medical device / artificial intelligence and among different stakeholders.

Understand the relationship between indication / intended use / intended purpose and development, including risk assessment.
Define the intended use / intended purpose for a healthtech product and derive user groups, patient groups, indications and contraindications.
Understand and derive an overview of the different stakeholders of a healthtech product and their different interests.

Overview of different development models, starting with requirements engineering, the classical waterfall model and V-model up to agile methods for software as medical device or AI concepts.
ISO 14971: Understanding and applying principles of risk management.
IEC 62366: Understanding and applying the principles of usability engineering.

**Artificial Intelligence:** Know the challenges of artificial intelligence in healthtech products, define an AI policy and develop a verification process.
The intended use is the "linchpin" in the development, approval and reimbursement of medicinal products or medical devices. Whether software as a medical device, artificial intelligence in medical devices, but also in pharmaceuticals or biotechnology, the intended use is the first and last touchstone - alpha and omega - of all healthtech concepts.

- Intended use, user and patient groups I/III: How the intended use of a healthtech product influences its development, safety, performance, marketing strategy and reimbursement possibilities.

- Intended use, user and patient groups II/III: How the intended use of a healthtech product determines the patient population and thus defines indications and contraindications.

- Intended use, user and patient groups III/III: How the intended use of a healthtech product determines the requirements for different user groups.

- Software as a medical device or drug: What is the market missing - what does the patient want? Derive product re-requirements by understanding market requirements and patient needs. (development planning).

- Software as a medical device or drug: Who is interested in the product, who benefits from it, who works with it? Derive concepts for usability and risk management by understanding the different user groups and their interests (verification and validation).

- Software as a medical device; artificial intelligence, digital biomarkers, new biotech concepts: development and market-ing in compliance with regulations by applying "existing" standards to future technologies (regulatory compliance / legal compliance).

The Module 4 "Development Process: Preclinical" includes an overview of preclinical efficacy and safety in drug development as well as in the development of medical devices and in vitro diagnostics. Emphasis will be placed on the applicable regulations and potential interactions with regulatory authorities in early product development. When a preclinical development plan becomes necessary and what is needed to start with will be explained in a practical way. An overview is also given of which preclinical studies and documents are required in order to be able to conduct an early clinical study in humans for the first time.

Module Nutrition in Medicine

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>395-0300-00L</td>
<td>Introduction to Nutrition</td>
<td>W</td>
<td>2 credits</td>
<td>1G</td>
<td>F. von Meyenn</td>
</tr>
<tr>
<td>Abstract</td>
<td>This first module of the CAS Nutrition in Medicine will provide an overview of the most important concepts of nutrition. The introduction to nutrition specific physiology, will be followed by a more detailed overview of the macro- and micronutrients as well as their importance to health and disease.</td>
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<tr>
<td>Objective</td>
<td>Students can describe the basic concepts of nutrition. Students can name the different macronutrients and can explain how they are metabolized. Students can classify vitamins and minerals and can describe the most important deficiencies.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies: Concepts and Theories assessed</td>
<td></td>
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<tr>
<td></td>
<td>Method-specific Competencies: Communication assisted, Teamwork fostered</td>
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<tr>
<td></td>
<td>Social Competencies: Cooperation and Teamwork fostered</td>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>395-0301-00L</td>
<td>Digital Nutrition Monitoring</td>
<td>W</td>
<td>2 credits</td>
<td>1G</td>
<td>F. von Meyenn</td>
</tr>
<tr>
<td>Abstract</td>
<td>This module introduces the basic concepts of classic dietary assessment and of dietary reference values. In addition, novel, digital methods for food monitoring as well as health in general will be introduced. Biomarkers for nutritional assessment will build the last part of this module.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Students can apply classic dietary assessment methods and interpret generated results. Students can describe the general concept of digital health monitoring. Students know how to apply methods for digital nutrition monitoring and understand their benefits and limitations.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies: Concepts and Theories assessed, Techniques and Technologies fostered</td>
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<tr>
<td></td>
<td>Method-specific Competencies: Media and Digital Technologies fostered</td>
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<tr>
<td></td>
<td>Social Competencies: Cooperation and Teamwork fostered</td>
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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>395-0302-00L</td>
<td>Nutrition in Metabolic Disease</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>F. von Meyenn</td>
</tr>
<tr>
<td>Abstract</td>
<td>The module Nutrition in metabolic disease will cover aspects of endocrinology and physiology in relation to nutrition, as well as specifically focus on nutritional aspects of obesity (including childhood obesity), type 2 diabetes including its therapy as well as muscle and exercise. In addition, different diet forms and their effects will be discussed.</td>
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<tr>
<td>Objective</td>
<td>Students understand how nutrition is closely linked to endocrinology. Students can develop nutritional strategies to improve health of obese patients. Students can apply nutritional concepts in the support of treatment and prevention of type 2 diabetes. Students can judge different diet forms in terms of their effect health/specific health aspects.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies: Concepts and Theories assessed, Techniques and Technologies fostered</td>
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<tr>
<td></td>
<td>Method-specific Competencies: Analytical Competencies assessed, Cooperation and Teamwork fostered</td>
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<td></td>
<td>Social Competencies: Communication fostered, Teamwork fostered</td>
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</tbody>
</table>

Module Individual Specialisation

One additional module may be chosen in agreement with the Programme Director.

Master’s Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1631 of 2653
The research project includes the study of existing literature, specification of the research question, choice of the methodological approach and/or study design, statistical considerations (if applicable), regulatory considerations, description about the data management and/or data collection, analysis and interpretation of data (if applicable), and the written and oral reporting of the findings.

The students shall demonstrate their ability to carry out a structured, scientific piece of work independently. Hereby they will be able to use digital tools and new study concepts independently and responsibly to conduct pragmatic and patient-centric clinical research.

Students enrolled in the MAS ETH in digital Clinical Research programme who have acquired at least the minimum number of required credits from two CAS are eligible to write the Master's thesis. They will use the knowledge gained in the first two CAS of the MAS programme to design a clinical research project investigating a question within their area of interest.

The 20-weeks research project must have a digital component, such as the use of digital biomarkers or remote patient monitoring. It must also take into account regulatory considerations. If a student considers conducting a clinical trial in context with their Master's thesis, they must prepare a complete protocol as well as the necessary regulatory documents. Other approaches to the research question are possible in consultation with the supervising professor. In general, the research project includes the study of existing literature, the specification of the research question, the choice of the methodological approach and/or study design, statistical considerations (if applicable), regulatory considerations, the description about the data management and/or data collection, the analysis and interpretation of data (if applicable), and the written and oral reporting of the findings.

Prerequisites /
notice
two CAS completed

MAS in Digital Clinical Research - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</tr>
</tbody>
</table>

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
The compulsory courses of NADEL are accessible only for students of the MAS in Global Cooperation and Sustainable Development and for qualified employees with at least two years experience in development cooperation and a Master's level or equivalent level of education as recognized by ETH. PhD students doing empirical research in development cooperation may be admitted “sur Dossier”.

The elective courses are open to master students of the ETH with registration/ waiting list. MAS students do have priority.

Programme Regulations 2021

Advanced Training Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>865-0065-00L</td>
<td>VET between Poverty Alleviation and Economic Development</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td></td>
</tr>
</tbody>
</table>

Only for MAS/CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.

ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

Abstract

The course aims at strengthening the capacity in portfolio management for VET, skills development and active labor market policies. It deals with basic issues and challenges of Vocational Education and Training (VET) in Developing Countries. In view of the many of school leavers VET has to place itself between the contradicting intensions of quality education and short-term training interventions.

Objective

The participants are able to
- Assess project proposals and ongoing project regarding their relevance and suitability in the specific country context
- Explain strengths and weaknesses of the opposing approaches “dual apprenticeship” and “competency based training” as well as synergies and incompatibilities between the two
- Describe the competent use of tools currently applied in VET

Content

• Basic concepts and terms
• Differences and commonalities between VET and neighboring systems
• Planning, assessment of VET interventions with different objectives: economic development, poverty alleviation, creation of self-employment or systems development
• VET as a cooperation system of stakeholders with different duties, interests and competencies
• Background, potential use and limitations of (national) qualification frameworks
• Half-day visit to important actors of the Swiss VET landscape

Prerequisites / notice

Students of the course must fulfil requirements specified on the homepage of NADEL.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Analytical Competencies assessed
Decision-making fostered
Problem-solving fostered
Project Management fostered

Method-specific Competencies
Communication assessed
Cooperation and Teamwork fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered

Social Competencies
Negotiation fostered
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

865-0024-00L| The SDGs in an Urbanising World                                      | W    | 1 credit | 2G     |           |

Does not take place this semester.

Only for MAS/CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.

Doctoral students dealing with empirical research in the area of development and cooperation (EZA) may be admitted "sur Dossier".

Registration only through the NADEL administration office.

Abstract

This course draws out good practices in promoting sustainability development at the city level. Participants gain insights on designing urban- focused development interventions.

Objective

Historically, cities have been hubs of innovation, economic activity and rising prosperity. However, the unprecedented speed and scale at which cities are growing today is a huge challenge. As epicenters of migration, environmental degradation, health hazards and unemployment, urban areas are especially vulnerable to disasters, social conflict and inequality. Despite this, some of the most promising initiatives to achieve the SDGs have been implemented by cities. What strategies and processes do successful city- based initiatives pursue? How can development organisations support mainstreaming the SDGs at the local level? What can be learnt from experiences so far? This course draws out good practices in promoting sustainability and equity at the city and local level. Participants gain insights on designing urban- focused development interventions.
### Subject-specific Competencies

- **Critical Thinking**
  - Understanding policy processes: Institutions and actors at the macro, meso and micro level

### Analytical Competencies

- **Concepts and Theories**
  - Qualitative and Participatory Research Methods for Engaging with Policy Processes: Strategies and Tools

### Method-specific Competencies

- **Data: 15.06.2024 12:39**
  - Reporting of qualitative results.
  - Reporting of qualitative results.
  - Reporting of qualitative results.
  - Reporting of qualitative results.
  - Reporting of qualitative results.

### Personal Competencies

- **Personal Competencies**
  - Actor-oriented approaches, methods and tools to analyse, engage with and contribute to policy processes
  - Policy in terms of rules and norms emerging from a negotiation process between interdependent actors
  - Political settlements, power distribution and inequalities of access to rights and resources
  - Exclusive and fragile institutions, and the influence of dominant coalitions
  - Understanding policy processes: Institutions and actors at the macro, meso and micro level
  - Political settlements, power distribution and inequalities of access to rights and resources

### Prerequisites / Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Prerequisites / notice</th>
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<tbody>
<tr>
<td><strong>Method-specific Competencies</strong></td>
<td>Students of the course must fulfill requirements specified on the homepage of NADEL. Electronic registration may be done only after registration with the NADEL secretariat.</td>
</tr>
<tr>
<td><strong>Personal Competencies</strong></td>
<td>Students of the course must fulfill requirements specified on the homepage of NADEL. Electronic registration may be done only after registration with the NADEL secretariat.</td>
</tr>
<tr>
<td><strong>Subject-specific Competencies</strong></td>
<td>Students of the course must fulfill requirements specified on the homepage of NADEL. Electronic registration may be done only after registration with the NADEL secretariat.</td>
</tr>
</tbody>
</table>

### Course Descriptions

**865-0004-00L Qualitative and Participatory Research Methods for Development Practitioners**

- **Objective**
  - ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

- **Abstract**
  - Registration only through the NADEL administration office.
  - Qualitative research has much to offer to the practical work of development organizations. This course will provide an overview of the principles and practice of qualitative research and illustrate ways in which qualitative research can be incorporated into the programme cycle. Participants will learn to collect and analyse data, using qualitative methods.

- **Content**
  - The qualitative research approach.
  - Qualitative research methods, including interviews, focus group discussions and participant observation.
  - Designing and planning qualitative studies.
  - Qualitative data analysis and interpretation.
  - Reporting of qualitative results.
  - Embedding qualitative research within a project cycle.

**865-0044-03L Engaging with Policy Processes: Strategies and Tools**

- **Objective**
  - ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

- **Abstract**
  - Registration only through the NADEL administration office.
  - The course enables participants to understand the significance of the engagement of civil society organisations in policy processes in order to overcome exclusion and foster voice. The course acquaints participants with concepts and practice of civil society participation in shaping policies at micro and macro level and provides practical tools for influencing political processes.

- **Content**
  - Understanding policy processes: Institutions and actors at the macro, meso and micro level
  - Political settlements, power distribution and inequalities of access to rights and resources
  - Policy in terms of rules and norms emerging from a negotiation process between interdependent actors
  - Actor-oriented approaches, methods and tools to analyse, engage with and contribute to policy processes

**865-0002-00L Migration and Development**

- **Objective**
  - ETH MA/MSc students apply with a letter of motivation to the NADEL administration office.

- **Abstract**
  - Globally, over 280 million people live outside their countries of origin. While the concept of migration has negative connotations for some, migration can bring significant benefits – to both countries of origin and destination, if the right policies and initiatives are in place.
  - The course explores the role that international cooperation can play in promoting the positive aspects of migration.

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**Data:** 15.06.2024 12:39  **Autumn Semester 2024**  **Page 1634 of 2653**
Planning and Monitoring of Projects

Course participants have improved understanding of the following issues:
- Definition of migration concepts and terms
- International legal frameworks related to migration
- The geography of migration flows
- Major drivers of migration
- The evolving concept of “migration and development”
- International cooperation organisations and their strategies and activities in terms of migration and development.

Content
Globally, over 280 million people are currently living outside their countries of origin, voluntarily and involuntarily; and a further 60 million people live in internal displacement settings within their countries of origin. Migration is multifaceted, and driven by various, often interlinked factors including conflict and violence, economic, social and political factors, as well as environmental and climate related events. While the concept of migration has negative connotations for some, migration can bring significant benefits – to both countries of origin and destination, if the right policies and initiatives are in place.

This course covers:
- Important terms and concepts related to migration;
- International legal frameworks related to migration;
- The geography of migration flows;
- Major drivers of migration;
- The evolving concept of migration and development;
- Actions, strategies and initiatives of international cooperation actors when it comes to migration and development.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Cooperation and Teamwork</td>
<td>Critical Thinking</td>
<td></td>
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<tr>
<td>assessed</td>
<td>assessed</td>
<td>fostered</td>
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</table>

865-0100-01L Planning and Monitoring of Projects

Does not take place this semester.

Only for MAS in Global Cooperation and Sustainable Development.

Abstract
The course provides a deeper understanding of the conceptual and methodological foundations of results-oriented Project cycle management, focusing on planning, monitoring and steering development projects.

Objective
The course participants prepare for their project assignments through improving their knowledge and skills related to selected aspects of project management.

Content
- Overview of key concepts and phases of project cycle management
- Intro to project planning, including the Logical Framework Approach, results chain and logframe matrix
- Intro to project monitoring, including the development of a monitoring and evaluation plan with indicators in order to assess project progress and steering
- Short intro to project evaluation, including main types, concepts and processes

Social Entrepreneurship – Driving Sustainability in Business

Course participants have improved understanding of the following issues:
- Definitions of “social entrepreneurship” and the difference with “entrepreneurship”
- Get inspired by concrete examples of successful social ventures
- Formulate a social business plan using the business canvas methodology
- Learning to think and act like a social entrepreneur
- The art and power of storytelling in an entrepreneurial context

Content
- Overview of key concepts and phases of project cycle management
- Intro to project planning, including the Logical Framework Approach, results chain and logframe matrix
- Intro to project monitoring, including the development of a monitoring and evaluation plan with indicators in order to assess project progress and steering
- Short intro to project evaluation, including main types, concepts and processes

Competencies

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<th>Method-specific Competencies</th>
<th>Social Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Decision-making</td>
<td>Customer Orientation</td>
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<tr>
<td>assessed</td>
<td>assessed</td>
<td>assessed</td>
<td>assessed</td>
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</tbody>
</table>

865-0020-00L Social Entrepreneurship – Driving Sustainability in Business

Does not take place this semester.

Only for MAS/CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.

ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

Abstract
This course introduces the concept of social entrepreneurship, understanding in which situations and under which conditions the concept can be applied, and the basics of developing a business strategy for a social enterprise.

Objective
This course introduces the concept of social entrepreneurship over three different blocks. The first part is dedicated to the definition, history, context and the successes and blockers of social entrepreneurship, including some real-world examples. In the second part the participants will learn to transform a social business idea into a concrete social business plan. The last block of the course is dedicated to the power of storytelling, where participants learn how to pitch their business ideas convincingly.

Content
- Definitions of “social entrepreneurship” and the difference with “entrepreneurship”
- Get inspired by concrete examples of successful social ventures
- Formulate a social business plan using the business canvas methodology
- Learning to think and act like a social entrepreneur
- The art and power of storytelling in an entrepreneurial context

Social and Cultural Aspects of International Development Cooperation

Course participants have improved understanding of the following issues:
- Overview of key concepts and phases of project cycle management
- Intro to project planning, including the Logical Framework Approach, results chain and logframe matrix
- Intro to project monitoring, including the development of a monitoring and evaluation plan with indicators in order to assess project progress and steering
- Short intro to project evaluation, including main types, concepts and processes

Content
In this course, social and cultural dynamics of international development cooperation are analysed, discussed, and connected to contemporary development cooperation activities and projects. Themes to be focused on include the impacts of colonisation in development cooperation, decolonisation, migration, gender, racism, and education.
The learning goal is for students to critically reflect on the influences of these themes on the design and implementation of development cooperation interventions, as well as:

- display basic knowledge of selected topics on social and cultural aspects of development cooperation
- consider which social, cultural and psychological factors influence human action, and discuss their importance for development cooperation
- explain different conceptions of development in western and non-western cultures and indicate possible consequences for development projects

Raising awareness on selected cultural and social aspects of development issues and their relevance for international development cooperation (DC):

- The importance of the concept of "culture" in DC
- Slavery, colonialism and decolonisation, and their historical and contemporary relics in DC (racialism, white saviour complex, discrimination, white superiority, and so on).
- The impacts of social and cultural dynamics on DC
- The role of religion in development projects and interventions
- The challenges and opportunities of migration in DC
- Cross-cutting issues in DC: gender, localisation, and others

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

865-0011-01L Water, Sanitation and Waste Management

Only for MAS in Global Cooperation and Sustainable Development

Objective

The course provides an overview of the links among sanitation, water supply, waste management and environmental and health aspects. It gives an understanding of the specific challenges and possible solutions in ensuring environmental services and illustrates their impact on the population and settlements.

Content

- Humanitarian Aid between intervention in crises, prevention and development tasks
- Non-governmental Organisations: Challenges today - in Switzerland and in partner countries
- Economy, private foundation and philanthropy: New actors with high aspirations
- Economic development: New approaches and interventions
- Multi-level development banks: Bretton Woods Institutions

Social Competencies

- Decision-making
- Problem-solving
- Project Management

Content

- Raising awareness on selected cultural and social aspects of development issues and their relevance for international development cooperation (DC):
Subject-specific Competencies

- The participants are able to present the global situation and development trends in the sector of sanitation, water supply, waste management and for its main actors;
- discuss the relationships between water supply, sanitation and health;
- explain the principles of technologies for drinking water treatment, the management of sewage and waste, as well as appraise their strengths and weaknesses;
- explain which sustainable concepts are implemented and how they can be inserted into the technical, institutional and social structures so that they are economically, ecologically and socially sustainable;
- provide information where good professional resources are available.

865-0010-02L Environment, Natural Resources and Climate Change

**Objective**

- Degradation of the environment and non-sustainable use of natural resources, including land, water, forests and biodiversity is threatening individual livelihoods as well as local, national and international economies. This lecture series will address conflicts related to unsustainable resource use and discuss trade-offs between environmental sustainability and economic development.

- The student will be able to:
  - portray the management of natural resources such as land, forest, water, and biodiversity in different contexts and discuss the key challenges in each sector
  - examine the implications of climate change on development and the sustainable management of natural resources
  - analyze conflicts and trade-offs between natural resource use and economic development
  - discuss the global priorities relating to human-induced changes to the environment, and how these can be met

**Competencies**

- Subject-specific Competencies: Concepts and Theories
- Assessed
- Method-specific Competencies: Analytical Competencies
- Assessed
- Social Competencies: Cooperation and Teamwork
- Assessed
- Personal Competencies: Critical Thinking
- Assessed

865-0003-00L Development Economics

**Objective**

- This course is an introduction to theoretical and empirical discussions on economic development, with a focus on the challenges of developing countries over the last 50 years. The course provides answers to the following questions: How can and should development be measured? What factors drive economic growth and contribute to poverty reduction?

**Content**

- measurement of development, poverty and inequality,
- growth theories
- trade and development
- education, health, population and development
- states and institutions
- economic policies for economic growth and poverty reduction
- economics of development aid

865-0010-02L Agriculture, Food and Nutrition Security

**Objective**

- Food security has been on top of the policy agenda for decades, but still a considerable proportion of the population in developing countries remains hungry and poorly nourished. This lecture series will explore how we produce and distribute food; it analyses the concept of food and nutrition security and discusses ways and means for measuring and achieving it in low-income countries.

**Content**

- measurement of development, poverty and inequality,
- growth theories
- trade and development
- education, health, population and development
- states and institutions
- economic policies for economic growth and poverty reduction
- economics of development aid

865-0008-00L Policy Impact Analysis

**Objective**

- The following topics will be discussed: Basic principles of epidemiology and global burden of disease distribution, Health systems and health system strengthening including economic aspects and health insurance, communicable diseases such as HIV/AIDS, Malaria, tuberculosis and neglected tropical diseases, mother and child health, non-communicable diseases and transition in LAMICs.

**Content**

- measure impact and effectiveness of policies and programs in the health sector;
- understand the concept of food and nutrition security, and discuss it's impact and causes
- reflect on some of the main economic challenges of the world food system and understand some of the tradeoffs between smallholders' decisions of labor, consumption, and production of food
- give insights on how international organizations work with farmers and governments in low income countries
- provide information where good professional resources are available.

**Competencies**

- Subject-specific Competencies: Concepts and Theories
- Fostered

865-0008-00L Policy Impact Analysis

**Objective**

- The following topics will be discussed: Basic principles of epidemiology and global burden of disease distribution, Health systems and health system strengthening including economic aspects and health insurance, communicable diseases such as HIV/AIDS, Malaria, tuberculosis and neglected tropical diseases, mother and child health, non-communicable diseases and transition in LAMICs.

**Content**

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- give insights on how international organizations work with farmers and governments in low income countries
- provide information where good professional resources are available.

**Competencies**

- Subject-specific Competencies: Concepts and Theories
- Fostered
This course introduces students to key methods for quantitative policy impact analysis and covers the different stages of the process. Acquired skills are applied on a real project from a development organization. Students also learn how to perform simple statistical analyses with the statistical software R.

**Objective**

- Students know strategies to test causal hypotheses using experimental methods and regression analysis.
- Students are able to formulate and implement a research design for a particular policy question and a particular type of data.
- Students are able to critically read and assess published studies on policy evaluation.
- Students are able to use the statistical software R for simple data analysis.
- Students can apply all the steps involved in a policy impact evaluation.

**Content**

Policy impact evaluation employs a wide variety of research methods, such as statistical analysis of secondary data, surveys or laboratory and field experiments. The course will begin with an overview of the various methodological approaches, including their advantages and disadvantages and the conditions under which their use is appropriate. It will continue with a discussion of the different stages of a policy impact evaluation, including hypothesis generation, formulating a research design, measurement, sampling, data collection and data analysis. For data analysis, linear regression models will be revised, with a focus on difference-in-difference methods and randomized controlled trials used for policy evaluation. Students, who already have a solid background in these methods can skip these sessions.

Throughout the course, students will work on the design of a policy impact evaluation for a real-world project.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories fostered
  - Techniques and Technologies fostered
- **Method-specific Competencies**
  - Analytical Competencies assessed
  - Decision-making assessed
  - Problem-solving assessed
  - Project Management fostered
- **Social Competencies**
  - Communication assessed
  - Cooperation and Teamwork fostered
  - Sensitivity to Diversity fostered
  - Negotiation fostered
- **Personal Competencies**
  - Adaptability and Flexibility fostered
  - Creative Thinking assessed
  - Critical Thinking assessed
  - Self-direction and Self-management fostered

**Abstract**

This course on gender and economics is intended to provide basic- and intermediate-level training to development practitioners and policy and program staff in international development agencies. The overall objective of the course is to strengthen the capacity of technical advisors and program staff on the importance of gender-responsive economic policy. The course conveys basic knowledge about gender aspects in economics. Key elements are:

- Feminist approaches to macroeconomics, microeconomics and international economics
- Critical analysis of global and regional economic trends, including those related to economic crises
- Gender-responsive economic policy for program implementation, policymaking, and advocacy

**Content**

Economic inequalities between men and women persist in many countries. For example, in many countries, men earn more money and are more likely to own land and control productive assets than women. This course on gender and economics is intended to provide basic- and intermediate-level training to development practitioners and policy and program staff in international development agencies. The overall objective of the course is to strengthen the capacity of technical advisors and program staff on the importance of gender-responsive economic policy. The course is taught in cooperation with SDC and UN women.

**Abstract**

This course provides a foundation in the principles, techniques, and strategies for storytelling in the context of systems change. Key topics include:

- Psychology of Stories
- Key Elements and Techniques of Storytelling
- Ethics & Authenticity
- Using Stories in Project Cycle Management

**Objective**

By the end of this course, participants will be able to apply and adapt the fundamentals of storytelling to support their work as development practitioners and as proponents of systems change. They will be able to integrate storytelling techniques into activities such as reporting, fundraising, and context analysis. They will be better equipped to construct stories that are engaging and illustrative of the complexity of systems change.
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Social Competencies
Communication assessed
Self-presentation and Social Influence fostered
Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered

Social Competencies
Communication assessed
Self-presentation and Social Influence fostered

865-0049-00L AI for Global Development Organisations
Only for CAS in Global Cooperation and Sustainable Development students, as well as specialists with at least 24 months of practical experience in international cooperation.
ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.
Registration only through the NADEL administration office.

Project Assignment

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>865-0800-00L</td>
<td>Project Assignment</td>
<td>O</td>
<td>25</td>
<td>45P</td>
<td>external organisers</td>
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</table>

Abstract
MAS ETH D&C students complete project assignments at renowned organizations in international cooperation. The goal is to get to know the complex working reality of the modern development cooperation on site, and to gain relevant work experience. The assignment has a performance component and a learning component.
The duration of the project assignment is between 8 and 10 months.

Objective
- Apply knowledge acquired during the semester to a specific project setting
- Get to know the complex interdisciplinary and intercultural working reality
- Gain experience in project-based collaboration with different social stakeholders
- Gain professional experience in international cooperation

Prerequisites / notice
For the implementation of these project assignments NADEL is cooperating with some 30 governmental and non-governmental development organizations. Preconditions for the start are the successful completion of the study semester, adequate language skills (en; fr; es; depending on the country of assignment) and the medical suitability. The costs are financed through a scholarship from the Swiss Agency for Development and Cooperation (SDC).

Policy Essay

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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>865-0900-00L</td>
<td>Policy Essay</td>
<td>O</td>
<td>6</td>
<td>13D</td>
<td>Supervisors</td>
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</table>

Abstract
For the final thesis, students choose a development policy topic in the context of their practical work. The focus is on the “critical reflection” of a freely chosen question.

Objective
- Recognize policy issues relevant to development in the own working context
- Identify the peculiarity and implications of a development policy issue for different stakeholder groups
- Work on a question from a scientific perspective
- Develop policy options for addressing an identified issue

Semester Thesis

865-0700-00L Semester Thesis
Only for MAS ETH in Global Cooperation and Sustainable Development

Abstract
The students work on a question in multidisciplinary groups applying theory-based approaches and sound methods. The results are discussed with experts and policymakers.
The thesis is a literature study with a strong application-oriented or empirical character based on scientific publications, expert opinions and reports from organizations. The work may also include limited information surveys.

Objective
- Practice scientific collaboration in a multidisciplinary team
- Apply themselves to a development topic in order to address policy relevant questions
- Present and discuss study results and policy implications in front of different audiences

Programme Regulations 2024

Core Courses
Electives
Written Papers
Modules
Project Assignment

MAS in Global Cooperation and Sustainable Development - Key for Type

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<tr>
<th></th>
<th>Compulsory</th>
<th>Eligible for credits and recommended</th>
<th>Eligible for credits</th>
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<td>O</td>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>W+</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
<td>Suitable for doctorate</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>diploma thesis</td>
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<td>R</td>
<td>revision course / private study</td>
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ECTS | European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### MAS in Nutrition and Health

#### Disciplinary Subjects

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>752-6105-00L</td>
<td>Epidemiology and Prevention</td>
<td>W+</td>
<td>3 credits</td>
<td>2V</td>
<td>M. Puhan, R. Heusser</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td>The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.</td>
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<td>The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.</td>
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<td>The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.</td>
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<td>752-2307-00L</td>
<td>Nutritional Aspects of Food Composition and Processing</td>
<td>W+</td>
<td>3 credits</td>
<td>2V</td>
<td>B. E. Baumer, J. M. Sych</td>
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<td><strong>Abstract</strong></td>
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<td>Lecture type course with an interdisciplinary approach for the evaluation of nutritional aspects of changes in food composition due to processing.</td>
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<td>Students should be able to</td>
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<td>- describe and compare the major concepts/criteria used for the evaluation of the nutritional quality of food</td>
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<td>- apply these criteria when assessing the effects of selected processing technologies on nutritional quality.</td>
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<td>- evaluate recent formulation strategies aimed to achieve additional physiological benefits for targeted population groups (i.e. functional foods).</td>
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<td>The course gives inputs on compositional changes in food due to processing (with focus on thermal/chilling, enzymatic, chemical, separation and emerging technologies) or new formulation strategies. New approaches for evaluating these changes (e.g. nutritional profiles) and how these are communicated to consumers are also discussed.</td>
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<tr>
<td>752-6301-00L</td>
<td>Nutrition-Related Physiology</td>
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<td>F. von Meyenn, E. Gasser</td>
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<td><strong>Abstract</strong></td>
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<td>Gives the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand.</td>
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<td>Some basic knowledge in physiology is recommended for this course, which revisits important physiological topics, emphasizing their relation to nutrition. The aim is to give the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand. For students with a background in medicine, pharmacy or biology, the course is useful as a review of previously acquired knowledge. Major topics are basic neuroanatomy and neurophysiology; general endocrinology; the physiology of taste and smell; nutrient digestion and absorption; intermediary metabolism and energy homeostasis; and some aspects of cardiovascular physiology and water balance.</td>
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<td><strong>Lecture notes</strong></td>
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<td>Handouts for each lecture will be uploaded to Moodle every week.</td>
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<td>766-6205-00L</td>
<td>Nutrient Analysis in Foods</td>
<td>W+</td>
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<td>3U</td>
<td>to be announced</td>
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<td><strong>Abstract</strong></td>
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<td>Does not take place this semester.</td>
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<td>Number of participants limited to 16.</td>
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<td>Permission from lecturers required for all students.</td>
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<td>In this practical course, different meals are prepared and then analysed for nutritional content in the laboratory. Based on these results, the nutritional value of each meal is critically evaluated and discussed, and the students must design a reformulated meal that has a superior nutritional content, justifying their choices.</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1641 of 2653
Content

The practical course Nutrient Analysis in Foods includes meal preparation (a half day in late 2023; date to be defined) and chemical analysis of four meals from four different types of diets (students will work in groups; one meal per group). The content of specific micronutrients and secondary phytonutrients (polyphenols and phytic acid) are analysed using common analytical methods. The analytical results are compared with calculated data from food composition databases using nutrition software and then critically evaluated.

The nutritional values of the meals are discussed, including a discussion of nutrient bioavailability. The students are also expected to reformatulate their meal to a more nutritional version, justifying their choices using evidence from peer-reviewed literature. Students will prepare a written report to summarise their findings and conclusions, supported by an oral presentation with colloquium in the group.

The practical course is accompanied by lectures on the basic principles of analytical chemistry that will be given in person with further details made available via Moodle.

Lecture notes

The cooking and laboratory methods will be described in a "script" which will be made available before the start of the course. All lectures will have full notes available via Moodle.

Prerequisites / notice

There are no prerequisites to attend this course, however, students must be available to attend on all days of the course, including the oral presentation and colloquium. Attendance is compulsory.

Students will work in groups, and will assess one group per meal.

Performance will be assessed by means of:
1) Contribution to laboratory practical work (29 Jan to 7 Feb 2024);
2) A written test on course content (via Moodle, completed by 9 Feb 2024);
3) A 15 min oral presentation of laboratory results in a seminar with colloquium (active discussion) (on 9 Feb 2024);
4) A (max) 8-page written report per group (deadline 16 Feb 2024).

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Social Competencies
Cooperation and Teamwork fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed

752-6101-00L Nutrition and Chronic Disease

Abstract

To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Objective

To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic disease, as well as the progression of complications of the chronic diseases.

Content

The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Lecture notes

There is no script. Powerpoint presentations will be made available on-line to students.

Literature

To be provided by the individual lecturers, at their discretion.

Prerequisites / notice

No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

752-6403-00L Nutrition and Performance

Abstract

The course introduces basic concepts of the interaction between nutrition and exercise performance.

Objective

To understand the potential effects of nutrition on exercise performance, with a focus on concepts and principles of nutrition before, during and after exercise.

Content

The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise.

Although this is a scientific course, it is a goal of the course to translate basic sports nutrition science into practical sports nutrition examples.

Lecture notes

Lecture slides and required handouts will be available on the ETH website (moodle).

Literature

Information on further reading will be announced during the lecture. There will be some mandatory as well as voluntary readings.

Prerequisites / notice

General knowledge about nutrition, human biology, physiology and biochemistry is a prerequisite for this course. The course builds on basic nutrition and biochemistry knowledge to address exercise and performance related aspects of nutrition.

The course is designed for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).

766-6304-00L Nutrition Research Procedure

Abstract

This course provides students interested in nutrition with fundamental tools and concepts in human nutrition research, including topics such as study design, statistical analysis, scientific writing and communicating results. Preparation of a research proposal will consolidate student learning. The course is designed for MAS and first semester MSc Nutrition and Health students.

Objective

The course will familiarise students with the fundamental concepts, methodologies and terminology that apply to human nutrition research. The course features both didactic presentations and in-class practical exercises including topics such as study design, statistics, scientific writing and communicating results. Students will have the opportunity to consolidate their learning by preparing a research protocol to study a nutrition-related health problem, which will be submitted for grading and presented in an end-of-semester graded poster presentation.

On completion of this course, students will have improved:
• Understanding of experimental study design in basic and clinical research
• Familiarity with the research process and methods used in human nutrition
• Understanding of basic statistics and analytical skills used in preparing and reporting research, including in tables and graphs
• Ability to report scientific results in writing and orally
• Skills in scientific writing and an understanding of the publication process
• Proficiency in retrieval and interpretation of scientific literature

Lecture notes

The teaching slides used in the lectures will be made available weekly on Moodle before each class, as pdf files.

Literature

There is no recommended textbook or prior reading required for this class. Students will be provided with recommendations for further reading where relevant, with the lecture notes.

Prerequisites / notice

Students are expected to attend and actively participate in the course, which includes the preparation of a research protocol that will be presented and graded during a poster presentation at the end of the semester.
Competencies

Subject-specific Competencies  
Concepts and Theories  
assessed

Techniques and Technologies  
assessed

Method-specific Competencies  
Problem-solving  
assessed

Project Management  
assessed

Personal Competencies  
Creative Thinking  
assessed

Critical Thinking  
assessed

Electives

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<td>752-2122-00L</td>
<td>Food and Consumer Behaviour</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>M. Siegrist, F. Michel</td>
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<tr>
<td>Abstract</td>
<td>This course focuses on food consumer behavior, consumer's decision-making processes and consumer's attitudes towards food products.</td>
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<td>Objective</td>
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<td>- to describe heuristics that influence consumer behavior in the food domain</td>
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<td>- to explain the consumer led food product development</td>
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<td>- to summarise how consumers perceive the environmental impact and the healthiness of foods</td>
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<td>- to assess the cultural, the environmental and the food policy impact on consumer behavior</td>
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<td>- to explain psychological factors influencing eating behavior</td>
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<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<td>Social Competencies</td>
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<td>Customer Orientation</td>
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<td>Sensitivity to Diversity</td>
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<td>Personal Competencies</td>
<td>Critical Thinking</td>
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<td>assessed</td>
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</table>

| 752-0801-00L   | Food Law and Legislation      | W    | 1    | 1V    | K. Krell Zbinden, E. Zbinden Kaessner |
| Abstract       | Introduction to the principles of the EU and international organisations, Set up and Application of the Swiss Food Law. |
| Objective      | Knowledge of the principles and the structure of the EU in general and in the area of food safety, overview of the relevant bilateral agreements CH-EU as well as on the most important international organisations. Basic knowledge of the structure of Swiss food law and its implementation in the context of self-controll in food companies. The process of food enforcement is known and issues can be assessed from a legal perspective. |
| Content        | General introduction into the EU and in the area of food safety (regulation on food safety), legislative procedures in the EU, introduction into the relevant bilateral agreements CH-EU, introduction into international organisations, general principles of the Swiss food law and the most important regulations as well as the most important legal procedures, legal settlement and the duties and responsibilities of the Food control authorities. |
| Lecture notes  | Copies of the presentations will be handed out or the presentations are made available via moodle. |
| Literature     | Documents about the EU regulation on Food Safety will be handed out. Swiss law is available online via the systematic collection of laws. |
| Prerequisites / notice | Qualifications: General knowledge of the food sciences. The lecture will be held in German. |
| Competencies   | Subject-specific Competencies  |      |      |       |                                |
|                | Concepts and Theories          |      |      |       | assessed                       |
|                | Techniques and Technologies    |      |      |       | assessed                       |
| Method-specific Competencies | Analytical Competencies       |      |      |       | assessed                       |
|                | Decision-making                |      |      |       | assessed                       |
|                | Media and Digital Technologies |      |      |       | fostered                       |
|                | Problem-solving                |      |      |       | assessed                       |
| Social Competencies | Cooperation and Teamwork |      |      |       | fostered                       |
|                | Sensitivity to Diversity       |      |      |       | fostered                       |
|                | Negotiation                    |      |      |       | fostered                       |
| Personal Competencies | Creative Thinking       |      |      |       | fostered                       |
|                | Critical Thinking              |      |      |       | assessed                       |
|                | Self-awareness and Self-reflection |      |      |       | fostered                       |

| 551-0317-00L   | Immunology I                   | W    | 3    | 2V    | M. Kopf, A. Oxenius           |
| Abstract       | Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response. |
| Objective      | Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response. |
| Content        | - Introduction and historical background |
|                | - Innate and adaptive immunity, Cells and organs of the immune system |
|                | - B cells and antibodies |
|                | - Generation of diversity |
|                | - Antigen presentation and Major Histoincompatibility (MHC) antigens |
|                | - Thymus and T cell selection |
|                | - Autoimmunity |
|                | - Cytotoxic T cells and NK cells |
|                | - Th1 and Th2 cells, regulatory T cells |
|                | - Allergies |
|                | - Hypersensitivities |
|                | - Vaccines, immune-therapeutic interventions |
| Lecture notes  | Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien" |
| Literature     | - Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020 |
| Prerequisites / notice | For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session. |
### Public Health Concepts

**W+** 3 credits  2V  R. Heusser

**Abstract**
The module “public health concepts” offers an introduction to key principles of public health. Students get acquainted with the concepts and methods of epidemiology. Students also learn to use epidemiological data for prevention and health promotion purposes. Public health concepts and intervention strategies are presented, using examples from infectious and chronic diseases.

**Objective**
At the end of this module students are able:
- to interpret the results of epidemiological studies
- to critically assess scientific literature
- to know the definition, dimensions and determinants of health
- to plan public health interventions and health promotion projects
- to draw a bridge from evidence to policies and politics

**Content**
Concepts of descriptive and analytical epidemiology, study designs, measures of effect, confounding and bias, screening, surveillance, definition of health and health promotion, health dimensions and health determinants, prevention strategies, public health interventions, public health action cycle, epidemiology and prevention of infectious and chronic diseases (HIV, COVID-19, Obesity, iodine/PH nutrition).

**Lecture notes**
Handouts are provided to students in the classroom.

**Competencies**

<table>
<thead>
<tr>
<th>Competency Area</th>
<th>Subject-specific Competencies</th>
<th>Concept and Theories</th>
<th>assessed</th>
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<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td>Project Management</td>
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<td>Social Competencies</td>
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<td>Personal Competencies</td>
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<td>Self-direction and Self-management</td>
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### Essentials in Translational Science

**W** 3 credits  2G  J. Goldhahn

**Abstract**
Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people (e.g. Medicines). The course should help to clarify basics of translational science, illustrate successful applications and enable students to integrate key features into their future projects.

**Objective**
After completing this course, students will be able to understand:
- Key steps of drug development and their interdependencies. Project management, communication & funding options. Students should be able to apply this knowledge in drug development programs in Pharma, Biotech or their own spin-off.

**Content**
This lecture will guide you through drug development from bench to bedside and provide industry perspectives which support you in your first industry role or when building a startup. The course will integrate knowledge across the many disciplines which are required to develop new medicines which are transformational for patients.

- Key steps of the Drug development process
  - Disease Biology and mechanism of action
  - Translation of ‘Mechanism of Action’ into patient and payer benefit
  - Drug design
  - Drug formulation
  - Toxicology
  - Pharmacokinetics & pharmacodynamics
  - Translational medicine
  - Clinical trials
  - Regulatory requirements
  - Patenting
  - Market access
  - How are these steps connected and impacting each other?

**Competencies**

<table>
<thead>
<tr>
<th>Competency Area</th>
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<th>Concepts and Theories</th>
<th>assessed</th>
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<td>Decision-making</td>
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<td>Critical Thinking</td>
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### Critical Appraisal of Evidence for Exercise in Health and Disease

**W** 3 credits  2V  E. Giannouli, E. de Bruin, R. Knols

**Abstract**
This course will discuss the mechanisms and latest evidence-based recommendations of physical activity and exercise for a series of conditions and populations.

In the second part of each lecture session, published randomized controlled trials of the respective lecture’s topic will be discussed and critically appraised based on established tools.
Objective
On completion of this course students will be able to:
1. understand the role of physical activity and sedentary behavior in the maintenance of health and the etiology, prevention and treatment of disease
2. synthesize effective physical activity and exercise interventions for the prevention and management of several diseases and populations
3. evaluate recent evidence regarding physical activity and exercise interventions

Content
New trends in physical activity for prevention and rehabilitation
Introduction to critical appraisal tools
Exercise for Cancer Rehabilitation
Exercise for Musculoskeletal Rehabilitation (Focus on Osteoarthritis and Low Back Pain)
Exercise in Parkinson’s disease
Exercise for Rehabilitation of Metabolic Disorders (Focus on Obesity and Diabetes type 2)
Exercise for age-related diseases and disorders, Part A (Focus on Frailty and Falls)
Exercise for Stroke Rehabilitation
Exercise in Dementia and Mild Cognitive Impairment
Exercise for Children’s Rehabilitation (Focus on Cerebral Palsy)
Exercise for age-related diseases and disorders, Part B (Focus on Sarcopenia and Osteoporosis)
Exercise in Multiple Sclerosis
Exercise for Cardiovascular Rehabilitation (Focus on Heart Failure)

Literature

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
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<th>Method-specific Competencies</th>
<th>Personal Competencies</th>
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<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Critical Thinking</td>
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<td>assessed</td>
<td>Decision-making</td>
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<td>Techniques and Technologies</td>
<td>Problem-solving</td>
<td>Integrity and Work Ethics</td>
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Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving

Personal Competencies
Critical Thinking
Integrity and Work Ethics

Master’s Thesis

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<td>O</td>
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<td>43D</td>
<td>Lecturers</td>
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</table>

Abstract
The study program is completed with the Master thesis, an independent scientific work. Topics are selected within the domains of the MAS program. The work is supervised by a lecturer of the MAS program.

Objective
The Master thesis must demonstrate the student's ability to independent, structured and scientific working.

MAS in Nutrition and Health - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Key</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>E- Recomended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr Suitable for doctorate</td>
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Key for Hours

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<tr>
<th>Type</th>
<th>Description</th>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

ECTS
European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
### MAS in Fire Safety Engineering

*Four-semester, part-time MAS programme, starting in autumn semester (even years).*

**Next start:** Autumn Semester 2024

#### Module

<table>
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<tr>
<th>Number</th>
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<td>Module 1: Fire Science ■</td>
<td>O</td>
<td>10</td>
<td>9G</td>
<td>A. Frangi, P. Jenny, M. Klippel, B. Merci, M. Siemon</td>
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<tr>
<td>121-0130-00L</td>
<td>Module 4: Structural Fire Design ■</td>
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<td>9G</td>
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#### MAS in Fire Safety Engineering - Key for Type

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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<td>Z</td>
<td>Courses outside the curriculum</td>
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<td>Dr</td>
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**Key for Hours**

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<td>practical/laboratory course</td>
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<td>revision course / private study</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1646 of 2653
**MAS in Building Process Leadership**

The MAS in "Gesamtprojektleitung Bau" is of a duration of 2 years, starting in autumn semester (n-service).

Start of the next course: Autumn Semester 2023

<table>
<thead>
<tr>
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<td>Does not take this semester.</td>
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<td><strong>Objective</strong></td>
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<td>The students are able to understand the following terminologies, processes and competences. They are able to put them into practice.</td>
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<td>- Expertise and personal skills</td>
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<td>- Organisational forms and SWOT analysis</td>
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<td>Our advanced studies' lectures are given in German. Please find an English written abstract and/or keywords in the field 'objective'.</td>
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<td>Please find the teaching material, the further readings and Information on our server.</td>
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<td>Self-direction and Self-management</td>
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</table>

| 067-0103-00L | Interests         | O    | 10 credits | 11G  | A. Paulus, S. Menz |
|              | **Abstract**      |      |            |      |           |
|              | In our third semester, we reconsider and re-evaluate our identity as a leading consultant. For this we see how the concept of leadership works on and shapes our skills. In line with our acquired knowledge we now pay attention to all involved interests: the perception of demand. Furthermore, it is a necessity to understand the tasks and duties of every role which you can take on. |
|              | **Objective**     |      |            |      |           |
|              | The students are able to understand the following terminologies, processes and competences. The are able to put them into practice. |
|              | - Interests and positions, perception of demands |
|              | - Concept of leadership |
|              | - Construction industry and real estate market |
|              | **Content**       |      |            |      |           |
|              | In our third semester, we reconsider and re-evaluate our identity as a leading consultant. For this we see how the concept of leadership works on and shapes our skills. In line with our acquired knowledge we now pay attention to all involved interests: the perception of demand. Furthermore, it is a necessity to understand the tasks and duties of every role which you can take on. |
|              | **Literature**    |      |            |      |           |
|              | www.map.arch.ethz.ch/en |

**MAS in Building Process Leadership - Key for Type**

<table>
<thead>
<tr>
<th>O</th>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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**Key for Hours**

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<td>exercise</td>
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<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
MAS in History and Theory of Architecture (GTA)

The MAS-program in "History and Theory of Architecture" is a two-year half-time course and contains 60 CP. The course starts in the autumn semester.

Attendance of classes supplemented by independent research; practical training periods and excursions; lectures/seminars on one to two days per week, in total 600 ca. contact hours, in addition private study ca. 600 hours (for each in-class day one day of work preparation), two individually tutored seminar papers on chosen subjects (200 hours) and credited Master's thesis (600 hours).

1. Semester

Seminars

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>056-0001-01L</td>
<td>Architecture and the City I</td>
<td>O</td>
<td>5</td>
<td>4S</td>
<td>A. J. Bideau</td>
</tr>
</tbody>
</table>

Abstract
Architects have repeatedly addressed the collective in order to counter criticism and to re legitimize their practice. In doing so, they have also turned their attention to episodes in architectural history. The decade 1967-1977 in particular saw important theoretical contributions to the question of the collective emerge. Here the seminar interpolates between practice and the production of theory.

Objective
In order to convey the range of historiographical approaches, different methodological approaches and disciplinary perspectives on the main topic of the semester will be used.

Specific examples will be used to understand the interplay between architectural and urban structures and the messages conveyed or circulating there in their time.

Content
Core questions of seminar:
- What makes the theme of the collective central at a particular historical moment? How can this paradigm be contextualized?
- What social desiderata are expressed in an architectural and urban form? Under what circumstances does such a representation take place? Who formulates what the collective interest is in each case?
- What historiography and theorizing do architects engage in and what insights do they hope to gain for their present?

Literature
Will be posted on the MAS platform.

Prerequisites / notice
Preparatory readings will be indicated in August.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Decision-making

Method-specific Competencies
- Media and Digital Technologies

Social Competencies
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity

Personal Competencies
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection

Methods

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<th>Number</th>
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<th>Lecturers</th>
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<tr>
<td>056-0005-01L</td>
<td>Methods of Academic Writing I</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>A. J. Bideau, S. Hefti</td>
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</table>

Abstract
Through hands-on teaching, the methods workshops introduce students to the various approaches to academic writing in the humanities and convey the methodological foundations of architectural history. Lecturers and students discuss and work on research papers and master's theses as well as the group's research project.

Objective
Students learn to identify and apply different methods of academic writing in architectural history. They acquire the ability to recognize and independently solve problems related to research and writing.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies

Method-specific Competencies
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity

Personal Competencies
- Integrity and Work Ethics
- Self-direction and Self-management

Study Trips

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tr>
<td>056-0106-00L</td>
<td>Study Trip I</td>
<td>O</td>
<td>2</td>
<td>4P</td>
<td>A. J. Bideau</td>
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</tbody>
</table>

Abstract
One-week study trip centered on walking as a method for researching, writing, and communicating architectural and urban history.

Objective
Students will engage in walking as a critical approach to urban and open space; reflect on the relationship of architecture and experience; and read key texts on spatial perception and the history and practice of walking.

Literature
Will be announced on the class platform.

Electives
see "electives" in Architecture BSc and MSc

Essays

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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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### 3. Semester

★★ Lectures, Seminars

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<th>Lecturers</th>
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<tbody>
<tr>
<td>056-0003-01L</td>
<td>Architecture and the City III</td>
<td>O</td>
<td>5</td>
<td>4S</td>
<td>A. J. Bideau</td>
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</table>

Abstract
Architects have repeatedly addressed the collective in order to counter criticism and to re-legitimize their practice. In doing so, they have also turned their attention to episodes in architectural history. The decade 1967-1977 in particular saw important theoretical contributions to the question of the collective emerge. Here the seminar interpolates between practice and the production of theory.

Objective
By analyzing historical texts on architectural theory, students will acquire the skills to understand these sources as voices in their time. In order to convey the range of historiographical approaches, different methodological approaches and disciplinary perspectives on the main topic of the semester will be used.

Specific examples will be used to understand the interplay between architectural and urban structures and the messages conveyed or circulating there in their time.

Content
Core questions of seminar:

- What makes the theme of the collective central at a particular historical moment? How can this paradigm be contextualized?
- What social desiderata are expressed in an architectural and urban form? Under what circumstances does such a representation take place? Who formulates what the collective interest is in each case?
- What historiography and theorizing do architects engage in and what insights do they hope to gain for their present?

Literature
Will be posted on the MAS platform.

Prerequisites / notice
Preparatory readings will be indicated in August.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Methods-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptness and Flexibility</td>
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<tr>
<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Media and Digital Technologies</td>
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<td>Self-direction and Self-management</td>
<td>Sensitivity to Diversity</td>
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★★ Workshop

★★ Master's Thesis

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<tr>
<td>056-0210-01L</td>
<td>MAS Thesis Preparation</td>
<td>O</td>
<td>5</td>
<td>9A</td>
<td>A. J. Bideau</td>
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Abstract
This one-semester module is dedicated to identifying the topic for the Master's thesis and developing the research plan. The Master's thesis itself is written in the following spring semester.

Objective
The aim is to develop a relevant hypothesis and research question for the Master's thesis that is based on an analysis of the current state of the field. Additionally, the research plan includes preparing an annotated bibliography, elaborating the methodological approach and a timeline of deliverables.

Content
The topic of the MAS master thesis is chosen by the students and further refined through individual consultation with the docents. At the end of the semester, the students present their research plan to external guest critics. The research plan comprises about 25,000 characters.

Literature
See internal MAS platform
### Competencies

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<th>Subject-specific Competencies</th>
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<td>Techniques and Technologies</td>
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| Method-specific Competencies | Analytical Competencies | fostered |
|------------------------------| Decision-making         | fostered |
|                              | Project Management       | fostered |

| Social Competencies          | Communication           | fostered |

| Personal Competencies        | Adaptability and Flexibility | fostered |
|------------------------------| Creative Thinking          | fostered |
|                              | Critical Thinking          | fostered |
|                              | Integrity and Work Ethics  | fostered |
|                              | Self-awareness and Self-reflection | fostered |
|                              | Self-direction and Self-management | fostered |

### MAS in History and Theory of Architecture (GTA) - Key for Type

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<th>Key</th>
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<td>Recommended, not eligible for credits</td>
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<td>Z</td>
<td>Courses outside the curriculum</td>
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### Key for Hours

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<td>lecture with exercise</td>
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<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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### ECTS

- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
MAS in Housing

1 year full time course in English, starting every autumn semester.
Further information on www.wohnforum.arch.ethz.ch

Lectures, workshops, individual and group tutorials and excursions organized in the framework of the four modules: Cultural, socio-economic, demographic and political aspects of housing and human settlements (M1); Adequate housing and neighbourhood development strategies (M2); Housing for migrants, refugees, and people displaced by disasters (M3); Housing research and evaluation methods (M4).

Introduction to the MAS Housing: Room HIT H 13 (Date and Time will follow in due time).
Presentation of MAS Thesis Proposals: Room HIT H 13 (Date and time will follow in due time).

Core Courses

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<tr>
<td>057-0103-10L</td>
<td>Module 1: Global Housing Issues, Challenges and Strategies</td>
<td>O</td>
<td>4</td>
<td>2G</td>
<td>J. E. Duyne Barenstein</td>
</tr>
<tr>
<td>Abstract</td>
<td>Globally over one billion people lack adequate housing. Meeting their housing needs requires innovative solutions that are affordable, inclusive, sustainable and scalable. We will critically review the causes and consequences of the current housing crisis and the various strategies through which a wide range of actors at local, national and international level are addressing the housing question.</td>
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<tr>
<td>Objective</td>
<td>The students will learn to understand the meaning of housing in relation to its broader socioeconomic, cultural, political, and spatial context and to critically reflect on the viability, effectiveness and sustainability of different housing strategies.</td>
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<td>Content</td>
<td>Housing is a human right but also one of the most daunting challenges of urbanisation globally. Currently over one billion people lack adequate and affordable housing, a number that may increase to 1.6 billion people within a decade. Ensuring access to adequate, safe and affordable housing to all is one of the targets of the 2030 Agenda for Sustainable Development. However, this target is unlikely to be met without a radical change in housing policies and practices. Indeed, meeting millions of people’s housing needs requires innovative solutions that are inclusive, sustainable and scalable. The course focuses on the causes and consequences of the global housing crisis. Further it will critically reflect upon the concept of adequate housing and on the various strategies through which national governments, municipalities, the private sector, and communities in different settings and situations have been, or are currently addressing the housing question.</td>
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<tr>
<td>Lecture notes</td>
<td>A reader will be distributed at the beginning of the semester containing an overview of all lectures, the involved exercises, and required readings.</td>
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<td>057-0104-10L</td>
<td>Module 2: Innovative Housing: Case Studies and Exercises</td>
<td>O</td>
<td>4</td>
<td>2G</td>
<td>J. E. Duyne Barenstein</td>
</tr>
<tr>
<td>Abstract</td>
<td>With the aim of understanding the role of architecture in responding to the constantly changing housing needs and demands we will visit and analyze a selected number of housing projects that are innovative from a social, institutional and architectural perspective.</td>
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<tr>
<td>Objective</td>
<td>The students will gain a better understanding of the socioeconomic, cultural and institutional factors determining innovation in the housing sector.</td>
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<tr>
<td>Content</td>
<td>All over the world a wide range of public and private organizations are responding to the qualitative and/or quantitative housing deficits through innovative projects. With the aim of understanding the role of architecture in responding to the constantly changing societal needs and aspirations we will visit and analyze a selected number of ground-breaking housing projects. Interactions with relevant stakeholders will enable students to reflect upon their innovative character from a social, institutional and architectural perspective. These visits will be followed by individual and group exercises; based on a common analytical framework the students will identify through secondary sources additional paradigm-shifting housing projects in different parts of the world with the aim of gaining a better understanding of the links between housing initiatives and their societal context.</td>
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<tr>
<td>Lecture notes</td>
<td>A reader will be distributed at the beginning of the semester containing an overview of all lectures, the involved exercises, and required readings.</td>
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<tr>
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<td>10</td>
<td>2G</td>
<td>J. E. Duyne Barenstein</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course offers an introduction to a wide range of research methods currently used in housing and neighbourhood studies. Students will be invited to reflect on the value of using different tools to inform evidence-based design processes and to provide rigorous answers to research questions by covering all steps of the research cycle.</td>
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<tr>
<td>Objective</td>
<td>Students will be acquire the theoretical and methodological skills to design and carry out an independent scientific research project.</td>
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<tr>
<td>Content</td>
<td>This course offers an introduction to a wide range of research methods currently used in housing and neighbourhood studies. Students will be invited to reflect on the value of using different tools to inform evidence-based design processes and to provide rigorous answers to research questions by covering all steps of the research cycle. Particular emphasis will be given to qualitative and participatory research methods that will enable the students to directly engage with stakeholders, such as residents, representatives of housing and neighborhood associations, and public authorities. By combining theory and practice, they will learn to apply them to a specific context and research question. Through lectures with practical group exercises the course will equip students with the required knowledge and skills to develop an individual research project that will lead to their MAS theses.</td>
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<tr>
<td>Lecture notes</td>
<td>A reader will be distributed at the beginning of the semester containing an overview of all lectures, the involved exercises, and required readings.</td>
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<tr>
<td>Prerequisites</td>
<td>Course only open to students enrolled in the ETH MAS in Housing.</td>
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<td>Module 4: Writing and Communication Skills for Built Environment Professionals</td>
<td>O</td>
<td>10</td>
<td>2K</td>
<td>J. E. Duyne Barenstein</td>
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<tr>
<td>Abstract</td>
<td>The course is intended to support the students to develop their individual research proposals and to attain the necessary skills to work independently and with scientific rigour on a project leading to their final MAS thesis.</td>
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<tr>
<td>Objective</td>
<td>In the framework of Module 4, students will learn the fundamentals of conducting their own research project, from defining a clear research question, to formulating valid hypotheses, and developing a feasible research design. The course is intended to support the students to develop their individual proposals and to attain the necessary skill to work independently and with scientific rigour on a project leading to their final MAS thesis.</td>
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<tr>
<td>Content</td>
<td>A core element of the MAS ETH in Housing is the elaboration of a research-based individual thesis. This module offers 10 ECTS credit points. In the framework of Module 4, students will learn the fundamentals of conducting their own research project, from defining a clear research question, to formulating valid hypotheses, and developing a feasible research design. The course is intended to support the students to develop their individual proposals and to possess the necessary skill to work independently and with scientific rigour on a project leading to their final MAS thesis.</td>
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Elective Courses

You need to attend one Seminarweek (2 CTS).

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1651 of 2653
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<thead>
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<th>Key for Type</th>
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<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
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**Key for Hours**

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<td>U</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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ECTS: European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## 1. Semester

### Core Courses

#### General Management and Human Resource Management

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---

**Abstract**
This course is an introduction to general management. This course follows a systemic view of organizations and adopts the congruence model as a framework to analyze the critical, interconnected elements of organizations.

**Objective**
By the end of this course, students will understand management as a set of skills, processes, tools and methods that enable organizations to achieve their goals and to coordinate operations in order to meet evolving customers’ and societal needs. The students will achieve these goals by being able to:

- Analyze organizations as open systems, and describe their critical elements,
- Apply conceptual tools and methods that help to analyze or approach the critical elements,
- Compare different notions of organizational performance, and explain why they matter,
- Discuss the relationships that connect the critical elements of an organization on the basis of real cases,
- Explain how change, internally or externally initiated, impact such relationships

**Content**
This course is an introduction to general management. This course follows a ‘systemic’ view of organizations and adopts the congruence model as a framework to analyze the critical, interconnected elements of organizations: Input (i.e., from external environment), strategy, people, work, formal and informal structure of the organization, and its outputs. In this course we will introduce these critical elements and learn how managers can analyze and approach these elements by means of different conceptual tools and methods in order to achieve performance. We will furthermore discuss the relationships that connect the critical elements together by means of real-life cases, whereby the focus will be on the critical reflection of particular cases of fits and misfits between those elements and on the application of a selection of tools and methods.

**Lecture notes**
The content of the course will rely on different readings, cases and selected chapters of following book:

Selected readings from the book and additional learning materials will be available on the course Moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=20842

**Literature**
The content of the course will rely on different readings and on selected chapters of following book:

Selected readings from the book and additional learning materials will be available on the course Moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=20842

**Prerequisites / notice**
Throughout the course different session preparation assignments, like reading book chapters or case studies will be handed out to the students on moodle. This preparation is required to participate in the lectures.

The final exam is requested for all types of students (BSc, MSc, MAs, PhD, and Exchange students). It is not possible to retake the exam within the same term or academic year. We strongly recommend Exchange students to take it into consideration when selecting the courses to attend.

**Competencies**

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<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Problem-solving</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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363-0301-00L | Work Design and Organizational Change | W+ | 3 credits | 2G | G. Grote

**Abstract**
Good work design is crucial for individual and company effectiveness and a core element to be considered in organizational change. Meaning of work, organization-technology interaction, and uncertainty management are discussed with respect to work design and sustainable organizational change. As course project, students learn and apply a method for analyzing and designing work in business settings.

**Objective**

- Know effects of work design on competence, motivation, and well-being
- Understand links between design of individual jobs and work processes
- Know basic processes involved in systematic organizational change
- Understand the interaction between organization and technology and its impact on organizational change
- Understand relevance of work design for company performance and strategy
- Know and apply methods for analyzing and designing work
The course is organized in a highly interactive fashion, where discussion in class is as important as the input by the lecturer. Understanding the dynamics in organizations is helped enormously by concrete examples, which will be provided by the lecturer, by talks by guest lecturers, and also the students themselves based on their prior experience from working in various roles (as employees, volunteers, student assistants etc.). Through class discussion we aim to deepen the understanding of the themes covered in the course. The current changes in organizations brought about by Covid-19 will also be an important example which allows to illustrate and discuss many of the key concepts of the course.

Specifically, the course will cover the following topics:

- Work design: From Adam Smith to job crafting
- Effects of work design on performance and well-being
- Approaches to analyzing and designing work
- Modes of organizational change and change methods
- Balancing stability and flexibility in organizations as design criterion
- The organization-technology interaction and its impact on work design and organizational change
- Example Flexible working arrangements (e.g. home office)
- Strategic choices for work design

All through the course, students will be guided to work on their projects also, with about 25% of class time devoted to the projects. In the final session, students will present the main results of their projects and discuss main insights also across projects.

Literature

A list of required readings will be provided at the beginning of the course.

Prerequisites / notice

The course includes the completion of a course project to be conducted in groups of four students. The project entails applying a particular method for analyzing and designing work processes and is carried out by means of interviews and observations in companies chosen by the students.

Competencies

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<th>Method-specific Competencies</th>
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<td>Decision-making</td>
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<td>Cooperation and Teamwork</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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Strategy, Markets and Technology

Number | Title | Type | ECTS | Hours | Lecturers
-------|-------|------|------|-------|------------
363-0403-00L | Introduction to Marketing | W+ | 3 credits | 2G | F. von Wangenheim, P. Bachmann

Abstract

This course provides an overview on essential perspectives of marketing and how marketing adds value to a business. It will teach concepts, frameworks and methods for marketing decision making. The course will also look at issues related to marketing implementation. Thereby, a particular focus will be on how data and data analytics can help to support marketers in their decision making.

Objective

After taking the class, students will be able to

1) Understand how marketing adds value to a business.
2) Provide an overview of key concepts in marketing that are applicable to any business.
3) Understand how consumers behave and how this impacts marketing
4) Learn how analytics and quantitative methods can help to improve decision making in marketing
5) Get to know the elements that shape a firm’s marketing strategy (segmentation, targeting, positioning) and marketing tactics (product, price, promotion, place)

Content

The class will center on the importance of marketing as an activity that creates long-term value for the benefit of organizations and their customers. It will teach concepts, frameworks and methods for marketing decision making.

Specifically, the course is aims to provide students with a) an overview on the role of marketing within a business, b) details on strategic marketing management decisions and tools, c) a profound knowledge on the individual elements of the marketing mix (product, price, promotion, place), d) an awareness of specific contexts of marketing, and e) first-hand experience on data-driven techniques to support marketers’ decision making.

Thus, this course will introduce key analytical tools to help solving respective managerial tasks. This is a lecture with integrated exercises. Access to a laptop is required for the exercises. The class might be thought in an in-person, remote or in a hybrid format. Students might also be taught via pre-recorded videos and assigned material for self-study.

Literature


The course might comprise mandatory and supplemental reading material. Other literature may be assigned in class.
Information and Operations Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<td>363-0421-00L</td>
<td>Management of Digital Transformation</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>E. Fleisch</td>
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</table>

Abstract
This course provides an overview of Digital Transformation within organizations, the opportunities that come with it, but also the issues managers face transforming their organizations into the digital age. Increasingly, information technology (IT) is not only being used as a tool to improve processes but to also create and capture new customer value and to gain and maintain competitive advantage.

Objective
This course introduces to the students the relevant subjects that form the digital transformation agenda of organizations' top-level management. After completing the 4 core learning blocks below, students will be able understand, analyze and critically question organization's digital transformation processes while also learning the frameworks and tools used by organizations to digitally transform.

1. Digital transformation strategies
2. Organizing the digital transformation
3. Digital transformation and technology
4. Digital transformation within industries

Throughout the course, students will learn from and discuss with guest lecturers their experiences of digital transformation.

Content
Digital Transformation has become a top management theme across all industries. It is part of the strategic agenda of management and supervisory boards with dedicated roles to drive forward its design and implementation. The lecture introduces many of the relevant subjects that together form the digital transformation agenda of organizations’ top-level management. It establishes the main themes, tools, and theoretical concepts. The lecture consists of 4 learning blocks, each with a focus on an area of Digital Transformation, and will feature guest lecturers from industry. The lecture is structured as follows:

Block 1: Strategy
• Digital Business Model Patterns
• Platform Companies
• Subscription Models
• Lessons from Theory Toolbox

Block 2: Organizational
• Towards an Agile Organization

Block 3: Technology
• “Future-proof” Infrastructure

Block 4: Industry
• Digital Transformation in the Health Care Industry
• Digital Transformation in the Automotive Industry

The course is divided into an onsite classroom part and an online self-learning part. All teaching materials will be available through the course page on Moodle.

Lecture notes
All lecture content is provided via the Moodle platform.

Literature
All relevant literature is provided via the Moodle platform.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Negotiation

Personal Competencies
- Creative Thinking
- Critical Thinking
- Self-direction and Self-management

363-0445-00L Production and Operations Management | W+ | 3 credits | 2G | T. Netland

Abstract
This core course provides insights into the basic theories, principles, concepts, and techniques used to design, analyze, and improve the operational capabilities of an organization.
Objective

This course provides students with a broad theoretical basis for understanding, designing, analyzing, and improving manufacturing operations. After completing this course:

1. Students can apply key concepts of POM to detail an operations strategy.
2. Students can do simple forecasting of demand and plan the needed capacity to meet it.
3. Students can conduct process mapping analysis, use it to design and improve processes and layouts, and elaborate on the limitations of the chosen method.
4. Students can choose IT, OT, and automation technology for manufacturing applications.
5. Students can design information flows, manage master data, and use it to plan and control a factory.
6. Students can design material flows in and beyond factories.
7. Students can design performance management systems.
8. Students can select and use problem-solving tools to improve quality and productivity.
9. Additional skills: Students acquire experience in teamwork.

Content

The course covers the most fundamental strategic and tactical concepts in production and operations management (POM).

Production and Operations Management (POM) is at the heart of any business. It is concerned with the business processes that transform input into output and deliver products and services to customers. Factory management is an important part of POM, but it is much more than what takes place inside the production facilities of companies like ABB, Boeing, BMW, LEGO, Nestlé, Roche, TESLA, and Toyota. Did you know that the largest portion of assets and employees in most organizations are engaged in the operations function? Although this course focuses on manufacturing, all types of organizations depend on their operational capabilities. With the ongoing globalization and digitization of manufacturing, POM has won a deserved status for providing a competitive advantage.

This course covers the following topics: Introduction to POM, Manufacturing strategy, Forecasting and capacity, Process design, Layout, Industry 4.0, Information flow, Material flow, Logistics/SCM, Performance management, Performance improvement, Quality management, and Maintenance.

This course is administered via Moodle. The course is designed around five elements:

2. Video lectures. Short video lectures presenting basic POM concepts.
3. Class lectures. Deep-dives with case examples on select topics.
4. FactoryVR group assignment. FactoryVR allows students to visit factories virtually.
5. Quizzes. A few quizzes during the semester help students check their progress and prepare for the written exam.

Literature

Suggested literature is provided in the syllabus.

Competencies

Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies

- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

Social Competencies

- Communication fostered
- Cooperation and Teamwork assessed
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies

- Adaptability and Flexibility fostered
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

Quantitative and Qualitative Methods for Solving Complex Problems

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<tr>
<th>Number</th>
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<tr>
<td>363-0541-00L</td>
<td>Economic Dynamics and Complexity</td>
<td>W+</td>
<td>3</td>
<td>3G</td>
<td>F. Schweitzer, L. Verginer</td>
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</table>

Abstract

What causes economic business cycles? How are limited resources, competition, and cooperation reflected in growth dynamics? To answer such questions, we combine macroeconomic models and methods of nonlinear dynamics. We study the role of bifurcations and control parameters for dynamic stability. Feedback cycles and coupled dynamics are reasons for limited predictability, instability and chaos.

Objective

Successful participant of the course is able to:
- understand the importance of different modeling approaches
- formalize and solve one- and two-dimensional nonlinear models
- identify critical conditions for stability and dynamic transitions
- analyze macroeconomic models of business cycles, supply and demand
- apply formal concepts to model economic growth and competition
**Micro and Macroeconomics**

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<th>Number</th>
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<tr>
<td>363-0565-00L</td>
<td>Principles of Macroeconomics</td>
<td>W+</td>
<td>3</td>
<td>2V</td>
<td>J.-E. Sturm</td>
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</table>

**Abstract**
This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

**Objective**
This course will help you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

**Literature**

This book can also be used for the course '363-0503-00L Principles of Microeconomics' (Filippini).

**Compétences**
Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.

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<thead>
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<th>Competencies</th>
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**363-0503-00L Principles of Microeconomics**

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<tr>
<th>Abstract</th>
<th>The course introduces basic principles, problems and approaches of microeconomics. This provides the students with reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution.</th>
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The learning objectives of the course are:

1. Students must be able to discuss basic principles, problems and approaches in microeconomics.
2. Students can analyse and explain simple economic principles in a market using supply and demand graphs.
3. Students can contrast different market structures and describe firm and consumer behaviour.
4. Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole.
5. Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics.
6. Students can apply simple mathematical concepts on economic problems.

The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a fair distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture "Principles of Microeconomics" is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.

Topics covered by the course are:
- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade

For students taking only the course "Principles of Microeconomics" there is a shorter version of the same book: N. Gregory Mankiw and Mark P. Taylor (2023), "Microeconomics", 6th edition, South-Western Cengage Learning.


Autumn Semester 2024

Number Title Type ECTS Hours Lecturers
363-0711-00L Accounting for Managers W+ 3 credits 2V H. Chen

Abstract The course Accounting for Managers offers an introduction to financial and managerial accounting, especially for students who aspire for a career in business and management with a science or engineering background.

Objective After attending the class, you should be able to:
- understand the accounting system, the reporting process, and be able to prepare financial statements
- feel comfortable reading and using the information presented in companies' annual reports
- understand cost concepts and conduct cost analyses
- become familiar with several classic decisions using managerial accounting information
- comment on the current events related to these topics

Content Accounting plays a critical role in the effective functioning of the financial market as well as the long-term success of a company. This course intends to provide an introduction to accounting for those who wish to pursue a career in business, and need the skills and knowledge to understand, analyze, and interpret accounting information to make informed decisions. The course is divided into two parts. In the first part, we focus on financial reporting and start with the basic accounting concepts and the accounting cycle, to learn how the financial system is set up in a company and how financial statements are prepared. We then delve deeper into each major account, and discuss how revenues and expenses are recognized, and how assets, liabilities, and equities are reported. In the second part, we focus on managerial accounting for internal managerial/operational decisions including fundamental topics such as cost behavior, cost estimation, CVP analyses, and relevant costing. We then cover budgeting and standard costing, which are important parts of accounting system in companies.

Prerequisites / notice This course is a prerequisite for the course Financial Management.

Competencies Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed
Objective

After taking this course, students will be able to:

- Analyze the complex spectrum of incentives facing different stakeholders in modern corporations, utilizing real-world mini-case studies to understand how these incentives can sometimes be dysfunctional.
- Gain a robust theoretical and practical understanding of how corporate democracies function and the dynamics of capital markets, equipping them with the knowledge to navigate and influence these environments effectively.
- Assess and critique the current incentive structures within corporations, drawing on a variety of academic and professional sources to understand the challenges and solutions proposed in the field of corporate governance.
- Conduct their own empirical research on corporate governance topics, applying methodologies and insights from both established and recent scholarly papers, thus developing skills necessary for academic and applied research in this area.
- Integrate concepts of sustainability and ESG (Environmental, Social, and Governance) factors into their understanding of corporate governance, recognizing the growing importance of these elements in shaping modern business practices and regulations.

This comprehensive skill set will enable students to critically engage with and contribute to discussions and developments within the field of corporate governance, preparing them for roles that require nuanced understanding of corporate structures and stakeholder interactions, including corporate acquisitions, security design, and management compensation.

Course Content

Target Audience

This course is designed for advanced master's students who have professional experience and a strong interest in finance, top management, and critical aspects of modern corporations.

Prerequisites

Students should have a solid understanding of foundational concepts in corporate finance and financial economics, including:

- Discounting and compounding
- Time value of money
- Net present value rule for investment projects
- Key characteristics of stocks and bonds
- Foundations of modern portfolio theory
- Capital Asset Pricing Model (CAPM)
- Black-Scholes option pricing formula
- Capital structure theories

Course Structure (subject to changes)

1. Introduction
2. Consequences of Poor Governance
3. Empirical Methods in Corporate Governance Research
4. Monetary Incentives
5. The Board of Directors
6. The CEO Retention Decision
7. Ownership & Control
8. Shareholder Voting
9. The Hostile Acquisition Threat
10. Firms vs. External Stakeholders

References

No textbook is required for this course. For further reading, students may refer to:

3. Multimodal supplements, including screencasts and short video clips, will support key topics.

Course Deliverables

- Active participation in class discussions
- Group presentations
- A 60-minute written exam, which will serve as the basis for grading.

3. Semester

Core Courses

Strategy, Markets and Technology

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>365-0387-00L</td>
<td>Corporate Sustainability</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>V. Hoffmann, C. Bening-Bach, B. Girod, L. Miehé</td>
</tr>
</tbody>
</table>

Abstract

The lecture explores current challenges of corporate sustainability and prepares students to become champions for sustainable business practices. The module combines asynchronous videos, live sessions, with a group work phase between weeks 5-10 of semester during which students deep-dive into one of 10 sustainability challenges.

Objective

Students

- assess the limits and the potential of corporate sustainability for sustainable development
- develop competencies that are useful in the context of corporate sustainability and beyond (analytical competency, critical thinking, problem solving)
- recognize and realize opportunities through team work for corporate sustainability in a business environment
- present strategic recommendations in teams
Corporate Sustainability is the flagship course of the Group for Sustainability and Technology at D-MTEC. In this course, students learn about key concepts in corporate sustainability and develop skills to implement them in the real world. The course prepares students for making well-informed sustainability decisions in their future careers.

The course uses constructive alignment to bring the various innovative teaching and learning elements (e.g., case-based experiential learning, reflective thinking and blended learning with videos and quizzes) into a coherent transformational journey. Students can now flexibly, efficiently, and effectively acquire the conceptual foundations that are essential for a substantial understanding of corporate sustainability.

http://www.sustec.ethz.ch/teaching/lectures/corporate-sustainability.html

Presentation slides will be made available on Moodle after lectures.

Presentation slides will be made available on Moodle after lectures. Literature recommendations will be distributed via Moodle, and are available from the start of the course.

TEACHING FORMAT/ ATTENDANCE: The course includes several mandatory sessions that participants must attend to successfully earn credit points. It is not possible to take the class purely online.

Subjects
- Corporate Sustainability
- Strategic Management

Competencies

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<tr>
<th>Competencies</th>
<th>Assessed</th>
<th>Fostered</th>
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<tr>
<td>Subject-specific Competencies</td>
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<tr>
<td>Concepts and Theories</td>
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<td>Analytical Competencies</td>
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<td>Decision-making</td>
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<td>Problem-solving</td>
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<td>Creative Thinking</td>
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<td>Self-awareness and Self-reflection</td>
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Prerequisites / notice

Number of participants is limited to 80. Registration through myStudies (first come, first served). Since some people deregister at the start of the semester, it makes sense to stay on the waiting list until after the semester start.

For further questions and if you are unable to sign up through myStudies, please contact the course assistant:
http://www.smi.ethz.ch/education/strategic-management.html

For participants of the MAS-MTEC program we offer a complementary course Practicing Strategy in which students will apply the concepts of Strategic Management to their real-life contexts and organizations. Please register simultaneously for both courses if you want to take part in this course.

For more information please see:
http://www.smi.ethz.ch/education/practicing-strategy.html
The course offers an introduction to the theory and practice of supply chain management. Students will learn how to develop supply chain strategies and supply chain networks based on firms competitive strategies and marketing priorities. Modern supply chains are not only essential to ensure functioning logistics but also help firms develop and maintain competitive advantage. The course material will be made available for download on Moodle:

https://moodle-app2.let.ethz.ch/course/view.php?id=20606

All organizational matters will be handled by the teaching assistant Yan Zou (yanzou@ethz.ch). Please use the SSCM Class Forum on Moodle as a first point of contact. The following textbook is recommended:


The following textbook is supplementary:


Prerequisites / notice
Students should install MS Excel and the Excel Solver before class, as it is used for within-class exercises. Students without the program and add-in installed may nevertheless participate within groups during the exercises.

Competencies

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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>363-0453-00L</td>
<td>Strategic Supply Chain Management</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Wagner</td>
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</tbody>
</table>

Abstract

The course offers an introduction to the theory and practice of supply chain management. Students will learn how to develop supply chain strategies and supply chain networks based on firms competitive strategies and marketing priorities.

Objective

After completing this course:
1. Students can explain the importance of supply chain management for a firm’s strategy and success.
2. Students are able to apply the tools and methods used to optimize a supply chain structure.
3. Students can differentiate supply chain network designs and their applicability in specific company and sector settings.
4. Students can describe and evaluate fundamental logistics and supply chain concepts.
5. Students are able to explain elements of a supply chain structure and their importance for supply chain strategy.
6. Students are familiar with current developments and trends in supply chain practices.

Content

Modern supply chains are not only essential to ensure functioning logistics but also help firms develop and maintain competitive advantage in globalized (supply) markets with numerous partners and competitors. While taking into account future opportunities and risks, effective supply chains ought to be aligned with and support the achievement of the firm's corporate, business and product strategies. This course will familiarize students with modern supply chain management theory and practice to develop and manage supply chains. Starting with the corporate strategy, firms align their supply chain strategy. They have to manage trade-offs, such as efficiency and responsiveness. Understanding a supply chain’s role within a firm and the implications of supply chain strategies for firm performance are the foundations of the course.

Building on the foundations, students get familiarized with the development of a supportive supply chain structure. This structure is in its core made up by logistical elements, such as facilities, inventory management and transportation. At the same time, supply chain management is inevitably cross-functional. As such, information and information infrastructure, sourcing decisions and pricing are further drivers to define a supply chain structure. Students will learn important elements in supply chain structure, including for example forecasting methods and network design modeling and optimization. Case study assignments and practical exercises within lectures allow students to gain hands-on experience and enhance their knowledge.

The wide range of topics involved in supply chain management makes the field very open to innovation and further development. In the course of the lecture, students have the chance to learn and discuss both overall trends and practical insights on development. The course furthermore encourages student involvement within lectures, in exchange with peers and with guest speakers. Case study assignments and tools for self-assessment help students to learn actively and continuously throughout the course.

Lecture notes

The course material will be made available for download on Moodle:

https://moodle-app2.let.ethz.ch/course/view.php?id=20606

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The lecture treats the main challenges of business transformation and the alignment of corporate development and IT activities. It presents a holistic approach to business transformation projects by introducing an integrated model dealing with three main design areas "strategy", "processes" and "information systems" and applying this model to various case studies.

The goal of the lecture is to understand the main challenges of corporate transformation and to demonstrate the application of a holistic project procedure model for corporate transformation projects with special emphasis on the alignment of business and IT.

The student should understand and be able to explain

- the main reasons for corporate transformation,
- the relevant management processes to manage corporate transformation,
- the interdependencies between strategy, processes and information systems, especially how this three levels interrelate,
- the critical success factors for the successful accomplishment of large scale corporate transformation projects,
- the main instruments of project, quality and change management and the different types of resulting IT projects.

The globalization of the world leads to an increasingly faster pace in business transformation. Enterprises have to adapt faster and even faster to the environmental changes in a global economy to remain competitive and to make sure they stay in business. In today's information age this does not only mean to adapt business strategy and business processes but also to adapt information systems to the new circumstances. The fast adaptation through large scale corporate transformation projects that change strategy, business processes and information systems is critical to ensure competitiveness for tomorrow. The introduction of new business processes and information systems typically takes years in very complex large scale projects. Many projects fail because of insufficient alignment between decision makers in business and IT. Unclear understanding of the overall project scope, undefined roles and responsibilities, unclear project processes, quality problems and resistance to change are some typical problems found in such projects. The lecture is subdivided into following modules:

Corporate development introduction and motivation,
Parallelization of corporate development and complexity reduction,
Planning process and project portfolio management in corporate development,
Management of large scale projects integration of strategy, processes and information systems,
Quality management in large scale projects,
Project management in large scale projects,
Change management within projects. The lecture is accompanied by four case studies that are used to exemplify the contents of the lecture by applying the concepts to real situations in corporate life.

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Quantitative and Qualitative Methods for Solving Complex Problems

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<tr>
<td>363-0305-00L</td>
<td>Empirical Methods in Management</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>S. Tillmanns</td>
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Abstract
In this class, students learn how to understand and conduct empirical research. It will enable them to manage a business based on evidence-based decision-making. The class includes assignments related to the lecture content.

Objective
The general objective of the course is to enable students to understand the basic principles of empirical studies. After successfully passing the class, they will be able to formulate research questions, design empirical studies, and analyze data by using basic statistical approaches.

Content
Data has become an important resource in today’s business environment, which can be used to make better management decisions. However, evidence-based decision-making comes along with challenges and requires a basic understanding of statistical approaches. Therefore, this class introduces problems and key concepts of empirical research, which might be qualitative or quantitative in nature. Concerning qualitative research, students learn how to conduct and evaluate interviews. In the area of quantitative research, they learn how to apply measurement and scaling methods and conduct experiments. In addition, basic statistical analyses like a variance analysis and how to conduct it in a standard statistical software package like SPSS or R are also part of the lecture. The lessons learned from the lecture will empower students to critically assess the quality and outcomes of studies published in the media and scientific journals, which might form a basis of their managerial decision-making. We recommend the lecture also to students without basic statistical skills, who plan to attend more advanced lectures in the field of artificial intelligence such as Marketing Analytics.

The lecture will be taught in presence. There will be individual assignments that students have to solve throughout the lecture. In addition to that, there will be some non-mandatory online exercises as an additional opportunity to prepare for the exam.

Literature
Literature and readings will be announced. For a basic understanding we recommend the Handbook of Good Research by Jürgen Brock and Florian von Wangenheim.

Prerequisites / notice
The course includes out-of-class assignments to give students some hands-on experience in conducting empirical research in management. Projects will focus on a particular aspect of empirical research, like the formulation of a research question or the design of a study. Assignments will be graded and need to be turned-in on time as they will be shown and discussed in class. Class participation is encouraged and can greatly improve students’ learning. In this spirit, students are expected to attend class regularly and come to class prepared.

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Operations Research
This course provides an introduction to operations research methods in the fields of management science and economics. Requisite mathematical concepts are introduced with a practical, problem-solving perspective.
The economic environment of today's companies is characterized by high cost pressure, declining margins, intensified international
competition, rising customer requirements and increasingly strict regulations. Strategic and operational decisions at all management levels
are becoming more and more complex due to the increasing amount of data, interrelationships, conditions and target criteria to be
considered. Often it is no longer possible to solve operational tasks with experience and common sense alone and to adequately estimate
the consequences of decisions without software support.

Quantitative models and methods of operations research and operations management offer decision support for complex problems.
Mathematical optimization models are used to precisely formulate operational decision problems so that they can subsequently be
analysed and optimized using suitable solution methods. A large number of quantitative real-world problems can be formulated and solved
in this general framework. Applications of operations research comprise, for instance, decision problems in production planning, supply
chain management, transportation networks, machine and workforce scheduling, blending of components, telecommunication network
design, airline fleet assignment and revenue management.

This course offers an introduction to operations research, emphasizing basic methodologies and underlying mathematical structures. The
following topics are covered in detail:
- Introduction to system modelling and operations research
- Linear models and programming
- Duality theory in linear programming and shadow prices
- Integer programming
- Dynamic optimization (under uncertainty) and applications in inventory management.

Lecture notes
A printed script will be made available.

Literature
Any standard textbook in Operations Research is a useful complement to the course.

Prerequisites / notice
Undergraduate calculus, linear algebra, probability and statistics are a prerequisite.

Micro and Macroeconomics

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<tr>
<th>Number</th>
<th>Title</th>
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<tr>
<td>363-0537-00L</td>
<td>Resource and Environmental Economics</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>A. Miftakhova, A. Minabutdinov</td>
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</tbody>
</table>

Objective
A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and
environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations,
diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource
and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness.
Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private
negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will
allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration
functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-
benefit analysis to environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last
two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of
environmental economic theory and policy at international level, e.g. to the problem of climate change.

Content
The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare
concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent
valuation; the economics of non-renewable resources, renewable resources, cost-benefit-analysis, sustainability concepts; international
aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and
environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and
fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental
internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider
problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of
environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then
develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power.
When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse
of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and
measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of
sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

Literature
Education

Competencies
Subject-specific Competencies: Concepts and Theories, Techniques and Technologies
Method-specific Competencies: Analytical Competencies

Financial Management

Skill-Based Training, 1. and 3. Semester

<table>
<thead>
<tr>
<th>Number</th>
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<tbody>
<tr>
<td>365-1099-00L</td>
<td>Design Thinking: A Human-Centred Approach to Problem Solving</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>D. Salehabadi</td>
</tr>
</tbody>
</table>

Abstract
In this course, students get to know Design Thinking, which is an innovation method that can be applied to solve a broad range of problems
from product development to social innovation. The students will engage in collaborative team exercise to learn about and directly apply the
type typical design thinking steps – empathize, define, ideate, prototype and test – by solving a real-world challenge.

Objective
During the course, students will:

- get to know the design thinking process working on a specific real-world challenge
- learn when to apply design thinking methodology
- learn how to empathize with users, how to formulate a clear problem statement, develop ideas, prototype as well as test them with potential users

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1663 of 2653
During the course, students will...
- get to know the design thinking process as:
  - a methodology to develop ideas and concepts – typically in the early phase of the innovation process (the fuzzy-front end)
  - a methodology used for product, service and business model innovation
  - a methodology used for organizational development: process improvements, redesign of organizational structures, etc.
- learn how to apply the design thinking methodology or parts of it
- learn how to empathize with users: simple interview techniques, observation, etc.
- learn how to formulate a clear problem statement
- learn how to develop ideas: potentially alternative brainstorming techniques
- learn how to prototype ideas with simple means
- learn how to test them with potential users: simple test structures

What the students should learn from the course:
- Students will be able to assess whether Design Thinking is useful methodology to solve challenges they face in their daily business activities
- Students will be able to use elements (i.e. a novel brainstorming technique, a novel feedback method, etc.) in their daily business activities

What the students will NOT learn:
- This 3-day training is by not extensive enough to provide a full-scale design thinking training that enables students to design, organize and run their own design thinking workshops and projects. For this, further courses, trainings and self-guided learning is necessary.

References to institutes, books and other material will be provided.

<table>
<thead>
<tr>
<th>Lecture notes</th>
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<tbody>
<tr>
<td>There is no script available.</td>
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<table>
<thead>
<tr>
<th>Content</th>
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<tbody>
<tr>
<td>Human Resource Management: Skills in Practice</td>
</tr>
<tr>
<td>Exclusively for MAS MTEC students (3rd semester).</td>
</tr>
<tr>
<td>Prior participation in the lecture &quot;Human Resource Management: Leading Teams&quot; (363-0302-00) in spring semester is recommended.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective</th>
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<tbody>
<tr>
<td>Participants are able to cope with potentially difficult HRM-related situations they may encounter as line managers and team leaders.</td>
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<table>
<thead>
<tr>
<th>Content</th>
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<tbody>
<tr>
<td>Based on several core Human Resource Management processes, this seminar teaches practical skills in HRM and leadership in teams.</td>
</tr>
<tr>
<td>Using a variety of interactive methods and discussions of real-life situations, it provides a highly practice-oriented approach to dealing with potential HRM- and team-related conflicts at work.</td>
</tr>
<tr>
<td>Topics covered in the seminar include (but are not limited to) questions around hiring new staff, employee motivation (or a lack thereof), measuring performance, fair and effective compensation, pros and cons of monetary incentives, opportunities and limitations of career development in organizations. Furthermore, participants will learn and practically apply techniques that help them to deal with team-related conflicts. Thereby, they gain a better understanding of how and why conflicts in teams may arise and how they can be solved.</td>
</tr>
<tr>
<td>The success of this seminar depends greatly on active student participation. Sharing real-life examples from participants' various organizational and professional backgrounds provides the material for engaged and insightful discussions in class as well as in small groups. Also, in order to maximize the learning effect of this seminar, participants will be asked to complete a variety of short assignments prior to and between the three modules. The assignments will help them to prepare for the modules and reflect on the various themes in more depth. Based on the assignments, the discussions during the seminar will be much more focused and effective.</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Literature</th>
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<tbody>
<tr>
<td>Will be announced and published ahead of each session.</td>
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<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
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<tbody>
<tr>
<td>Prior participation in Prof. Grote's lecture 'Human Resource Management: Leading Teams' is highly recommended.</td>
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<table>
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<tr>
<th>Content</th>
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<tbody>
<tr>
<td>Innovation, Creativity and Personality Traits</td>
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<tr>
<td>Does not take place this semester.</td>
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<table>
<thead>
<tr>
<th>Objective</th>
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<tbody>
<tr>
<td>Participants will generate a richer notion of innovation and creativity by reflecting on the role of individuals on the innovation processes, the cognitive abilities and personality traits that are involved in this process</td>
</tr>
<tr>
<td>Through a personal assessment, participants will learn how the discussed cognitive abilities and traits are observable and measurable</td>
</tr>
<tr>
<td>Through a personal assessment, participants will learn about their own cognitive abilities and personality traits related to innovation and creativity and in comparison with other groups with similar backgrounds.</td>
</tr>
<tr>
<td>Participants will gain awareness of the use of their own creativity and problem-solving skills and will learn the reasons why these type of processes can foster creativity and innovation in their daily life and their jobs</td>
</tr>
<tr>
<td>Through discussions with field experts and the knowledge from their self-assessments, participants will gain insight on the fit or misfit of career paths and cognitive abilities and personality traits</td>
</tr>
<tr>
<td>Through the workshop debrief session, participants will learn the reasons why these type of processes can foster creativity and innovation.</td>
</tr>
<tr>
<td>Participants will create one and receive one concrete and actionable plan for helping someone overcome one weakness in their own work environment. Participants will also learn from the plans created by their peers.</td>
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<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior participation in Prof. Grote's lecture 'Human Resource Management: Leading Teams' is highly recommended.</td>
</tr>
</tbody>
</table>
Adaptability and Flexibility

The Personal Branding and Storytelling course will be divided into the following sessions:

Introduction to Personal Branding and Storytelling

- Media and Digital Technologies
- P. Geissbühler

This highly interactive course will help you to understand and then define your own brand story. By carefully looking at your own values, you will develop a personal action plan based on the channels most relevant to your industry and profession. You will be given the opportunity to tell your story and obtain feedback.

Storytelling Practice: you will spend time developing your personal story. We will have exercises and break into small teams as needed.

Brand Building: using the pre-work material, we will look at your current personal brand vs. your desired brand. We will take an in-depth look at all parts of a brand house and help you define your own Unique Selling Points (USPs). We will have exercises and break into small teams as needed.

Storytelling Basics: gain a common understanding of the importance of storytelling and different frameworks to approach it.

Storytelling Practice: you will spend time developing your personal story. We will have exercises and break into small teams as needed.

You will be given the opportunity to tell your story and obtain feedback. Communication Channels: we will review the various online and offline communications channels open to you to build your brand with a strong focus on LinkedIn. You will develop a personal action plan based on the channels most relevant to your industry and profession.

Post-Work: all students are asked to load a video of themselves where they showcase their personal brand and then do peer-to-peer reviews.

Attendance at both days of the course, active participation in the exercises and finishing the post-class assignment is mandatory for successful completion of the course. Students will be expected to fully complete the pre-work required, including gathering the Trusted Network Survey data and filling in the first part of the Personal Journal. Literature and readings will be announced beforehand.

Competencies

Subject-specific Competencies
- Concepts and Theories
- fostered
- Techniques and Technologies
- fostered

Method-specific Competencies
- Analytical Competencies
- fostered
- Problem-solving
- fostered

Personal Competencies
- Adaptability and Flexibility
- fostered
- Creative Thinking
- fostered
- Self-awareness and Self-reflection
- fostered

Prerequisites / Notice

Please notice that participation in the entire two days of the course is a requirement. Due to the short duration of the course and its highly interactive nature, there are no exceptions.

Minimum number of participants: 15 students.

Abstract

We all have a “personal brand” - whenever you are interacting others, you are projecting an image of yourself. Are you ready to take charge of your own brand story and proactively guide your image? Would you like to learn how to effectively tell your story in a memorable way? This course will teach you skills you can rely on throughout your career to help you achieve your goals.

Objective

This highly interactive course will help you to understand and then define your own brand story. By carefully looking at your own values, attributes and strengths from an internal and external perspective, you will first define a genuine and meaningful personal brand for yourself and then learn the storytelling skills you will need to authentically connect with and influence your audience. In addition, you will look at the various channels of communication you can use to proactively build your personal brand, with particular attention on LinkedIn.

Specific take-aways from this course:
- Your current personal brand
- Your desired personal “brand house”
- Storytelling frameworks
- Building of your personal story and practice giving it
- Review of online & offline communication channels with an action plan to activate
- Revision of your LinkedIn profile to reflect your personal brand
- Your Personal Journal to keep and reflect on throughout your career as well as the toolkit you need to refresh your brand house as needed

Content

The Personal Branding and Storytelling course will be divided into the following sessions:

Pre-Work: you will be expected to distribute a survey to 5-6 members of your trusted network (e.g. friends, family and work colleagues). The surveys are private and only you will see the information. The survey will be the basis of defining your current personal brand.

Additional pre-work will be reading through some articles and completing the first section of your Personal Journal.

Brand Basics: gain a common understanding of what a brand really is and why it is important. We will explore the difference between a corporate brand and a personal brand.

Brand Building: using the pre-work material, we will look at your current personal brand vs. your desired brand. We will take an in-depth look at all parts of a brand house and help you define your own Unique Selling Points (USPs). We will have exercises and break into small teams as needed.

Storytelling Basics: gain a common understanding of the importance of storytelling and different frameworks to approach it.

Storytelling Practice: you will spend time developing your personal story. We will have exercises and break into small teams as needed.

You will be given the opportunity to tell your story and obtain feedback. Communication Channels: we will review the various online and offline communications channels open to you to build your brand with a strong focus on LinkedIn. You will develop a personal action plan based on the channels most relevant to your industry and profession.

Post-Work: all students are asked to load a video of themselves where they showcase their personal brand and then do peer-to-peer reviews.

Attendance at both days of the course, active participation in the exercises and finishing the post-class assignment is mandatory for successful completion of the course. Students will be expected to fully complete the pre-work required, including gathering the Trusted Network Survey data and filling in the first part of the Personal Journal. Literature and readings will be announced beforehand.
Negotiation Skills

Exclusively for MAS MTEC students (3rd semester).

Abstract
Participants are introduced to practical frameworks for negotiations and apply them in negotiation simulations, discussions, and exercises. In this course, participants are introduced to the practical dimensions of how individuals and organizations represent their interests in negotiations.

Objective
Participants will learn basic frameworks and theories for

- negotiation context analysis
- preparing to negotiate
- best-practices for effectively negotiating

and apply them to practical contexts through discussions, group exercises, and simulations.

Content
This two-day skills course gives students a basic introduction to how individuals and organizations represent their interests and create value in negotiations, which are often defined as exchanges between parties designed to reconcile their differences and produce a settlement. The course comprises a mixture of lectures, discussions, group work, and simulations. Students do not need any experience or knowledge of negotiations, though those that do are invited to share their experience in discussions.

The first day focuses on:
- Planning and preparation for negotiations
- Analyzing and understanding different types of negotiation contexts
- Common frameworks for negotiations
- 2-party negotiation simulation

The second day focuses on:
- Social dimensions (power, influence, persuasion, behavior cues, culture, and gender) of negotiations
- Ethics and ethical dilemmas in negotiations
- 5-party negotiation simulation

The course is structured to give an introductory overview of the topics. Recommended readings for further studies will be provided on moodle. Students will be required to read the instructions for the negotiation simulation before arriving in class. Attendance and participation are required on both course days.

Literature
Pre-session reading is composed of:

- instructions/mandate for a negotiation simulation (before each session)

All required and recommended readings will be available on moodle.

Personal Leadership Skills

Exclusively for MAS MTEC students in the 3rd semester of class 2023-2025.

Please register by 01.08.2024 at the latest via myStudies.

Abstract
With the aim of preparing the students to take on managerial responsibility, this 2x3 days-seminar teaches basic and practical management skills.

Objective
To convey management behavior based on practical examples, own experiences, and team discussions complemented by short theory sessions (subsidized from the donation for promotion and training in enterprise sciences at the ETHZ).

Content
When talking of leadership, one in most cases refers to the interaction between superior and associate. However, leadership in modern times also involves the interaction with peers, with one's own superior as well as with other stakeholders. Thus, not leadership but personal leadership skills are needed which also comprise communication, self-management, and personality aspects.

In the light of this, this seminar offers you the opportunity to acquire competencies in all of the just-mentioned subjects and to reflect on your current behavior as (future) leader. The more familiar we are with ourselves, the more we become aware of our needs, the freer we are to express ourselves and to interact with others.

The seminar will be a mixture of theory inputs, discussions, self-reflecting moments, group work with short presentations as well as some role plays to give you the opportunity not only to get to know the relevant theories and models, but also to apply and test them. This shall enable you to return to your daily work life and be ready for the challenges of being a (future) leader.

Be familiar with and feel able to able current concepts and theories related to leadership skills based on practical examples, own experiences, and team discussions complemented by short theory sessions.

Content:
1 Fundamentals of Communication
2 Communication in Business Life
3 Self-Management
4 Personality and Understanding Human Nature
5 Fundamentals of Leadership
6 Leadership Tools
Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

365-1189-00L

Personal Leadership (1/4): Sharpen Your Communication Skills

Exclusively for MAS MTEC students in the 1st semester of class 2024-2026.

Abstract
Leadership starts with communication: Conveying one’s message and the related needs to the other person or listening to the other person and checking whether one’s understanding is correct can be challenging because it is not only verbal, but also para- and nonverbal communication which are key. With this seminar you sharpen your skill set and learn how to make your communication more effective.

Objective
By attending this first of in total four seminars covering leadership skills, you will:

- Sharpen your general communication skills: Become able how to successfully manage all relevant verbal but also para- and nonverbal components of communication to create and maintain successful communicative interactions which are respectful, goal-oriented and at eye-level.
- Boost your communication skills as a leader irrespective whether you are a project leader, subject matter expert, scrum/agile master, team lead in a self-organised team or hierarchical leader: Have the communicative skills to manage key situations in a business context such as presentations, meetings, recruiting interviews but also a potential termination dialogue.

Content
This seminar targets people that lead or wish to lead – in the role of project leader, subject matter expert, scrum/agile master, team lead in a self-organised team or hierarchical leader – and want to improve their communicative skills as they are key to build and maintain sustainable (work) relationships of any kind. In order to not only learn about tools and strategies to make communication more effective, but also to directly try them out and test them, the seminar builds on a mixture of theory inputs, discussions, self-reflecting moments, group work with short presentations as well as some role plays. This shall enable you to return to your daily (work) life as a better communicator but also to be ready for the challenges of being a current or future leader.

The first seminar day focuses on sharpening your general communication skills. You will learn among others what communication really is and which components are needed to make communication successful. You become aware of how to phrase a message to make it as easily understandable as possible, if necessary by also taking into account cultural differences. Furthermore, you will work on your inner clarity, will improve your listening skills and will become able to read the para- and nonverbal cues of the other person in order to adapt your own communication to what has not yet been fully said.

The second seminar day focuses on boosting your communication skills as a leader: You will learn how to structure the content of a presentation or text in a listener- or reader-friendly way to increase your argumentative impact while also working on your voice and nonverbal expression to become even more persuasive. The rest of the day will focus on key situations in a business environment, i.e. how to make meetings more interactive and thus successful, how to manage a recruiting process to retain the most promising candidate for the open position but also how to terminate an employment relationship in a respectful way so that you prepare the toughest of all possible communicative situations in a safe environment.

Electives, 1. and 3. Semester

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>365-1145-00L</td>
<td>Managers' Guide to Investing</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>P. Romann</td>
</tr>
</tbody>
</table>

Abstract
This is a practical guide to investing for decision makers.
Successful investing requires an understanding of assets, markets, and strategies to achieve your financial goals. Whether you delegate this task or get involved personally, you need to understand how professional investing works.

Objective
The goal is to enable you to define your own personal investment strategy.
- Understand your pension fund as one of your largest investments
- Learn from pension fund investment methodology
- Understand main asset building blocks: stocks, bonds, and alternatives
- Understand how markets work are influenced by central banks
- Appreciate importance of leverage, arbitrage, and the role of derivatives
- Design your first investment strategy
Content 1. How your Pension Fund works?
- Contributions vs. Investments: how assets are built up over decades
- Assets vs. Liabilities. Investments vs. pension promises
- Choice of risk level: asset-liability derived investment dictates risk level
- Importance of conversion rate: how your pension salary fluctuates
- Your potential flexibility: discover personalization your pension fund offers

Case Study: Understand key information of your pension fund

2. How your Pension Fund invests?
- Asset classes: the pillars of pension fund investing
- Diversification and risk: the main line of defense for pension funds
- Optimal asset-allocation: how pension fund decides on asset mix
- Passive vs. active: why active fails and pension funds passivize investments
- ESG factor considerations

Case Study: Portfolio optimization techniques

3. How Markets work?
- Monetary policy: central banks decide on interest rates impacting markets
- Fiscal policy: governments borrowing to finance projects, risk of debt
- Inflation: how it is controlled, and when it is not
- Developed vs. emerging markets: higher growth at higher risk
- Market cycles: the dynamics of markets and economy

Case Study: Covid crash 2020, Post Covid bubble 2021, Inflation crash 2022

4. How Asset Classes work?
- Bond markets and valuation: why bond prices fall when interest rates rise
- Stock markets and valuation: why stock prices fluctuate
- Derivative instruments: key concepts and how to use them without the math
- Alternatives: Private Equity, Hedge Funds, Insurance Linked

Case Study: Stock valuation; Bond risk measure: “duration”

5. How to design my Personal Investment Strategy?
- Start with the pension fund methodology: what can I learn?
- Investment horizon: long-term vs. Short-term
- Risk capacity and appetite: Biting off more than one can chew
- ESG other criteria
- My personal “edge”

Case Study: Design/explain/defend your personal strategy

365-1143-00L Digital Transformation: Integrating Cloud and Business
"Exclusively for MAS MTEC students (1st and 3rd semester)."

<table>
<thead>
<tr>
<th>365-1143-00L</th>
<th>Digital Transformation: Integrating Cloud and Business &quot;Exclusively for MAS MTEC students (1st and 3rd semester).&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Digitalization changes our life and how companies do business. As a consequence, the role of IT and Cybersecurity changes, and these changes create new and unknown disruptive challenges for organizations. Based on practical experience we will look into some of these areas like Cybersecurity, governance, organization etc. always with a risk management focus.</td>
</tr>
<tr>
<td>Objective</td>
<td>The course will help you understand: 1. How digital transformation affects businesses (insights across industries), processes and organizations 2. That this is not only a technology but a human change as well 3. How today’s governance and organization need to be adopted to these trends 4. How current Cybersecurity approaches look like integrating the cloud</td>
</tr>
<tr>
<td>Content</td>
<td>The role of IT and Cybersecurity changed dramatically over time. The movement to the Cloud and the digital transformation as such is in the process of shaping a new world, cyber security (and privacy) being at the core of it. Digital transformation as well as security arrived now at the board level. This drives a lot of changes in a lot of different areas: The role of internal IT has to be re-defined; governance processes have to be changed; even the impact on finance and budgeting is not to be underestimated. This course focuses on these challenges and how they can be approached (and have been approached) in the industry. It will base on practical experience with companies across Europe and in different industries. Besides touching on the basics of Cybersecurity it gives a broader view on the challenges in today’s architectural and governance frameworks and how you can approach these challenges on the technological as well as on the human side. We will jointly work on how the Cloud influences these developments and what changes are necessary to capture the opportunities while maintaining an acceptable risk level. We want to approach this in an interactive format, while adding background information over the course of the first day (e.g. an introduction to Cybersecurity). Between the first full day and the day 2 (half-day) you work on a case study to be presented and discussed on day 2. On the final slot we will wrap up and fill the blanks and address the questions which remained open.</td>
</tr>
<tr>
<td>365-1181-00L</td>
<td>Introduction to Quantum Computing: Current Challenges and Business Insights &quot;Exclusively for MAS MTEC students (1st and 3rd semester).&quot;</td>
</tr>
<tr>
<td>Abstract</td>
<td>In recent years quantum computing has become one of the most talked-about technological promises yet it is still often misunderstood. This 2-day course will give you an introduction to the basic principles of quantum computing and related technologies with lectures from both academic experts and business leaders.</td>
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Content
Quantum computing is a type of computing that uses quantum mechanics principles, such as superposition and entanglement, to process information. Unlike classical computers, which store information in bits (either 0 or 1), quantum computers use quantum bits, or qubits, which can exist in multiple states simultaneously. However, quantum computing is still in its early stages of development and faces significant challenges, such as maintaining the stability of qubits and minimizing errors due to environmental noise.

On day 1 of the 2-day course there will be introductory lectures to quantum computing and related quantum technologies such as quantum communication, quantum sensing, and quantum simulation by experts from academia. You will get an overview of Quantum mechanics, quantum computing algorithms as well as quantum hardware. In addition, we will offer lab tours where state-of-the-art quantum computing equipment can be seen in action, presented by scientists doing cutting-edge research at ETH Zurich.

Guest lectures from Swiss businesses in the field of quantum technologies will share their view on the current and future market and present their companies’ histories, strategies, and goals. Together we will discuss some of the current challenges facing quantum computing as well as potential future directions for research and development in this field.

On day 2, further guest lectures will present challenges on which the students can work in teams, followed by a final round of presentations and feedback.

The students will benefit from first-hand insights by experts in the field with diverse backgrounds (academic, startup, business, industrial).

Grading (ungraded semester performance) is based on active participation on both days.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Creative Thinking
- Critical Thinking

Objective
After taking this course, students will
- have a basic, pragmatic, and practical understanding of quantum computing: how it works, what makes it different from classical computing, what kinds of problems it may be useful for, and what kinds of problems it won’t be useful for
- be able to judge the real-world impact of quantum computing today and in the coming years, as well as the challenges and opportunities it poses with respect to data security, simulation of complex systems, optimization problems, and AI/ML, to name a few examples
- be able to name and explain on a high level other quantum technologies (besides quantum computing) that may have a significant impact on the market, now or in the future
- be able to explain examples of business models in the area of quantum technology
- have had hands-on experience from working at challenges in developing business models in the quantum technology sector
- have had the chance to network and facilitate contacts with companies and experts at local research institutions and players in the local quantum technologies network

365-1083-00L Leading the Technology-Driven Enterprise

W 1 credit 1S J. O’Neil, D. Röttger

Exclusively for MAS MTEC students (1st and 3rd semester).
An enrolment for the lecture “Introduction to Management” (363-0341-00) is mandatory.

Abstract
The bloc-course is about change leadership. It provides MAS students with coaching and mentoring from two senior change leaders in the attempt to develop critical management skills and bridge the gap between theory and practice.

Objective
The general objective of the course is to enable MAS students with post work experience to think critically about concepts discussed in class during the course on Introduction to Management (i.e., the transformation process by Nadler and Tushman, 1980) and their own professional challenges.

Content
In today’s VUCA world that is Volatile, Uncertain, Complex and Ambiguous, how will you lead disruptive change due to Innovation and Technology evolution instead of being swept away by it? Have you mastered the process of leading change? Do you have a specific plan of action for the most critical problem you are trying to solve right now? If not, this is the course for you. You will learn lessons from relevant, current case studies that will bring out specific learnings in each of the 4 modules of the class – Innovation, Change Management, Leadership and Application.

The first module explores how you can be a practical and effective Innovator as an Intrapreneur Leading an established Technology Driven Enterprise, or as an Entrepreneur. Starting with clear definitions of the ‘problem’ and the ‘customer’, you will work through the steps of clarifying the value proposition of the innovative process or product, testing, pivoting and fast iterations, and moving with confidence to implementation.

With Technology and Innovation being necessary but insufficient starting points, the next two modules will dig deep into successful Change Management and Leadership at all levels to ensure aligned and effective execution. The case studies will highlight both successes, and failures, of prior experiences. This class is taught ‘by practitioners for practitioners’ with the final module focused on a customized Framework of Application introduced during prior modules. You will bring your priority challenge to the class, and through small group work and individual coaching, you will develop a plan of action. A final ‘elevator speech’ will give immediate feedback with which you can enhance the plan and apply it immediately back in your organization.

Separately, the D-MTEC MAS Mentoring Programme is available, should you desire continuing help to support your planning and execution after the course, or more generalized career development ideas.

Literature
Literature and readings will be announced beforehand.

365-1166-00L Learning Factory: Introduction to Lean and Industry

W 1 credit 1V T. Netland, R. Lorenz

4.0

Exclusively for MAS MTEC students (1st and 3rd semester).
A prior or parallel enrolment for the lecture "Production and Operations Management" (363-0445-00) is mandatory.

Abstract
This course (i) introduces the fundamentals of Lean Production and (ii) shows how new Industry 4.0 technologies can support a lean transformation. Through lectures, hands-on serious games, reflection and discussions, students learn (i) how lean production differs from other forms of production and (ii) how lean in synergy with new technologies can increase productivity in a production setting.

Objective
After taking this course, students will be able to:
1. Operationalize and apply lean principles in manufacturing
2. Design a production system that minimizes quality errors
3. Select and apply new Industry 4.0 technologies to support the lean transformation
4. Evaluate the challenges of implementing and scaling Industry 4.0 technologies
5. Work in a team to solve problems with selected problem-solving tools
6. Understand the role of behaviors and leadership in lean and Industry 4.0 transformations
This course is organized as a block course with two full lecture days. Day 1 focuses on the fundamental lean production principles and practices. Students get intimately familiar with lean production through a hands-on and immersive serious game and integrated reflection rounds. Day 2 focuses on how new technologies challenge and enhance the classic lean principles through presentations, hands-on exercises, and discussions. After each day, students write reflection notes.

**Content**

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: fostered
  - Techniques and Technologies: fostered

- **Method-specific Competencies**
  - Analytical Competencies: fostered
  - Decision-making: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: fostered

**Social Competencies**

- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Negotiation: fostered

**Personal Competencies**

- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered

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**365-1059-00L Practicing Strategy**

*W* 1 credit 1S  
G. von Krogh, T. Gersdorf, C. H. Park

**Abstract**

This lecture is a special course for MAS students which supplements the Strategic Management course. Participants work on real-life strategy problems in a two-day workshop and apply concepts & methods from the Strategic Management course to develop suitable solutions.

**Objective**

The course has two goals. First, participants learn to decompose complex real life problems into underlying strategic issues. Second, students learn to transfer and use the concepts and methods from the Strategic Management lecture to develop solutions for the identified strategic issues in real-life business contexts.

**Content**

The course consists of two workshop days. However, most work for participants takes place in the phase between the two workshop days when participants engage in group work to solve a real-life strategic issue.

**First workshop day:**

Participants revisit core concepts and methods from the Strategic Management lecture. Moreover, participants learn the conceptual steps of defining strategic questions and developing suitable solutions for real-life settings. This conceptual process is then illustrated with an in-depth case study of a strategy consulting project that one of the lecturers conducted. The second part of the workshop day is the starting point for the group work phase. Participants identify a strategic problem that they face at work and team up (each group consists of 4-6 participants) to develop solutions by applying the concepts and methods from the Practicing Strategy class. At the end of the first workshop day, each group has defined one strategic question and developed a rough course of action for developing solutions until the second workshop day.

**Between workshop days:**

Participants work in small groups to develop solutions for the strategic problem that they identified on the first workshop day. This phase requires participants to select concepts and methods that are suitable to approach the strategic question. Moreover, students collect and analyze data. Subsequently, participants draw upon their analysis to develop solutions to the strategic problem. In this phase, participants can rely on the support and feedback from the teaching team.

**Second workshop day:**

Participants present their group work followed by an in-depth discussion and feedback session for each group project.

**Prerequisites / notice**

Successful registration and participation (either parallel enrollment or successful completion in a previous semester) in the course “Strategic Management” is required (see Course Catalogue page for details).

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Problem-solving: assessed
  - Project Management: assessed

- **Social Competencies**
  - Communication: assessed
  - Cooperation and Teamwork: assessed
  - Leadership and Responsibility: assessed
  - Negotiation: assessed

- **Personal Competencies**
  - Adaptability and Flexibility: assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: assessed
  - Self-direction and Self-management: assessed

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**365-1183-00L Cases in Machine Learning**

*W* 2 credits 1S

C. Cuchiero, A. Ferrario, J. Teichmann

**Abstract**

Machine learning has revolutionized various domains across industry sectors. Advances in GenAI has triggered this development and has created additional fantasies for future applications. Hence, an understanding its practical applications is crucial for professionals in today’s data-driven world. This course delves into the concepts of ML, its applications and use cases and ethical considerations.
Analytical Competencies
There is no mandatory literature for this course. Additional reading will be distributed during the course.

The course consists of five sessions taking place on weekdays during after-work hours. The course includes two guest speakers working in cooperation and teamwork.

After taking this course, participants will foster
- Understand the fundamental concepts of ML with some basic hands-on cases
- Understand and reflect on the ethical implications of ML algorithms, discuss bias, fairness, and transparency in AI systems.
- Understand the concepts behind advances in deep learning and reinforcement learning, transformers
- Learn about applications of deep learning and reinforcement learning in finance
- Learn about key areas of AI in robotics, like computer vision, imitation learning, planning, robot control
- Get an overview of deep learning in different industries like logistics, automobile, healthcare
- Learn about the power and limits of LLMs
- Learn about prompt engineering, fine tuning and working with LLMs

Subject-specific Competencies
Advancements in artificial intelligence (AI) have opened up exciting opportunities across various domains. In this lecture, we explore the potential and hurdles in four key areas: machine learning, deep learning, reinforcement learning, and language models across different applications, with a focus on finance and robotics.

Day 1: Introduction to Machine Learning, Transparency, Interpretability and ethical aspects of ML

Day 2: Introduction to Deep Learning, Reinforcement Learning, Transformers, applications in finance and robotics, overview of deep learning across industries

Day 3: Focus on Large Language Models with Applications from prompt engineering and working with large language models in a business context

By the end of this course, students will have a comprehensive understanding of machine learning, its ethical dimensions, and practical applications.

The course is held in a workshop format with lecture and group work elements. Active participation on all course days is mandatory. Participants will work in groups on selected cases and have the opportunity to follow some basic coding examples in a Jupiter Notebook. Programming skills are not mandatory. An understanding of basic machine learning concepts is welcomed but also not mandatory (e.g. you took the class “Fundamentals of ML for Executives” or “AI for Executives”).

In the beginning of the course, we will do a short primer on mathematics and statistics and some fundamental aspects of machine learning to bring all students on the same level.

Grading (ungraded semester performance) is based on active participation in the class and a short written report (ungraded) after the course.

Competencies
- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
  - Analytical Competencies
  - Media and Digital Technologies
  - Creative Thinking
  - Critical Thinking

- Method-specific Competencies
  - Fostered

- Social Competencies
  - Fostered

- Personal Competencies
  - Fostered

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<td>Understanding Human Behavior - Research and Business Insights</td>
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<td>1 credit</td>
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Abstract
Human capital is the most precious resource of every company, while customers are the backbone of a company’s functioning. This course demonstrates applications of behavioral science theories to improve decision making within the company and to better understand its customers. In this course, psychology meets finance, data science and analytics to address practical business problems.

Objective
The course objective is to provide a crash-course of behavioral economics and decision science with a special focus on aspects particularly important in business and international companies. The aim of the course will be to apply theoretical knowledge obtained during the classes at ETH in practical business cases stemming from ETH industry partners.

Content
This block course is divided into three components:

1. Theory Part: Students get familiar with the Nobel-Prize winning theories, key concepts, models and findings in decision science and behavioral economics. The covered topics include judgment and decision making, heuristics, biases and heuristics, nudges, psychometrics, risk appetite elicitation, digital and physiological footprints of decisions, and impact of emotions and environment on decisions. The material will be aligned with relevant real-life examples that relate to important societal and business problems. The students will be introduced to the behavioral study design, behavioral analytics and research methods that can be applied in a business environment accounting for its advantages and limitations.

2. Business Insights Part: In this part, students learn how the behavioral aspects enter into business processes, workflows and customer relations. For the upcoming semester, Dr. Rafael Huber from Cablecom and ZHAW will join the course to give a workshop on agile working. The attendance of the second guest lecturer will be confirmed soon.

3. Application of Behavioural Insights: In this part, students will have the opportunity to go through various simulated cases and exercises.

Attendance during the meetings and solving the business case are mandatory requirements for successful completion of the course. Course material includes the lecture slides and scientific papers.

Lecture notes
The course consists of five sessions taking place on weekdays during after-work hours. The course includes two guest speakers working in an applied field of behavioral sciences and several cases and (reflective) exercises. Discussed topics include complex decision-making, individual resilience, risk, forecasting techniques, human-technology interaction, methodology of behavioral interventions and studies.

The course has a form of an interactive lecture where discussions and exchanges are welcome.

Literature
There is no mandatory literature for this course. Additional reading will be distributed during the course.

Prerequisites / notice
This course is open to all third-semester students of the Master of Advanced Studies of Management and Technology, ETH Zurich.
Alliances within innovation ecosystems are essential for developing new business models that address the increasing complexity of technologies and systems, as well as the intensifying global competition. Organizations are compelled to prioritize selected partnerships for value creation. We will emphasize the role of alliances and collaborations in driving innovation within these ecosystems.

Objective

Learning outcomes professional competence
- learn and understand the management basics of inter-firm collaboration and organizational networks (strategy considerations incl. collaborative business models; cultural aspects including both corporate culture and international aspects, risk management, communication, etc.)
- realize the value creation potentials of alliances (added value)
- understand underlying theoretical models (mainly from the institutional economics, focusing on transaction cost and principal agent theory)
- identify and understand specific forms of collaboration (strategic alliances, joint ventures, Networks, etc.)
- apply tools hands on in real companies (planned in collaboration with companies)

Learning outcomes methodological competence
- Writing academic papers
- Developing structured documentation of interviews (in form of a presentation)
- Transferring theory directly into practical application
- Contributing to the learning journey

Learning outcomes social competence
- Improving communication skills as basics for collaboration
- Developing and applying team work skills
- Work together with industrial partners
- Coping with conflicts resolution in teams

Content

The ever-increasing complexity of technologies and systems, coupled with heightened competitive pressure and the need to shorten time-to-market, drives organizations to concentrate on their core competencies. Collaborating with external partners presents a crucial value creation opportunity, significantly impacting daily management activities. This lecture aims to provide a comprehensive understanding of the unique management requirements for successful cooperation.

Content:
- Introduction to the theory and management of inter-firm collaboration and networks.
- Examination of the formation, management, and evolution of collaborations and networks.
- Exemplary collaborations in marketing, development, and manufacturing.
- Special forms of collaborations: innovation ecosystems, strategic alliances, joint ventures, Networks, etc.

Learning Journey:
- Week 1: Introductory day providing an overview of the theoretical framework, explaining the course concept, case stud(i)es and intro to the first assignment.
- Weeks 2-5: First assignment focusing on key aspects of the framework: Networked Business Strategies; Culture and People Orientation; Leadership, Interaction and Communication; Resilience, Risk and Trust; Agile Structures and Processes; Collaborative Skills Development. This assignment will build the foundational knowledge necessary for the second part of the seminar.
- Mid-Semester: Presentation of the first assignment results, supplemented with additional input using a case study, preparation for the second assignment.
- Second Assignment: Analysis of real alliance projects within partner companies, i.e. preparing and conduction an interview, summarizing the interview into a presentation.
- Final day: Best practice exchange session to conclude the course.

This structured approach ensures a thorough understanding of inter-firm collaboration management, equipping participants with the necessary skills to navigate and leverage these partnerships effectively.

Lecture notes
- Lecture slides
- Current course material
- Harvard Case Studies

Literature
A list with recommended publications will be distributed in the lecture.

Classic Books:
- HBR Collaborating Effectively ISBN 978-1-4221-6264 4
- HBR on Mergers and Acquisitions: ISBN 1-57851-555-6

Prerequisites / notice
The number of students participating in the lecture is limited to 30.
The seminar "Cases in Technology Marketing" introduces students to key concepts and tools in technology marketing and familiarizes them subsequently with the challenges that (marketing) managers face in technology intensive markets by using real-life cases.

### Competencies
#### Subject-specific Competencies
- Concepts and Theories: assessed
- Analytical Competencies: assessed

#### Method-specific Competencies
- Decision-making: fostered
- Problem-solving: fostered

#### Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

#### Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### Courses

**363-1051-00L Cases in Technology Marketing**

**Number of participants limited to 20.**

Students have to apply for this course by sending a CV and an one-page motivation letter until 31.8.2023 to Theresa Schachner: tschachner@ethz.ch.

Additionally please enroll via myStudies. Places will be assigned on the basis of your motivation letter.

**Abstract**
The seminar “Cases in Technology Marketing” introduces students to key concepts and tools in technology marketing and familiarizes them subsequently with the challenges that (marketing) managers face in technology-intensive markets by using real life cases.

**Objective**
1. Understanding and applying common business tools and frameworks
2. Understanding current challenges of managers in technology-intensive markets
3. Defining and analyzing comprehensive business problems using the example of a leading Swiss manufacturing company (Bühler AG)
4. Developing and evaluating different alternative case solutions
5. Making decisions on case solutions, justifying and defending them
6. Transferring case solutions into practice by formulating specific instructions for the management
7. Creation of novel, innovative ideas that help the company to gain a competitive edge
8. Cooperation in teams and coordination of teamwork
9. Adequate communication to and eye-level discussions with C-level managers

**Content**
The seminar “Cases in Technology Marketing” introduces students to key concepts and tools in technology marketing and familiarizes them subsequently with the challenges that (marketing) managers face in technology-intensive markets by using real-life cases.

Students will have to work in groups and together solve past, current and future managerial problems in the form of cases. The team member composition will rotate for each case, enabling students to foster their teamwork abilities besides the application of theoretical concepts to the applied case questions. The students will have to present their case solutions to the lecturer and a top executive of a leading Swiss company (details see below). Also, they will be enabled to compare their solutions with what has actually been done or is yet to be done.

The three case studies presented in this course cover real managerial issues of the Swiss manufacturer Bühler AG (www.buhlergroup.com). A Bühler top executive will present the cases and discuss the students’ presentations and solutions. As such, the course allows for in-depth discussions of the real-life case solution with the C-level manager and hereby enables students to transfer their learnings from theoretical considerations to the applied field. The course will be rounded off with a day visit to the Bühler facilities in Uzwil, Switzerland, where students will have the chance to further connect with management and discuss the acquired key concepts, tools, and case study insights on-site.

**Prerequisites / notice**
In addition to course enrolment, students have to apply for this course by sending a CV and a short motivation letter until 31.08.2023 to Dr. Theresa Schachner: tschachner@ethz.ch.

**363-0393-00L Corporate Strategy**

**Due to didactic considerations, the number of participants for this course is limited to 45.**

Please register through myStudies to enroll for the course. Slots are assigned on a first-come first-serve basis (in the order of the registration date on myStudies). We will confirm your registration by e-mail. If you have any inquiries about the course, please contact the course assistant.

**Abstract**
This course focuses on the challenges in managing multi-business corporations, and covers topics related to the vertical and horizontal scope of business activities.
Objective

Content

The course is a combination of lectures about concepts/methods, guest lectures, case studies, and individual assignments. Large- and medium-sized corporations play a central role in the economic activity of most developed and developing countries. Many of these organizations perform multiple business activities in multiple markets. In the face of increasing international competition, globalization, technological development, deregulation, and the emergence of new markets and industries, operating such a portfolio of business activities poses important managerial challenges forcing corporations to continuously re-consider their vertical and horizontal scope and boundaries.

The course Corporate Strategy draws from a wide range of theories and methods to develop an understanding of the conceptual frameworks, debates, and developments concerning decisions associated with the management of multi-business corporations. We will cover the key questions driving a firm's corporate strategy, including:

- In what markets to compete with which businesses?
- Which activities should be performed by the firm and which should be outsourced (i.e. "make" or "buy" decisions)?
- What are the most appropriate approaches to growth and divestiture?
- How do institutional forces impact corporate strategy?

Specifically, we will examine how organizations manage their portfolio of business activities and markets to achieve competitive advantage through vertical integration, cooperative strategies such as strategic alliances and joint ventures, corporate diversification, mergers and acquisitions, divestitures, and globalization/international strategies, and strategic renewal.

The course homepage can be found at: http://www.smi.ethz.ch/education/corporate-strategy.html

Prerequisites / notice

Having participated in the course Strategic Management by Prof. Georg von Krogh/Dr. Stephan Hertenig is an advantage but not a requirement.

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Analytical Competencies assessed

Problem-solving assessed

Personal Competencies

Creative Thinking assessed

Critical Thinking assessed

Self-direction and Self-management assessed

363-1163-00L Developing Digital Biomarkers

W 3 credits 2V F. Da Conceição Barata

Particularly suitable for students with a technical background who are interested in healthcare.

Abstract

The course gives an introduction to digital biomarkers and provides students with the foundations to develop their own digital biomarkers. The widespread use of mobile technologies (e.g., wearable sensors, mobile applications, social media, and location-tracking technologies) has the potential to meet the health monitoring needs of the world's aging population and the ever growing number of chronic patients. However, this premise is based on the application of Machine Learning algorithms that allow us to use this data in many different ways. In this course we will analyze systematic ways to collect data, review the most relevant methods and applications in healthcare, discuss the main challenges they present and apply the newly gained knowledge in practical assignments.

The course has four core learning objectives. Students should:

• understand the anatomy of digital biomarkers
• understand the potential and applications of digital biomarkers
• be able to critically reflect and assess existing digital biomarkers
• be able to design and implement a digital biomarker

The course will consist of four topic clusters that will allow the discussion of the most relevant digital biomarker applications in healthcare:

1) Digital Biomarkers: From biological to digital biomarkers. How are they motivated, defined and how can they be leveraged for monitoring? Prognostic vs. diagnostic vs. predictive biomarkers. Passive sensing vs. active sensing. Digital biomarker vs. Digital therapeutics.

2) Consumer-centric device data: Today, vast amount of physiological, environmental, and behavioral observations can be collected with consumer-centric devices. To derive clinical meaningful information from this data is, however, difficult. We will analyze strategies for extracting knowledge from those measurements.

3) Methodology: In the last decade, neural networks (also known as “deep learning”) have helped push the boundaries of the state-of-the-art in a myriad of domains. They have also uncovered a number of different problems. We will discuss advantages and disadvantage as well as alternative methods for their application to digital biomarker data.

4) Applications: Digital biomarkers are still an emerging subfield, but given that longitudinal digital biomarker data are arguably easy to acquire in large quantities, it is expected that many relevant Machine Learning applications will emerge in the near future. We will review and discuss current and future applications and challenges.

Literature


Prerequisites / notice

Some programming experience in Python is required, and some experience in Machine Learning is highly recommended.
Enabling Entrepreneurship: From Science to Startup  

Students should provide a brief overview (unto 1 page) of their business ideas that they would like to commercialise through the course. If they do not have an idea, they are required to provide a motivation letter stating why they would like to do this elective. If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

The total number of students will be limited to 50.

Abstract  
This elective is relevant for students who have developed a technology and are keen to evaluate the steps in starting a startup. This is also relevant for students who would like to start a startup but do not have a technology, but are clear on a specific market and the impact they would like to create.

Objective  
Students have technology competence or an idea that they would like to convert into a startup. They are now in the process of evaluating the steps necessary to do so. In summary:

1. Students want to become entrepreneurs.
2. The students can be from business or science & technology.
3. The course will enable the students to identify the relevance of their technology or idea from the market relevance perspective and thereby create a business case to take it to market.
4. The students will have exposure to investors and entrepreneurs (with a focus on ETH spin-offs) through the course, to gain insight to commercialise their idea.

Content  
The students would cover the following topics, as the build their idea into a business case:

1. Technology excellence: this assumes that the student has achieved a certain degree of competence in the area of technology that he or she expects to bring to the market
2. Market need and market relevance: The student would then be expected to identify the possible markets that may find the technology of relevance. Market relevance implies the process of identification of how relevant the market perceives the technology, and whether this can sustain over a longer period of time
3. IP and IP strategy: Intellectual property, whether in the form of a patent or a trade secret, implies the secret ingredient that enables the student to achieve certain results that competitors are unable to copy. This enables the student (and subsequently the startup) to hold on to the market that they create with customers
4. Team including future capabilities required: a startup requires multiple people with complementary capabilities. They also need to be motivated while at the same time protecting the interests of the startup
5. Financials: There is a need of funding to achieve milestones. This includes funding for salaries and running of the company
6. Investors and funding options: There are multiple funding options for a startup. They all come with different advantages and limitations. It's important for a startup to recognise its needs and find the investors that fit these needs and are best aligned with the vision of the founders
7. Preparation of business case: The students will finally prepare the business case that can help them to articulate the link of the technology with the market need and its willingness to pay
8. Legal overview, company forms and shareholders’ agreements (including pitfalls)

The seminar includes talks from invited investors, entrepreneurs and legal experts regarding the importance of the various elements being covered in content, workshops and teamwork. There is a particular emphasis on market validation on each step of the journey, to ensure relevance.

Lecture notes  
Since the course will revolve around the ideas of the students, the notes will be for the sole purpose of providing guidance to the students to help convert their technologies or ideas into business cases for the purpose of forming startups. Theoretical subject matter will be kept to a minimum and is not the focus of the course.

Literature  
Book  
Sethi, A. “From Science to Startup”  
ISBN 978-3-319-30422-9

Prerequisites / notice  
This course is relevant for those students who aspire to become entrepreneurs.

Students applying for this course are requested to submit a 1 page business idea or, in case they don't have a business idea, a brief motivation letter stating why they would like to do this course.

If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

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## Competencies

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## Location

Autumn Semester 2024

Data: 15.06.2024 12:39
Entrepreneurial Leadership  W  4 credits  3S  Z. Erden Özkol, S. Brusoni, O. von Dzengelevski, G. von Krogh

Limited number of participants.

Students apply for this course via the official website no later than 18.08.2024 (https://www.mtec.ethz.ch/studies/special-programmes/els.html). Once your application is confirmed, registration in myStudies is possible.

Abstract
This seminar provides master and PhD students at MTEC with the challenging opportunity of a real case on strategy, innovation and leadership in close collaboration with the senior management of a leading company: UBS.

Objective
The general objective of the course is to enable MTEC students to develop leadership skills by dealing with real-world business problems, thinking critically about the concepts discussed in their study programs and learning how to apply these concepts to provide practical implications. It provides students with coaching and mentoring from senior leaders in the company and professors from D-MTEC to bridge the gap between theory and practice.

Content
This seminar provides ambitious ETH students and doctoral candidates with a rewarding learning opportunity: a real case study of strategy and innovation in close collaboration with the top management of an outstanding company: UBS.

What you can expect:
You will work in teams on specific high priority assignments that flow from the company. Delving into the assignments you will both contribute to solving strategic issues and have an impact on their implementation at the company.

To gain insight into the company and its culture you will receive briefings from senior management, conduct interviews with experts and run workshops with your case managers. In the final presentations you will pitch your findings to key stakeholders and top management representatives and receive valuable feedback.

Furthermore you will be coached and supported by MTEC professors on the topics of project scoping, problem definition and solving, process improvement, strategy and board presentation.

The course is directed and organized by PD. Dr. Zeynep Erden and Dr. Isabel Spicker as part of the MTEC Leadership Development Programme.

What we expect from you:
You are an ambitious ETH student or doctoral candidate who is looking for a rewarding learning opportunity and is eager to go the extra mile. You will work on a real case study of strategy, technology and innovation in close collaboration with the senior management of an outstanding company. The recommendations that you formulate in collaboration with members of your team as well as with internal and external experts will be discussed at the partner and director levels. This demands a deep understanding of the company’s leadership culture.

In this endeavour, you are coached and supported by
- Stefano Brusoni, Chair of Technology and Innovation Management
- Georg von Krogh, Chair of Strategic Management and Innovation
- Oliver von Dzengelevski, Chair of Production and Operations Management
- Zeynep Erden, Lecturer, D-MTEC
- Isabel Spicker, D-MTEC

Literature
Literature and readings will be announced in the coaching sessions.

Prerequisites / notice
Please apply for this course via the official website (https://mtec.ethz.ch/studies/programme-elements/special-programmes/els.html). Apply no later than August 18, 2024. The number of participants is limited to 18.

ECTS: 4
Participants receive a certificate.
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| Social Competencies | Communication | fostered |
| Cooperation and Teamwork |                      |         |
| Customer Orientation |                      |         |
| Leadership and Responsibility |                      |         |
| Self-presentation and Social Influence | fostered |         |
| Sensitivity to Diversity | fostered |         |
| Negotiation | fostered |         |

| Personal Competencies | Adaptability and Flexibility | assessed |
| Creative Thinking |                      |         |
| Critical Thinking |                      |         |
| Integrity and Work Ethics | fostered |         |
| Self-awareness and Self-reflection | assessed |         |
| Self-direction and Self-management | assessed |         |

### Management Research 363-0887-00L

**Participation in both sessions and completion of all assignments is required to receive the credit.** This course requires preparation time and completion of an assignment before the first course day. Please check the Moodle course page for more information.

**Abstract**

Students learn how to approach management research from various perspectives, how to evaluate empirical research, and how to develop their own research projects.

**Objective**

You will learn how to approach management research from various perspectives, how to evaluate empirical research, and how to develop your own research project. The successful completion of the course will help you to:

- Think critically and make compelling arguments about the strengths and weaknesses of published management research
- Find and review appropriate literature and previous research for your thesis
- Develop and frame interesting and relevant research questions and problem statements
- Design your research and choose an appropriate methodology for analysis (specific research methods and techniques are not discussed in this course)
- Structure your manuscript
- Plan and manage your thesis project

**Content**

This course combines lectures, group discussions and individual assignments.

- **Day 1**: Course introduction, group analysis exercises and discussions, lectures on main topics.
- **Between course days 1 and 2**: Individual and group work on assignments.
- **Day 2**: Assignment review and discussion, lectures on main topics, conclusion session.

**Target audience:**

The course is designed with two groups of students in mind: first, students who write their master thesis at the SMI chair and second, students who write their master thesis in the field of management at other MTEC chairs. For both groups, the focal topics of this course will arise frequently during the journey of writing their thesis, and the majority of topics are relevant for all students. However, we will provide some specific content (grading guidelines, thesis format) which might not be applicable for students tutored at other MTEC chairs.

**Course topics:**

1. Thesis topic and thesis proposal:
   - Choice of thesis topic, identification of research gap, formulation of research questions, writing of thesis proposal
2. Literature review:
   - Search and evaluation of academic literature, use of reference tools, writing of theoretical background chapter of thesis
3. Empirical research design:
   - Types of empirical research designs, choice of methodology, overview of data collection and analysis methods
4. Research output and report:
   - Writing of introduction, results and conclusion, thesis format and structure
5. Thesis assessment:
   - SMI grading criteria, MTEC guidelines

**References:**


**Prerequisites / notice**

This course is for all students who write their master thesis at the Department of Management, Technology, and Economics. The course is required for all M.Sc. students and MAS students who write their master thesis at the Chair of Strategic Management and Innovation. The course is graded based on the assignments, peer feedback, and participation in group discussions. The first assignment is due before the first course day. Please check the assignments on the Moodle course page. If you sign up for the course on short notice before the first course day, please advise the lecturer of your registration by email.
Abilities and Flexibility fostered

Subject-specific Competencies
Media and Digital Technologies fostered

Social Competencies
Communication fostered

Personal Competencies
Critical Thinking fostered

The course covers the economics of risk and insurance, in particular the following topics will be discussed:

- You know how risk and risk management is defined and applied in different industries
- You know the challenges of decision making under risk and uncertainty and its effects on organisations
- Know about and (partially) apply some risk management tools
- Gain some more in-depth knowledge in a selected field within risk management through the semester project (e.g. transport systems, IT, insurance)

This course consists of three main elements:

A) Attendance of lectures that provide the theoretical foundations of “Psychological Aspects of Risk Management and Technology” together with reading assignments for each lecture.

B) Attendance of guest lectures that provide a rich source of practical insights and enable the transfer of theory into practice by discussing real-life cases with experts from various industries.

C) Furthermore, this course enables you to apply what you have learned in the classroom into practice by participating in a group assignment in which you gain insights into various risk industries (e.g., aviation, healthcare, insurance) and topics (e.g., risks in cyber-attacks, mountaineering, autonomous vehicles). These projects help students understand key aspects through in-depth application of the course material on real-life topics. Each group project will be mentored and graded by one of the lecturers (70% of course grade). To round off the course at the end of the year, you will have the opportunity to present your group’s findings to the lecturers and to your peers (30% of course grade).

Content
The course is organized into fourteen sessions. Sessions comprise a mixture of (guest) lectures, case discussions, and presentations.

- Elements of risk management:
  - Risk identification and evaluation
  - Risk mitigation
  - Risk communication

- Psychological and organizational concepts relevant in risk management
  - Decision-making under uncertainty
  - Risk perception
  - Resilient organizational processes for managing uncertainty

- Case studies on different elements of risk management (e.g., rule-making, training, managing project risks, automation)

Lecture notes
There is no script, but slides will be made available before the lectures.

Literature
There are texts for each of the course topics made available before the lectures.

Prerequisites / notice
The course is restricted to 40 participants who will work closely with the lecturers on case studies prepared by the lecturers on topics relevant in their own companies (SWICA, SWISS, University Hospital Zurich).

Competencies
Subject-specific Competencies
Concepts and Theories assessed

Method-specific Competencies
Techniques and Technologies assessed

Social Competencies
Communication assessed

Personal Competencies
Adaptability and Flexibility fostered

The course introduces students to basic microeconomic models of risk attitudes and highlight the role insurance can – or cannot – play for individuals facing risks.
Content

Everyday, we take decisions involving risks. These decisions are driven by our perception of and our appetite for risk. Insurance plays a significant role in people's risk-management strategies.

In the first part of this lecture, we discuss a normative decision concept, Expected Utility theory, and compare it with empirically observed behaviour.

Students then learn about the rationale for individuals to purchase insurance, and for companies to offer it. We derive the optimal level of insurance demand and discuss how it depends on our model's underlying assumptions.

We then discuss the consequences of information asymmetries in insurance markets and the consequences for insurance supply.

Finally, we discuss refinements in decision theory that help account for observed behaviours that don't fit with the basic models of microeconomic theory. For example, we'll explore how behavioural economics can be leveraged by the insurance industry.

Literature

Main literature:
- Handbook of the Economics of Risk and Uncertainty. Volume1;

Further readings:

References will be given on a topic-by-topic basis during the course.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Techniques and Technologies</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Analytical Competencies</td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
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<tr>
<td>Leadership and Responsibility</td>
<td>fostered</td>
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<tr>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
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<tr>
<td>Creative Thinking</td>
<td>fostered</td>
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<tr>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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<tr>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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</table>

363-0389-00L Technology and Innovation Management

Abstract

This course focuses on the sources of innovation (with a specific focus on digital technologies), the tools and techniques that organizations deploy to innovate routinely, and the strategic implications of technical change at different levels of analysis: individuals, firms and whole ecosystems.

Objective

This course intends to enable all students to:
- Acquire and understand the basic jargon, concepts and methods necessary to discuss, in a precise and concise manner, innovation processes and their outcomes at different levels of analysis
- Analyze the differences between individual and organizational decision processes and their innovative outcomes
- Evaluate critically the potential of different (digital) technologies to impact business organizations.

Content

Organizations and people are faced with a fundamental decision: they have to allocate resources between well-known tasks that reliably generate positive results; or explore new ways of doing things, new technologies, products and services. The latter is a high risk choice. Its rewards can be high, but the chances of success are small. How do firms organize to take these decisions? What kind of management skills are necessary to take them? What kind of tools and methods are deployed to sustain managerial decision-making in highly volatile environments? These are the central questions on which this course focuses, relying on a combination of lectures, case-based discussion, and guest speakers.

Lecture notes

Slides will be available on the Moodle page

Literature

Readings will be available on the Moodle page

Prerequisites / notice

The course content and methods are designed for students with some background in management and/or economics

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
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<td>Analytical Competencies</td>
<td>Decision-making</td>
<td>assessed</td>
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<tr>
<td>Media and Digital Technologies</td>
<td>Problem-solving</td>
<td>assessed</td>
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<td>Social Competencies</td>
<td>Communication</td>
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<td>Leadership and Responsibility</td>
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<td>Sensitivity to Diversity</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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</table>

363-0790-00L Technology Entrepreneurship

Abstract

Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding.

This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are success factors in the creation of new firms, including founding, financing and growing a venture.

Objective

This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures. A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases.
The main objectives of the course are:

- Get an idea of climate change causes, physical vs. transition risks, consequences and scenarios, economic trade-offs, and the barriers for mitigation policies.
- Understand climate risk modelling and how to derive actionable results from it.
- Understand the basics of sustainability risks and ESG, basics of sustainability and the role of banks and insurers.
- Learn about the latest regulatory developments and the most relevant sustainability frameworks and initiatives.
- Learn from experts from industry and agencies how they tackle the challenges towards a sustainable economy.
- Get practice insights on a sustainable investment strategy.
- Learn about regulation and types of greenwashing.
- Learn about green fintech initiatives and startups from the Swiss ecosystem.

The Course is offered as a block course, allowing for a workshop character. Students will work in groups on selected cases on each day and share their thoughts and findings with industry professionals. Participation on all course days is mandatory. Performance assessment is based on active contribution and presentation of group work and cases.

Climate change is on par with political instability, violent conflicts, cybersecurity and volatile interest rates. However, there is one exception – these other factors will eventually reverse course – climate change will not. This MAS MTEC elective lecture aims to empower future business leaders to navigate the intersection of climate risk and sustainability. By engaging with industry experts, start-ups, and thought leaders, participants will gain practical insights and actionable strategies to create positive impact within their organizations and beyond. During the 4 days, participants will also learn and hear from the guest speakers about cultivating leadership skills to address climate-related challenges, ethical decision-making, and fostering a culture of resilience in order to promote organizational agility and adaptability.

The course is not targeted to participants with a background and work experience in the finance, banking, or insurance sector only. This course will benefit from participants with diverse backgrounds and industry experience.

**Master’s Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>365-1170-00L</td>
<td>Epigeeum’s Avoiding Plagiarism</td>
<td>0</td>
<td>0</td>
<td></td>
<td>external organisers</td>
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</tbody>
</table>

Further information will be provided after course registration via myStudies.

**Abstract**

Epigeeum’s Avoiding Plagiarism Online Course covers the basics on how to avoid intentional as well as unintentional plagiarism and how to correctly use citations and references.

**Objective**

The course should be considered as the minimum knowledge standard. Especially for students with less expertise in structuring and writing academic texts we recommend to attend specifically designed preparation courses which provide a more comprehensive and in-depth guidance (please see Study Plan and Master Thesis Guidelines).

By the end of this course, you will be able to:

- Define plagiarism and describe different types of plagiarism
- Recognize and describe key terms relating to plagiarism
- Understand the importance of referencing
- Compile accurate citations and references
- Correctly paraphrase and acknowledge others’ work
- Make better use of referencing software to manage your citations and references
- Develop strategies to help you avoid plagiarism in your own work.
This course is designed to help you understand what plagiarism is and how to avoid it. The key features of the course include:

- Interviews with students and tutors sharing their thoughts on plagiarism
- Key terms and different types of plagiarism explained
- Interactive activities to help you learn what plagiarism is
- Interactive activities to help you practise how to correctly cite and reference different sources
- Strategies to help you develop an action plan to avoid plagiarism
- Online resources to help extend your learning, including articles on real-life cases of plagiarism.

Prerequisites / notice

Plagiarism guidelines defined by ETH Zurich are authoritative.

365-0899-00L Master's Thesis in a Company

<table>
<thead>
<tr>
<th>O</th>
<th>12 credits</th>
<th>24D</th>
<th>Professors</th>
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</table>

In the Master thesis students prove their ability to independent, structured and scientific working. In the Master’s thesis students prove their ability to do independent, structured and scientific work. The Master’s thesis is written in collaboration with an industrial partner, organisation or institution and is supervised by an MTEC professor and a company supervisor.

Company supervisor:
The Master’s thesis is written in collaboration with an industrial partner, organisation or institution (all of which may be referred to as a company in the following). A company employee acts as external supervisor for the Master’s thesis.

Supervising professor:
In addition to a company supervisor, you need a D-MTEC professor to serve as the main supervisor of your thesis.

The topic has to address a concrete problem affecting either your current employer or another company.

You have to fulfil the following requirements before you can register for a Master’s thesis:

- You must have passed the “365-1170-00L Epigeum’s Avoiding Plagiarism Online Course” which covers anti-plagiarism topics and citation rules in your 1st semester of study. Handling the intellectual property of others is not only an integral part of the Master’s thesis, but also a part of every semester paper you will write at ETH.

- You must have read the “Citation Etiquette” information sheet on plagiarism (https://ethz.ch/content/dam/ethz/special-interest/study-programme-websites/mas-mtec-dam/Education/education-files/Citation%20etiquette%20-%20plagiarism-citationetiquette.pdf)

MAS in Management, Technology, and Economics - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
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<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>D</td>
<td>Suitable for doctorate</td>
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</table>

Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
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<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
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<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
MAS in Medical Physics

Compulsory Courses (for both Specialisations)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>465-0953-00L</td>
<td>Anatomy and Physiology for Medical Physicists I</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>F. Kuhn</td>
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<tr>
<td>Abstract</td>
<td>Introduction to structure and function of the human body. The lectures will be based on current clinical practices in Radiology, Neuroradiology and Nuclear Medicine.</td>
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<tr>
<td>Objective</td>
<td>Physiological and anatomical knowledge of the human body to ensure the correct understanding of basic concepts and to facilitate the collaboration of medical physicists and other health professionals.</td>
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<tr>
<td>Content</td>
<td>Anatomy and physiology for medical physicists I &amp; II provides insights into structure and function of the human body. The content is presented in an accessible manner targeted to physicist working in a medical environment. The lectures will be based on current clinical practices in Radiology, Neuroradiology and Nuclear Medicine. After an introduction to cells and tissues the following systems will be addressed: 1) Support &amp; Movement (musculoskeletal system, biomechanics); 2) Neuroscience (central and peripheral nervous system); 3) Auto-regulation (endocrine system) &amp; Internal Transport (blood &amp; cardiovascular system); 4) Environmental Exchange (respiratory, urinary, digestive &amp; reproductive system).</td>
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<tr>
<td>465-0953-00L</td>
<td>Biostatistics</td>
<td>O</td>
<td>4</td>
<td>2V+1U</td>
<td>B. Sick</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course deals with simple quantitative and graphical as well as more complex methods of biostatistics. Contents: Descriptive statistics, testing hypotheses, confidence intervals, correlation, simple and multiple linear regression, classification and prediction, diagnostic tests, measurement of agreement, causality versus association.</td>
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<tr>
<td>Objective</td>
<td>- know the commonly used methods in biostatistics - perform simple data analysis with R</td>
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<tr>
<td>227-0385-10L</td>
<td>Biomedical Imaging</td>
<td>O</td>
<td>6</td>
<td>5G</td>
<td>S. Kozerke, K. P. Prüssmann</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to diagnostic medical imaging based on electromagnetic and acoustic fields including X-ray planar and tomographic imaging, radio-tracer based nuclear imaging techniques, magnetic resonance imaging and ultrasound-based procedures.</td>
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<tr>
<td>Objective</td>
<td>Upon completion of the course students are able to:</td>
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<tr>
<td></td>
<td>• Explain the physical and mathematical foundations of diagnostic medical imaging systems</td>
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<td>• Characterize system performance based on signal-to-noise ratio, contrast-to-noise ratio and transfer function</td>
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<td>• Design a basic diagnostic imaging system chain including data acquisition and data reconstruction</td>
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<td>• Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications</td>
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<tr>
<td>Content</td>
<td>• Introduction (intro, overview, history)</td>
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<td></td>
<td>• Signal theory and processing (foundations, transforms, filtering, signal-to-noise ratio)</td>
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<tr>
<td></td>
<td>• X-rays (production, tissue interaction, contrast, modular transfer function)</td>
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<td></td>
<td>• X-rays (resolution, detection, digital subtraction angiography, Radon transform)</td>
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<td></td>
<td>• X-rays (filtered back-projection, spiral computed tomography, image quality, dose)</td>
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<td></td>
<td>• Nuclear imaging (radioactive tracer, collimation, point spread function, SPECT/PET)</td>
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<td></td>
<td>• Nuclear imaging (detection principles, image reconstruction, kinetic modelling)</td>
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<td></td>
<td>• Magnetic Resonance (magnetic moment, spin transitions, excitation, relaxation, detection)</td>
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<td></td>
<td>• Magnetic Resonance (plane wave encoding, Fourier reconstruction, pulse sequences)</td>
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<tr>
<td></td>
<td>• Magnetic Resonance (contrast mechanisms, gradient- and spin-echo, applications)</td>
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<td></td>
<td>• Ultrasound (mechanical wave generation, propagation in tissue, reflection, transmission)</td>
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<td>• Ultrasound (spatial and temporal resolution, phased arrays)</td>
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<td></td>
<td>• Ultrasound (Doppler shift, implementations, applications)</td>
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<td></td>
<td>• Summary, example exam questions</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes and handouts</td>
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<tr>
<td>Literature</td>
<td>Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011</td>
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<tr>
<td>Prerequisites</td>
<td>Analysis, Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
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<td>Method-specific Competencies</td>
<td>Techniques and Technologies</td>
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<td></td>
<td>Decision-making</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>fostered</td>
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<td>Social Competencies</td>
<td>Problem-solving</td>
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<td>Cooperation and Teamwork</td>
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<td>Adaptable and Flexibility</td>
<td>fostered</td>
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<td>Creative Thinking</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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<tr>
<td>465-0966-00L</td>
<td>Physics in Radiodiagnostic and Nuclear Medicine</td>
<td>O</td>
<td>2</td>
<td>3G</td>
<td>F. Bochud</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course is dedicated to introduce MAS students from Medical Physics to the field of radiodiagnostic and nuclear medicine. Dedicated practicals will illustrate the theory with an emphasis on the relationship between dose and image quality as well as the security problems related to the work with radiations.</td>
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<tr>
<td>Objective</td>
<td>This 1-week theory and practical class offers the possibility to enjoy a variety of research and clinical areas in diagnostic and nuclear medicine. It gives insight into practical concepts and techniques that are discussed thoroughly as the class is performed within actual laboratories with real radiation sources.</td>
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</table>
Introduction to the fundamentals of medical radiation physics. Functional chain due to radiation exposure from the primary physical effect to the radiobiological and radiological point of view. Dosimetric concepts of radiation protection in medicine. Mode of action of radiation sources used in medicine and its illustration by means of Monte Carlo simulations.

Understanding the functional chain from primary physical effects of ionizing radiation to clinical radiation effects. Dealing with dose as a quantitative measure of medical exposure. Getting familiar with methods to generate ionizing radiation in medicine and learn how they are applied for medical purposes. Eventually, the lecture aims to show the students that medical physics is a fascinating and evolving discipline where physics can directly be used for the benefits of patients and the society. The lecture is covering the basic principles of ionizing radiation and its physical and biological effects. The physical interactions of photons as well as of charged particles will be reviewed and their consequences for medical applications will be discussed. The concept of Monte Carlo simulation will be introduced in the excercises and will help the student to understand the characteristics of ionizing radiation in simple and complex situations. Fundamentals in dosimetry will be provided in order to understand the physical and biological effects of ionizing radiation. Deterministic as well as stochastic effects will be discussed and fundamental knowledge about radiation protection will be provided. In the second part of the lecture series, we will cover the generation of ionizing radiation. By this means, the x-ray tube, the clinical linear accelerator, and different radioactive sources in radiotherapy, radiotherapy and nuclear medicine will be addressed. Applications in radiology, nuclear medicine and radiotherapy will be described with a special focus on the physics underlying these applications.


Practical Work

Dosimetry

Praktische Umsetzung der Lerninhalte der Vorlesung Medizinphysik I & II bezüglich Dosimetrie bei perkutanen Strahlenexpositionen. Überprüfung der resultierenden Dosierteilungen.

Die Kursunterlagen werden im Blockkurs abgegeben. Voraussetzung: Besuch der Vorlesung Medizinische Physik I

Subject-specific Competencies

Concepts and Theories

Method-specific Competencies

Concepts and Theories

Assessed

Lecturers

P. Manser

M. Pruschy

E. V. Schuler

Assessed

Assessed

Autumn Semester 2024

Specialisation in General Medical Physics

Major in Radiation Therapy

Content

The course starts with the physical basis of radiography (from X-ray production to image detectors) and continues with the basic parameters of image quality in radiography (contrast, resolution, noise) and their measurement methods. Specific applications of radiation diagnostic are then considered separately. The physics of fluoroscopy and mammography is presented with emphasis on the type of detectors. Computer tomography starts from mono- to multidetectors for medical imaging and the corresponding image quality.

The course deals with the physical interactions of photons and charged particles with matter in simple and complex situations. Fundamentals in dosimetry will be provided in order to understand the physical and biological effects of ionizing radiation. Deterministic as well as stochastic effects will be discussed and fundamental knowledge about radiation protection will be provided. In the second part of the lecture series, we will cover the generation of ionizing radiation. By this means, the x-ray tube, the clinical linear accelerator, and different radioactive sources in radiotherapy, radiotherapy and nuclear medicine will be addressed. Applications in radiology, nuclear medicine and radiotherapy will be described with a special focus on the physics underlying these applications.

Content

The course starts with the physical basis of radiography (from X-ray production to image detectors) and continues with the basic parameters of image quality in radiography (contrast, resolution, noise) and their measurement methods. Specific applications of radiation diagnostic are then considered separately. The physics of fluoroscopy and mammography is presented with emphasis on the type of detectors. Computer tomography starts from mono- to multidetectors for medical imaging and the corresponding image quality.

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Content

The course starts with the physical basis of radiography (from X-ray production to image detectors) and continues with the basic parameters of image quality in radiography (contrast, resolution, noise) and their measurement methods. Specific applications of radiation diagnostic are then considered separately. The physics of fluoroscopy and mammography is presented with emphasis on the type of detectors. Computer tomography starts from mono- to multidetectors for medical imaging and the corresponding image quality.

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Content

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The course deals with the physical interactions of photons and charged particles with matter in simple and complex situations. Fundamentals in dosimetry will be provided in order to understand the physical and biological effects of ionizing radiation. Deterministic as well as stochastic effects will be discussed and fundamental knowledge about radiation protection will be provided. In the second part of the lecture series, we will cover the generation of ionizing radiation. By this means, the x-ray tube, the clinical linear accelerator, and different radioactive sources in radiotherapy, radiotherapy and nuclear medicine will be addressed. Applications in radiology, nuclear medicine and radiotherapy will be described with a special focus on the physics underlying these applications.
### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0341-00L</td>
<td>Medical Physics I</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>P. Manser</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to the fundamentals of medical radiation physics. Functional chain due to radiation exposure from the primary physical effect to the radiobiological and medically manifest secondary effects. Dosimetric concepts of radiation protection in medicine. Mode of action of radiation sources used in medicine and its illustration by means of Monte Carlo simulations.</td>
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</tr>
<tr>
<td>Objective</td>
<td>Understanding the functional chain from primary physical effects of ionizing radiation to clinical radiation effects. Dealing with dose as a quantitative measure of medical exposure. Getting familiar with methods to generate ionizing radiation in medicine and learn how they are applied for medical purposes. Eventually, the lecture aims to show the students that medical physics is a fascinating and evolving discipline where physics can directly be used for the benefits of patients and the society.</td>
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</tr>
<tr>
<td>Content</td>
<td>The lecture is covering the basic principles of ionizing radiation and its physical and biological effects. The physical interactions of photons as well as of charged particles will be reviewed and their consequences for medical applications will be discussed. The concept of Monte Carlo simulation will be introduced in the excercises and will help the student to understand the characteristics of ionizing radiation in simple and complex situations. Fundamentals in dosimetry will be provided in order to understand the physical and biological effects of ionizing radiation. Deterministic as well as stochastic effects will be discussed and fundamental knowledge about radiation protection will be provided. In the second part of the lecture series, we will cover the generation of ionizing radiation. By this means, the x-ray tube, the clinical linear accelerator, and different radioactive sources in radiology, radiotherapy and nuclear medicine will be addressed. Applications in radiology, nuclear medicine and radiotherapy will be described with a special focus on the physics underlying these applications.</td>
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<tr>
<td>Lecture notes</td>
<td>A script will be provided.</td>
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<td>Prerequisites / notice</td>
<td>For students of the MAS in Medical Physics (Specialization A) the performance assessment is offered at the earliest in the second year of the studies.</td>
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<td>Subject-specific Competencies: Concepts and Theories assessed, Techniques and Technologies assessed</td>
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<tr>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>227-0943-00L</td>
<td>Radiobiology</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>M. Pruschy</td>
</tr>
<tr>
<td>Abstract</td>
<td>The purpose of this course is to impart basic knowledge in radiobiology in order to handle ionizing radiation and to provide a basis for predicting the radiation risk.</td>
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<tr>
<td>Objective</td>
<td>By the end of this course the participants will be able to:</td>
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<td></td>
<td>a) interpret the 6 Rs of radiation oncology in the context of the hallmarks of cancer</td>
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<td>b) understand factors which underpin the differing radioresistances of different tumors</td>
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<td>c) follow rational strategies for combined treatment modalities of ionizing radiation with targeted and immunological agents</td>
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<td>d) understand differences in the radiation response of normal tissue versus tumor tissue</td>
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<td>e) understand different treatment responses of the tumor and the normal tissue to differential clinical-related parameters of radiotherapy (dose rate, LET etc.).</td>
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<tr>
<td>Content</td>
<td>Einführung in die Strahlenbiologie ionisierender Strahlen: Allgemeine Grundlagen und Begriffsbestimmungen; Mechanismen der biologischen Strahlenwirkung: Strahlenwirkung auf Zellen, Gewebe und Organe; Modifikation der biologischen Strahlenwirkung; Strahlenzytogenetik; Chromosomenveränderungen, DNA-Defekte, Reparaturprozesse; Molekulare Strahlenbiologie: Bedeutung inter- und intrazellulärer Signalübermittlungsprozesse, Strahlen-induzierter Zelltod, Zellzyklus-Checkpoints; Radioimmunologie, Strahlenrisiko: Strahlensyndrome, Krebsinduktion, Mutationsauslösung, pränatale Strahlenwirkung; Strahlenbiologische Grundlagen des Strahlenschutzes; Nutzen-Risiko-Abwägungen bei der medizinischen Strahlenanwendung; Prädictive strahlenbiologische Methoden zur Optimierung der therapeutischen Strahlenanwendung.</td>
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<tr>
<td>Lecture notes</td>
<td>Beilagen mit zusammenfassenden Texten, Tabellen, Bild- und Grafikdarstellungen werden abgegeben</td>
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<tr>
<td>Literature</td>
<td>Literaturliste wird abgegeben.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The former number of this course unit is 465-0951-00L.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies: Concepts and Theories assessed, Analytical Competencies assessed</td>
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### Practical Work

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>465-0956-00L</td>
<td>Dosimetry</td>
<td>W</td>
<td>4 credits</td>
<td>6G</td>
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</tr>
<tr>
<td>Abstract</td>
<td>Dosimetry in radiotherapy. Planning and implementation of a percutaneous radiation exposure on an anthropomorphic phantom. Verification of the resulting dose distribution.</td>
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<tr>
<td>Objective</td>
<td>Praktische Umsetzung der Lerninhalte der Vorlesungen Medizinphysik I &amp; II bezüglich Dosimetrie bei perkutanen Strahlenexpositionen</td>
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<tr>
<td>Content</td>
<td>Dosimetrie in der Strahlentherapie. Planung und Durchführung einer perkutanen Strahlenexposition an einem anthropomorphen Phantom. Überprüfung der resultierenden Dosisverteilungen.</td>
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<tr>
<td>Lecture notes</td>
<td>Die Kursunterlagen werden im Blockkurs abgegeben.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Voraussetzung: Besuch der Vorlesung Medizinische Physik I</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies: Concepts and Theories assessed</td>
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<th>Hours</th>
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<tbody>
<tr>
<td>465-0800-00L</td>
<td>Practical Work</td>
<td>W</td>
<td>4 credits</td>
<td>external organisers</td>
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</tr>
<tr>
<td>Abstract</td>
<td>The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialization. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.</td>
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<tr>
<td>Objective</td>
<td>The practical work is aimed at training the student’s capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.</td>
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### Electives

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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0965-00L</td>
<td>Micro and Nano-Tomography of Biological Tissues</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Stamponi, F. Marone Welford</td>
</tr>
<tr>
<td>Abstract</td>
<td>The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.</td>
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<tr>
<td>Objective</td>
<td>Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.</td>
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</table>
Content

Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and extends the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

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<thead>
<tr>
<th>Lecture notes</th>
<th>Literature</th>
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<tbody>
<tr>
<td>Available online</td>
<td>Will be indicated during the lecture.</td>
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<table>
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<tr>
<th>Lecture notes</th>
<th>Literature</th>
</tr>
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<tbody>
<tr>
<td>Lecture slides and handouts.</td>
<td>Will be indicated during the lecture.</td>
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<tr>
<th>Prerequisites / notice</th>
<th>Notice</th>
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<tbody>
<tr>
<td>Basic programming skills in Matlab (or willingness to learn) are needed for the exercises. Basic knowledge of calculus is needed, approximately corresponding to the 3rd year of a bachelor degree in physics, mathematics, computer science, engineering or comparable discipline.</td>
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<table>
<thead>
<tr>
<th>Abstract</th>
<th>Objective</th>
<th>Content</th>
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</thead>
</table>
| Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells. | Students shall develop a thorough understanding of the foundations of radiotherapy from a physics and mathematics perspective, focusing on algorithmic components. After completing the course students should be able to implement the main components of a radiotherapy treatment planning system. | Radiotherapy is one of the main treatment options against cancer. Today, more than 50% of cancer patients receive radiation as part of their treatment. Modern radiotherapy is a highly technology driven field. Research and development in medical physics has improved the precision of radiotherapy substantially. Using intensity-modulated radiotherapy (IMRT), radiation can be delivered precisely to tumors while minimizing radiation exposure of healthy organs surrounding the tumor. Thereby, medical physics has provided radiation oncologists with new curative treatment approaches where previously only palliative treatments were possible. This lecture will provide a detailed introduction to radiotherapy treatment planning and will consists of three blocks:

1. The first part of the course considers the physical interactions of radiation in tissue. The physical interactions give rise to dose calculation algorithms, which are used to calculate the absorbed radiation dose based on a CT scan of the patient.

2. The second part considers the mathematical aspects of treatment planning. Mathematical optimization techniques are introduced, which are used in intensity-modulated radiotherapy to determine the external radiation fields that optimally irradiate the tumor while minimizing radiation dose to healthy organs.

3. The third part deals with additional aspects of central importance for radiotherapy planning. This includes biomedical imaging techniques for treatment planning and target delineation as well as image registration algorithms. |

The lectures are followed by computational exercises where students implement the main components of a radiotherapy treatment planning systems in two dimensions in Matlab.
The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue’s anisotropies of biopsies.

### Major in Biomechanics

#### Core Courses

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>227-0386-00L</td>
<td>Biomedical Engineering</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
</tr>
</tbody>
</table>

### Abstract

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the basic vocabulary of biomedical engineering and getting familiar with concepts that govern common medical instruments and the most important organs from an engineering point of view.

### Objective

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs.

In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

### Content

- History of BME and the role of biomedical engineers. Ethical issues related to BME.
- Biomedical sensors both wearable and also biochemical sensors.
- Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices.
- Bioinformatics: genomic and proteomic tools, databases and basic calculations.
- Equations describing basic reactions and enzyme kinetics.
- Medical optics: Optical components and systems used in hospitals.
- Basic concepts of tissue engineering and organ printing.
- Biomaterials and their medical applications.
- Function of the heart and the circulatory system.
- Transport and exchange of substances in the human body, compartment modeling.
- The respiratory system.
- Bioimaging.
- Orthopedic biomechanics.
- Lectures (2h), discussion of practical exercises (1h) and homework exercises.

### Lecture notes

Introduction to Biomedical Engineering
by Enderle, Banchard, and Bronzino

AND

moodle page of the course

### Prerequisites / notice

No specific requirements, BUT

- ITET, MAVT, PHYS students will have to learn a lot of new words related to biochemistry, biology and medicine, while HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.).
**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: fostered
- Project Management: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

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**227-0965-00L Micro and Nano-Tomography of Biological Tissues**

**W** 4 credits 3G M. Stampanoni, F. Marone Welford

**Abstract**
The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

**Objective**
Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

**Content**
Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

**Lecture notes**
Available online

**Literature**
Will be indicated during the lecture.

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**376-1651-00L Clinical and Movement Biomechanics**

**W** 4 credits 3G D. K. Ravi, S. H. Hosseini Nasab, R. List, further lecturers

**Abstract**
Measurement and modeling of the human movement during daily activities and in a clinical environment.

**Objective**
The students are able to analyse the human movement from a technical point of view, to process the data and perform modeling with a focus towards clinical application.

**Content**
This course includes study design, measurement techniques, clinical testing, accessing movement data and analysis as well as modeling with regards to human movement.

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**376-1985-00L Trauma Biomechanics**

**W** 4 credits 2V+1U K.-U. Schmitt, M. H. Muser

**Abstract**
Trauma biomechanics in an interdisciplinary research field investigating the biomechanics of injuries and related subjects such as prevention. The lecture provides an introduction to the basic principles of trauma biomechanics.

**Objective**
This lecture serves as an introduction to the field of trauma biomechanics. Emphasis is placed on the interdisciplinary nature of impact biomechanics, which uses the combination of fundamental engineering principles and advanced medical technologies to develop injury prevention measures. Topics include: accident statistics and accident reconstruction, biomechanical response of the human to impact loading, injury mechanisms and injury criteria, test methods (including crash tests), computer simulations, aspects of vehicle safety. Real world examples mainly from automobile safety are used to augment lecture material.

**Lecture notes**
Handouts will be made available.

**Literature**
### Competencies

**Subject-specific Competencies**
- Concepts and Theories assessed
- Techniques and Technologies assessed

**Method-specific Competencies**
- Analytical Competencies assessed
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving assessed

**Social Competencies**
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity assessed
- Negotiation fostered

**Personal Competencies**
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

### Practical Work

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>465-0800-00L</td>
<td>Practical Work</td>
<td>O</td>
<td>4</td>
<td>external organisers</td>
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</tbody>
</table>

**Abstract**
The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialization. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

**Objective**
The practical work is aimed at training the student’s capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.

### Electives

<table>
<thead>
<tr>
<th>Number</th>
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</thead>
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<tr>
<td>151-0524-00L</td>
<td>Continuum Mechanics I</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>A. E. Ehret</td>
</tr>
</tbody>
</table>

**Abstract**
The lecture deals with constitutive models that are relevant for the design and analysis of components and structures. These include anisotropic linear elasticity, linear viscoelasticity, plasticity and viscoplasticity. The basic concepts of homogenization and laminate theory are introduced. Theoretical models are complemented by examples of engineering applications and experiments.

**Objective**
After successful completion of the course students are able to:
- explain basic theories for solving continuum mechanics problems
- proficiently apply these theories by solving application-related academic examples
- relate the theories and examples to real engineering applications and challenges
- distinguish between different mechanical behaviors of materials
- systematically select appropriate constitutive theories suitable to analyze and model these materials

**Content**
Anisotropic Elasticity, Linear Elastic and Linear Viscous Material Behavior, Viscoelasticity, Micro-Macro Modelling, Lamine Theory, Plasticity, Viscoplasticity, Examples of Engineering Applications, Comparison with Experiments

**Lecture notes**
Yes

**Prerequisites / notice**
The lecture will be taught in English.

### Microrobotics

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<tr>
<th>Number</th>
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<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>151-0604-00L</td>
<td>Microrobotics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>B. Nelson</td>
</tr>
</tbody>
</table>

**Abstract**
Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

**Objective**
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

**Content**
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microrobots

**Lecture notes**
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

**Prerequisites / notice**
The lecture will be taught in English.

### Biomechanics of Sports Injuries and Rehabilitation

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<tr>
<th>Number</th>
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</tr>
</thead>
<tbody>
<tr>
<td>376-2017-00L</td>
<td>Biomechanics of Sports Injuries and Rehabilitation</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>K.-U. Schmitt, J. Goldhahn</td>
</tr>
</tbody>
</table>

**Abstract**
This lectures introduces the basic principles of injury mechanics and rehabilitation fociussing on sports injuries.

**Objective**
Within the scope of this lecture you will learn the basic principles of trauma biomechanics. Based on examples from sports, you will get to know different mechanisms that can possibly result in injury. Investigating the background and cause of injury should allow you to assess the injury risk for sports activities. Furthermore you should be able to develop measures to prevent such injury.
This lecture deals with the basic principles of injury mechanics and rehabilitation. Mechanisms that can result in injury are presented. Furthermore possibilities to prevent injuries are discussed. Thereby the lecture focuses on sports injuries.

Handouts will be made available.


A course work is required. The mark of this course work contributes to the final credits for this lecture. Details will be given during the first lecture.

Bone Biology: Basics, Research and Clinics

The course gives an introduction into bone biology and provides an overview on current research methods and clinical approaches. Emphasis is put on skeletal development and metabolism, osteoporosis as well as fracture healing. Each topic is structured into three parts: basics, research and clinics.

After completing the Bone Biology course, students will be able to:
1. Remember and apply basics in bone biology and disease
2. Remember clinical features and surgical approaches
3. Select adequate research methods and approaches
4. Evaluate publications on topics presented in the lecture

Competencies
- Subject-specific Competencies: Concepts and Theories assessed
- Analytical Competencies: Techniques and Technologies fostered
- Decision-making: Analytical Competencies fostered
- Media and Digital Technologies: Problem-solving fostered
- Project Management: fostered

Communication: fostered
- Cooperation and Teamwork: assessed
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the basic vocabulary of biomedical engineering and getting familiar with concepts that govern common medical instruments and the most important organs from an engineering point of view.

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

History of BME and the role of biomedical engineers. Ethical issues related to BME. Biomedical sensors both wearable and also biochemical sensors. Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices. Bioinformatics: genomic and proteomic tools, databases and basic calculations. Equations describing basic reactions and enzyme kinetics. Medical optics: Optical components and systems used in hospitals. Basic concepts of tissue engineering and organ printing. Biomaterials and their medical applications. Function of the heart and the circulatory system. Transport and exchange of substances in the human body, compartment modeling. The respiratory system. Bioimaging. Orthopedic biomechanics. Lectures (2h), discussion of practical exercises (1h) and homework exercises.

Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

No specific requirements, BUT ITET, MAVT, PHYS students will have to learn a lot of new words related to biochemistry, biology and medicine, while HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.).
Practical Work

fostered

The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected
Image Analysis and Computer Vision

Available online

Communication

Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Analytical Competencies

The practical work is aimed at training the student's capability to apply and connect specific skills acquired during the MAS specialization. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

Subject-specific Competencies

O
2V
, F. Marone Welford

This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Project Management

Social Competencies

Communication

Cooperation and Teamwork

Customer Orientation

Leadership and Responsibility

Self-presentation and Social Influence

Sensitivity to Diversity

Negotiation

Personal Competencies

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

Prerequisites:

Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux.

The course language is English.

Practical Work

Number

465-0800-00L

Abstract

The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialization. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

Objective

The practical work is aimed at training the student’s capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.

Electives

Number

227-0965-00L

Abstract

The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

Objective

Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

Content

Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

Lecture notes

Available online

Literature

Will be indicated during the lecture.

227-0967-00L

Computational Neuroimaging Clinic

Prerequisite: Successful completion of course “Methods & Models for fMRI Data Analysis”, “Translational Neuromodeling” or “Computational Psychiatry”
Abstract
This seminar teaches problem solving skills for computational neuroimaging, based on analyses of neuroimaging and behavioural data. It deals with a wide variety of real-life problems that are brought to this meeting from the neuroimaging community at Zurich, e.g. mass-univariate and multivariate analyses of fMRI/EEG data, or generative models of fMRI, EEG, or behavioural data.

Objective
1. Consolidation of theoretical knowledge (obtained in the following courses: 'Methods & models for fMRI data analysis', 'Translational Neuroimaging', 'Computational Psychiatry') in the setting of concrete research questions.
2. Acquisition of practical problem solving strategies for computational modeling of neuroimaging data.

Content
This seminar teaches problem solving skills for computational neuroimaging, based on analyses of neuroimaging and behavioural data. It deals with a wide variety of real-life problems that are brought to this meeting from the neuroimaging community at Zurich, e.g. mass-univariate and multivariate analyses of fMRI/EEG data, or generative models of fMRI, EEG, or behavioural data.

Prerequisites / notice
The participants are expected to have successfully completed at least one of the following courses: 'Methods & models for fMRI data analysis', 'Translational Neuroimodelling', 'Computational Psychiatry'.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered

Social Competencies
- Problem-solving: assessed
- Communication: fostered

Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered

227-0969-00L Methods & Models for fMRI Data Analysis

Abstraction
Does not take place this semester.

Objective
To obtain in-depth knowledge of the theoretical foundations of SPM and DCM and of their practical application to empirical fMRI data.

Content
This course teaches state-of-the-art methods and models for fMRI data analysis in lectures and exercises. It covers all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, statistical inference, multiple comparison corrections, event-related designs, and Dynamic Causal Modelling (DCM). A Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data.

Prerequisites / notice
The participants are expected to have successfully completed at least one of the following courses: 'Methods & models for fMRI data analysis', 'Translational Neuroimaging', 'Computational Psychiatry'.

402-0674-00L Physics in Medical Research: From Atoms to Cells

Objective
The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

227-2037-00L Physical Modelling and Simulation

Objective
This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.

Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1691 of 2653
Micro and Nano-Tomography of Biological Tissues

The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

Objective

Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

Content

Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

Lecture notes

Will be indicated during the lecture.

Literature

Available online

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>227-0965-00L</td>
<td>Micro and Nano-Tomography of Biological Tissues</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Stampanoni, F. Marone Welford</td>
</tr>
<tr>
<td>Abstract</td>
<td>The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.</td>
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<td>Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.</td>
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<td>Content</td>
<td>Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.</td>
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<tbody>
<tr>
<td>376-1103-00L</td>
<td>Frontiers in Nanotechnology</td>
<td>W</td>
<td>4 credits</td>
<td>4V</td>
<td>V. Vogel, further lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.</td>
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<tr>
<td>Objective</td>
<td>Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within mammade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.</td>
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<tr>
<td>Content</td>
<td>The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.</td>
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</table>

Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

<table>
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<td>376-1714-00L</td>
<td>Biocompatible Materials</td>
<td>W</td>
<td>4 credits</td>
<td>3V</td>
<td>K. Maniura, M. Rottmar, M. Zenobi-Wong</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.</td>
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<tr>
<td>Objective</td>
<td>The course covers the following topics: 1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials. 2. The concept of biocompatibility. 3. Introduction into methodology used in biomaterials research and application. 4. Introduction to different material classes in use for medical applications.</td>
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<tr>
<td>Content</td>
<td>Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed. A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.</td>
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</table>
Biomedical Engineering and Biotechnology W 4 credits 3V M. Fussenegger

Abstract
Biomedical Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective
Biomedical Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content

Lecture notes
Handout during the course.

Practical Work

<table>
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<tr>
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Abstract
The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialization. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

Objective
The practical work is aimed at training the student’s capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.

Electives

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Abstract
Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Objective
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

Content
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microrobots

Lecture notes
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

Prerequisites / notice
The lecture will be taught in English.

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Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs.

In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

Content
History of BME and the role of biomedical engineers. Ethical issues related to BME. Biomedical sensors both wearable and also biochemical sensors. Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices. Bioinformatics: genomic and proteomic tools, databases and basic calculations. Equations describing basic reactions and enzyme kinetics. Medical optics: Optical components and systems used in hospitals. Basic concepts of tissue engineering and organ printing. Biomaterials and their medical applications. Function of the heart and the circulatory system. Transport and exchange of substances in the human body, compartment modeling. The respiratory system. Bioimaging. Orthopedic biomechanics. Lectures (2h), discussion of practical exercises (1h) and homework exercises.
Introduction to Biomedical Engineering
by Enderle, Banchard, and Bronzino

AND

Prerequisites / notice
No specific requirements, BUT
HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.).

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
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- Negotiation

Personal Competencies
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- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Prerequisites / notice
No special requirements are needed for attending. Basic knowledge in chemistry and cell biology is expected.

Abstract
The course addresses undergraduate and graduate students interested in getting introduced into the basic concepts of biomineralization.

Objective
The course aims to introduce the basic concepts of biomineralization and the underlying principles, such as supersaturation, nucleation and growth of minerals, the interaction of biomolecules with mineral surfaces, and cell biology of inorganic materials creation. An important part of this class is the independent study and the presentation of original literature from the field.

Content
Biomineralization is a multidisciplinary field. Topics dealing with biology, molecular and cell biology, solid state physics, mineralogy, crystallography, organic and physical chemistry, biochemistry, dentistry, oceanography, geology, etc. are addressed. The course covers definition and general concepts of biomineralization (BM)/types of biominerals and their function/crystal nucleation and growth/biological induction of BM/control of crystal morphology, habit, shape and orientation by organisms/strategies of compartmentalization/the interface between biomolecules (peptides, polysaccharides) and the mineral phase/modern experimental methods for studying BM phenomena/inter-, intra-, extra- and epicellular BM/organic templates and matrices for BM/structure of bone, teeth (vertebrates and invertebrates) and mollusk shells/calcification/silification in diatoms, radiolaria and plants/calcium and iron storage/impact of BM on lithosphere and atmosphere/evolution/taxonomy of organisms.

1. Introduction and overview
2. Biominerals and their functions
3. Chemical control of biomineralization
4. Control of morphology: Organic templates and additives
5. Modern methods of investigation of BM
6. BM in matrices: bone and nacre
7. Vertebrate teeth
8. Invertebrate teeth
9. BM within vesicles: calcite of coccoliths
10. Silica
11. Iron storage and mineralization

Lecture notes
Script with more than 600 pages with many illustrations will be distributed free of charge.

Prerequisites / notice
No special requirements are needed for attending. Basic knowledge in chemistry and cell biology is expected.

Abstract
The goal of this course is to teach MSc students the necessary skills for doing research in the fields of tissue engineering and regenerative medicine.

Objective
Practical exercises on topics including sterile cell culture, light microscopy and histology, and biomaterials are covered. Practical work on 1) S. Mann, Biomineralization, Oxford University Press, 2001, Oxford, New York
3) P. M. Dove, J. J. DeYoreo, S. Weiner (Eds.) Biomineralization, Reviews in Mineralogy & Geochemistry Vol. 54, 2003

Prerequisites / notice
No special requirements are needed for attending. Basic knowledge in chemistry and cell biology is expected.

Abstract
Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.
Analytical Competencies

The students gain an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxodic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure’s shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X-rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams on some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue’s anisotropies of biopsies.

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Further references will be provided in the course.

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Lecture topics:

1. Introduction
2. Membrane and Transport
3-4. Action potential and Hodgkin-Huxley

Measuring bioelectronic signals

5. Detection and Noise
6. Measuring currents in solutions, nanopore sensing and patch clamp pipettes
7. Measuring potentials in solution and core conductance model
8. Measuring electronic signals with wearable electronics, ECG, EEG
9. Measuring mechanical signals with bioelectronics

In vivo stimulation and recording

10. Functional electric stimulation
11. In vivo electrophysiology

Optical recording and control of neurons (optogenetics)

12. Measuring neurons optically, fundamentals of optical microscopy
13. Fluorescent probes and scanning microscopy, optogenetics, in vivo microscopy

14. Measuring biochemical signals

Lecture notes
A detailed script is provided to each lecture including the exercises and their solutions.

Literature
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites / notice
The course requires an open attitude to the interdisciplinary approach of bioelectronics.
In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).

Competencies

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465-0970-00L Image Guided Medical Interventions

Abstract
Computer assistance and robotics have entered many fields of interventional medicine, shaping the way high-precision procedures are performed today. In this lecture series, we will present the methods and technologies used in image-guided radiotherapy, from the use of medical images to model the patient's anatomy to intraoperative navigation and registration.

Objective
Upon completion of the course, students are able to explain the methods and technologies for image guidance and stereotactic radiotherapy. In particular, they are able to design the calibration of in-room imaging solutions and other navigation systems to verify and correct patient position in high-precision radiotherapy. In addition, they are familiar with common tools used in medical image processing research.

Content
Basics of imaging and image processing for IGRT:
* 3D/4D imaging.
* Segmentation (thresholding, region growing and similar).
* Filtering (morphological filters and similar fundamentals).
* Modelling and rendering of volumes and surfaces.
* Image registration.
* Conventions for position and orientation representation.

Technologies and methods for localisation and navigation:
* Reference systems mapping.
* Kinematic of a robotic treatment couch.
* Optical tracking systems, calibration and use.
* Registration of points and surfaces.
* In-room imaging and geometry calibration of X-ray systems.
* 2D/3D and 3D/3D registration.
* Organ motion.

Technologies and methods for on-line treatment verification
* In-room imaging for verification of proton therapy treatment

If you like playing with medical imaging and computer vision tools, you could be interested in this course.

_major in bioelectronics_
### Core Courses

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- Scaling laws at micro/nano scales  
- Electrostatics  
- Electromagnetism  
- Low Reynolds number flows  
- Observation tools  
- Materials and fabrication methods  
- Applications of biomedical microrobots |

Lecture notes  
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The lecture will be taught in English.

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Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices.  
Bioinformatics: genomic and proteomic tools, databases and basic calculations.  
Equations describing basic reactions and enzyme kinetics.  
Medical optics: Optical components and systems used in hospitals.  
Basic concepts of tissue engineering and organ printing.  
Biomaterials and their medical applications.  
Function of the heart and the circulatory system.  
Transport and exchange of substances in the human body, compartment modeling.  
The respiratory system.  
Bioimaging.  
Orthopedic biomechanics.  
Lectures (2h), discussion of practical exercises (1h) and homework exercises. |

Lecture notes  
Introduction to Biomedical Engineering  
by Enderle, Banchard, and Bronzino

AND  
moodle page of the course

Prerequisites / notice  
No specific requirements, BUT  
ITET, MAVT, PHYs students will have to learn a lot of new words related to biochemistry, biology and medicine, while HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.).

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The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.

Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocrucules of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.
Practical Work

<table>
<thead>
<tr>
<th>Number</th>
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<td>Practical Work</td>
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Objective: The practical work is aimed at training the student's capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.

Electives

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<tr>
<th>Number</th>
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<tr>
<td>227-1033-00L</td>
<td>Neuromorphic Engineering I</td>
<td>W</td>
<td>6</td>
<td>2V+3U</td>
<td>T. Deibrück, G. Indiveri, S.-C. Liu, M. Payvand</td>
</tr>
</tbody>
</table>

Objective: Understanding the characteristics of neuromorphic circuit elements.

Content: Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

Physical Modelling and Simulation

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<tr>
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<tr>
<td>227-2037-00L</td>
<td>Physical Modelling and Simulation</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>J. Smajic</td>
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</table>

Objective: Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.
The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or choose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

376-1103-00L

Frontiers in Nanotechnology

W 4 credits 4V V. Vogel, further lecturers

Abstract

Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.

Objective

Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within mammalian and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the-art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

Content

Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging techniques that will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

Lecture notes

All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typcial 1-2 journal articles per lecture that cover selected topics.

402-0674-00L

Physics in Medical Research: From Atoms to Cells

W 6 credits 2V+1U B. K. R. Müller

Abstract

Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.

The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocite behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting,oxic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often qualitatively characterized by photons with a broad range of wavelengths from ultraviolet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

529-0837-01L

Biomicrofluidic Engineering

W 6 credits 3G A. de Mello

Abstract

Microfluidics describes the behaviour, control and manipulation of fluids geometrically constrained within sub-uL environments. Microfluidic devices enable physical and chemical processes to be controlled with exquisite precision and in an fast and efficient manner. This course introduces the underlying concepts, features and applications of microfluidic systems in the chemical and life sciences.

We will investigate the theoretical concepts behind microfluidic device operation, the methods of microfluidic device manufacture and the application of microfluidic architectures to important problems faced in modern day chemical and biological analysis.

A central component of this course is a research project. This will allow students to develop a practical understanding of the benefits of miniaturization in chemical and biological experimentation. Projects will be performed in groups of between four and six students and will include both experimental and simulation aspects. Each group, under the guidance of a mentor, will plan and execute a novel research project. The results of this activity will be disseminated through an "academic-style" research article and a "conference-style" oral presentation. Course grades will be evaluated through both a written exam and the project grade.
Content

Specific topics covered in the course include, but are not limited to:

1. Theoretical Concepts
Scaling laws, features of thermal/mass transport, diffusion, basic description of fluid flow in small volumes, microfluidic mixing strategies.

2. Microfluidic Device Manufacture
Basic principles of conventional lithography of rigid materials, ‘soft’ lithography, polymer machining (injection molding, hot embossing, and 3D-printing).

3. Electrokinetics
Principles of electrophoresis, electroosmosis, high performance capillary electrophoresis, electrokinetic scaling laws, chip-based electrophoresis and isoelectric focusing.

4. Mass Transfer Phenomena
Key features of mass transport in microfluidic systems, diffusive transport, diffusion-convection, Péclet number, Taylor-Aris diffusion, chaotic mixing and Damköhler numbers.

5. Heat Transfer Phenomena
Key features of thermal transport in microfluidic systems, conduction, convection, heat transfer by convection in internal flows, heat transfer processes in microfluidic devices.

6. Microfluidic Systems for Materials Synthesis
Microfluidic reactors for the controlled synthesis of colloidal nanomaterials, advanced automation for bespoke materials discovery & characterization.

7. Point-of-Care Diagnostics
Microscale tools for diagnostics, challenges associated with point-of-care (PoC) diagnostic testing, requirements for PoC devices, common PoC device formats, applications of PoC diagnostics in the developing world.

8. Microscale DNA Amplification
Amplification and analysis of nucleic acids using batch, continuous flow and droplet-based microfluidic reactors.

9. Small volume Molecular Detection
Spectroscopic approaches for analyte detection in small volumes with a particular focus on single molecule detection.

10. Droplets and Segmented Flows
Formation, manipulation and use of liquid/liquid segmented flows in chemical and biological experimentation.

11. Single Cell Analysis
Applications of microfluidic tools in cellular analysis, flow cytometry, enzymatic assays and single cell analysis.

Lecture notes
Lecture handouts, background literature, problem sheets and notes will be provided electronically through the course Moodle site.

Literature
There is no set text for the course. All relevant literature will be provided electronically through the course Moodle site.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<td>Communication</td>
<td>Adaptability and Flexibility</td>
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636-0108-00L  Biological Engineering and Biotechnology  6 credits  W  3V  M. Payvand

Abstract
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content

Lecture notes
Handout during the course.

Major in Neuroinformatics

Core Courses

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>227-1037-00L</td>
<td>Introduction to Neuroinformatics</td>
<td>W</td>
<td>6</td>
<td>2V+1U+1A</td>
<td>V. Mante, B. Grewe, G. Indiveri, M. Payvand</td>
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</tbody>
</table>

Abstract
The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.
**Objective**
Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

**Content**
This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.

**Abstract**
The course introduces bioelectricity and the sensing concepts that enable obtaining information about neurons and their networks. The sources of electrical fields and currents in the context of biological systems are discussed. The fundamental concepts and challenges of measuring bioelectric signals and the basic concepts to record optogenetically modified organisms are introduced.

**Objective**
During this course the students will:
- learn the basic concepts in bioelectronics including the sources of bioelectric signals and the methods to measure them
- be able to solve typical problems in bioelectronics
- learn about the remaining challenges in this field

**Content**
Lecture topics:

1. Introduction
   Sources of bioelectric signals

2. Membrane and Transport
   3-4. Action potential and Hodgkin-Huxley

Measuring bioelectric signals

5. Detection and Noise
6. Measuring currents in solutions, nanopore sensing and patch clamp pipettes
7. Measuring potentials in solution and core conductance model
8. Measuring electronic signals with wearable electronics, ECG, EEG
9. Measuring mechanical signals with bioelectronics

In vivo stimulation and recording

10. Functional electric stimulation
11. In vivo electrophysiology

Optical recording and control of neurons (optogenetics)

12. Measuring neurons optically, fundamentals of optical microscopy
13. Fluorescent probes and scanning microscopy, optogenetics, in vivo microscopy

14. Measuring biochemical signals

**Lecture notes**
A detailed script is provided to each lecture including the exercises and their solutions.

**Literature**
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

**Prerequisites / notice**
The course requires an open attitude to the interdisciplinary approach of bioelectronics. In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).

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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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**227-0393-10L Bioelectronics and Biosensors**

<table>
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<td>Measuring bioelectric signals</td>
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<tr>
<td>2V+2U</td>
<td>Measuring currents in solutions, nanopore sensing and patch clamp pipettes</td>
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<td>J. Vörös, M. F. Yanik</td>
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**227-0421-00L Learning in Deep Artificial and Biological Neuronal Networks**

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</table>
Deep-Learning (DL) a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods.

The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialization. Tuors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

The practical work is aimed at training the student’s capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.

This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:

1) The number of participants is limited to 120 students (MSc and PhDs).

2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

Prerequisites:
- Background in basics of semiconductor physics helpful, but not required.
- Enrolment to this course unit only possible at ETH. No external organisers.
- Please mind the ETH enrolment deadlines for UZH students: https://ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html

Objective

The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today’s neuroscience papers.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today's neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to 'error backpropagation' in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

Content

Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al, 2015, Silver et al., 2018), ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

Abstract

Practical Work

Prerequisites /
notice

Content

Objective

Prerequisites /
notice

Literature

Prerequisites:

Neuromorphic Engineering I

Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialization. Tuors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

The practical work is aimed at training the student’s capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.

Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time simulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (diifferential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, analog to digital converters), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:

1) The number of participants is limited to 120 students (MSc and PhDs).

2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

Prerequisites:
- Background in basics of semiconductor physics helpful, but not required.

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Prerequisites:
- Background in basics of semiconductor physics helpful, but not required.

Prerequisites:
- Background in basics of semiconductor physics helpful, but not required.
Introduction to the corresponding module directly at UZH as an incoming student.

UZH Module Code: SPV0Y005

Mind the enrolment deadlines at UZH:

Abstract
The course gives an introduction to human and comparative neuroanatomy, molecular, cellular and systems neuroscience.

Objective
The course gives an introduction to the development and anatomical structure of nervous systems. Furthermore, it discusses the basics of cellular neurophysiology and neuropharmacology. Finally, the nervous system is described on a system level.

Content
1) Human Neuroanatomy I&II
2) Comparative Neuroanatomy
3) Building a central nervous system I,II
4) Synapses I,II
5) Glia and more
6) Excitability
7) Circuits underlying Emotion
8) Visual System
9) Auditory & Vestibular System
10) Somatosensory and Motor Systems
11) Learning in artificial and biological neural networks

Prerequisites / notice
For doctoral students of the Neuroscience Center Zurich (ZNZ).

227-0965-00L Micro and Nano-Tomography of Biological Tissues

Abstract
The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

Objective
Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

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Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

Practical Work

The goal of this course is to teach MSc students the necessary skills for doing research in the fields of tissue engineering and regenerative medicine.

Practical exercises on topics including sterile cell culture, light microscopy and histology, and biomaterials are covered. Practical work on manufacturing and evaluating hydrogels and scaffolds for tissue engineering will be performed in small groups. In additional to practical lab work, the course will teach skills in data acquisition/analysis.

The practical work is aimed at training the student's capability to apply and connect specific skills acquired during the MAS specialization. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Prerequisites

A laptop is needed with the below Systems Requirements:
- Memory: 16 GB
- Processor: 3rd gen i7
- DirectX® 11.0 compliant AMD Radeon/NVIDIA® GeForce® card with 2 GB RAM
- Storage: 15 GB

Mac computer can be used by pre-installing Windows through bootcamp (older Macs) or Parallels Desktop (14d trial license, 35 CHF license purchasable in the IT shop of ETH).

Practical Work

### 376-1622-00L Practical Methods in Tissue Engineering

- **W 5 credits 4P**
- **Lecturers**: M. Zenobi-Wong, S. J. Ferguson, S. Grad, S. Schürle-Finke

**Abstract**

The goal of this course is to teach MSc students the necessary skills for doing research in the fields of tissue engineering and regenerative medicine.

**Objective**

Practical exercises on topics including sterile cell culture, light microscopy and histology, and biomaterials are covered. Practical work on manufacturing and evaluating hydrogels and scaffolds for tissue engineering will be performed in small groups. In additional to practical lab work, the course will teach skills in data acquisition/analysis.

**Prerequisites / notice**

A laptop is needed with the below Systems Requirements:
- Memory: 16 GB
- Processor: 3rd gen i7
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### 376-1714-00L Biocompatible Materials

- **W 4 credits 3V**
- **Lecturers**: K. Maniura, M. Rottmar, M. Zenobi-Wong

**Abstract**

Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

**Objective**

The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

**Content**

Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Lecture notes**

Handouts are deposited online (moodle).

**Literature**


(available online via ETH library)

Handouts and references therin.

Electives

### 327-1101-00L Biomineralization

- **W 2 credits 2V**
- **Lecturers**: K.-H. Ernst

**Abstract**

The course addresses undergraduate and graduate students interested in getting introduced into the basic concepts of biomineralization.

The course aims to introduce the basic concepts of biomineralization and the underlying principles, such as supersaturation, nucleation and growth of minerals, the interaction of biomolecules with mineral surfaces, and cell biology of inorganic materials creation. An important part of this class is the independent study and the presentation of original literature from the field.
Biomineralization is a multidisciplinary field. Topics dealing with biology, molecular and cell biology, solid state physics, mineralogy, crystallography, organic and physical chemistry, biochemistry, dentistry, oceanography, geology, etc. are addressed. The course covers definition and general concepts of biomineralization (BM) / types of biominerals and their function / crystal nucleation and growth / biological induction of BM / control of crystal morphology, habit, shape and orientation by organisms / strategies of compartmentalization / the interface between biomolecules (peptides, polysaccharides) and the mineral phase / modern experimental methods for studying BM phenomena / inter-, intra-, extra- and epicellular BM / organic templates and matrices for BM / structure of bone, teeth (vertebrates and invertebrates) and mollusk shells / calcification / silification in diatoms, radiolaria and plants / calcium and iron storage / impact of BM on lithosphere and atmosphere / evolution / taxonomy of organisms.

1. Introduction and overview
2. Biominerals and their functions
3. Chemical control of biomineralization
4. Control of morphology: Organic templates and additives
5. Modern methods of investigation of BM
6. BM in matrices: bone and nacre
7. Vertebrate teeth
8. Invertebrate teeth
9. BM within vesicles: calcite of coccoliths
10. Silica
11. Iron storage and mineralization

Lecture notes
Script with more than 600 pages with many illustrations will be distributed free of charge.

Literature
3) P. M. Dove, J. J. DeYoreo, S. Weiner (Eds.) Biomineralization, Reviews in Mineralogy & Geochemistry Vol. 54, 2003

Prerequisites / notice
No special requirements are needed for attending. Basic knowledge in chemistry and cell biology is expected.
Objective

The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

Abstract

The course introduces bioelectricity and the sensing concepts that enable obtaining information about neurons and their networks. The sources of electrical fields and currents in the context of biological systems are discussed. The fundamental concepts and challenges of measuring bioelectronic signals and the basic concepts to record optogenetically modified organisms are introduced.

During this course the students will:
- learn the basic concepts in bioelectronics including the sources of bioelectronic signals and the methods to measure them
- be able to solve typical problems in bioelectronics
- learn about the remaining challenges in this field

Content

Lecture topics:

1. Introduction
2. Sources of bioelectric signals
3-4. Action potential and Hodgkin-Huxley
5. Measuring bioelectric signals
6. Detection and Noise
7. Measuring currents in solutions, nanopore sensing and patch clamp pipettes
8. Measuring potentials in solution and core conductance model
9. Measuring mechanical signals with bioelectronics

In vivo stimulation and recording
10. Functional electric stimulation
11. In vivo electrophysiology

Optical recording and control of neurons (optogenetics)
12. Measuring neurons optically, fundamentals of optical microscopy
13. Fluorescent probes and scanning microscopy, optogenetics, in vivo microscopy

14. Measuring biochemical signals

Lecture notes

A detailed script is provided to each lecture including the exercises and their solutions.

Literature

Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites / notice

The course requires an open attitude to the interdisciplinary approach of bioelectronics. In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).
### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### Abstract

**Nanostructured Materials Safety**

**Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection**

**Objective**

Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials

**Content**

Building upon new technologies to engineer and functionalize well-defined nanostructured materials, a plethora of exciting discoveries were made and found their way in our daily life. These customized nanomaterials provides extraordinary properties and make them attractive for many innovative applications. Exactly these new properties may have the potential to be responsible for unforeseen side effects, which hamper a straightforward translation into new products. Therefore, the safety research provide the evidence for a responsible and sustainable use of nanomaterials.

The lecture will focus on basic principles of nanotoxicology, provide the understanding of the potential side effects of nanomaterial in a context-specific way addressing the main exposure routes such as inhalation, ingestion, topical applications and intravenous injections as well as it will provide impulses for safer material designs.

**Structure of the planned lecture (2 x 45 min)**

1. Introduction: the principles of nanotoxicology
2. Lung- particles interactions: two disease scenarios and their molecular mechanism
3. GI – particles interactions: intendent and unintendent particle exposure via food
4. Skin – particles interactions: body care products and their influence on skin physiology
5. intravenous injection: colloidal stability, protein corona and cellular effects
6. Micro- / Nanoplastics and development of a safety research plan
7. End of semester exam

### Lecture notes

Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website

### Prerequisites / notice

course “Introduction to Toxicology”

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**Bone Biology: Basics, Research and Clinics**

**Abstract**

The course gives an introduction into bone biology and provides an overview on current research methods and clinical approaches. Emphasis is put on skeletal development and metabolism, osteoporosis as well as fracture healing. Each topic is structured into three parts: basics, research and clinics.

**Objective**

After completing the Bone Biology course, students will be able to:

1. Remember and apply basics in bone biology and disease
2. Remember clinical features and surgical approaches
3. Select adequate research methods and approaches
4. Evaluate publications on topics presented in the lecture

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**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: fostered
- Decision-making: fostered
- Problem-solving: fostered
- Project Management: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered

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**Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1708 of 2653**
The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

<table>
<thead>
<tr>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computational Biology</td>
<td>W</td>
<td>6</td>
<td>3G+2A</td>
<td>T. Vaughan, C. Magnus, T. Stadler</td>
</tr>
</tbody>
</table>

**Abstract**

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

**Objective**

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

- epidemiology
- pathogen evolution
- macroevolution of species

**Content**

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

**Lecture notes**

Lecture slides will be available on moodle.

**Literature**

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

- *Yang, Z. 2006. Computational Molecular Evolution.*
- *Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.*

**Prerequisites / notice**

Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place in Basel before the start of the semester.

**Competencies**

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<td>Media and Digital Technologies</td>
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**Social Competencies**

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### Practical Work

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<tr>
<td>465-0800-00L</td>
<td>Practical Work</td>
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<td>4</td>
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<td>external organisers</td>
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</table>

**Abstract**

The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialization. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

**Objective**

The practical work is aimed at training the student’s capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.

### Electives

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<tr>
<th>Number</th>
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<tr>
<td>327-1101-00L</td>
<td>Biomineralization</td>
<td>W</td>
<td>2</td>
<td></td>
<td>K.-H. Ernst</td>
</tr>
</tbody>
</table>

**Abstract**

The course addresses undergraduate and graduate students interested in getting introduced into the basic concepts of biomineralization.
The course aims to introduce the basic concepts of biomineralization and the underlying principles, such as supersaturation, nucleation and growth of minerals, the interaction of biomolecules with mineral surfaces, and cell biology of inorganic materials creation. An important part of this class is the independent study and the presentation of original literature from the field.

### Content

Biomineralization is a multidisciplinary field. Topics dealing with biology, molecular and cell biology, solid state physics, mineralogy, crystallography, organic and physical chemistry, biochemistry, dentistry, oceanography, geology, etc. are addressed. The course covers definition and general concepts of biomineralization (BM) / types of biominerals and their function / crystal nucleation and growth / biological induction of BM / control of crystal morphology, habit, shape and orientation by organisms / strategies of compartmentalization / the interface between biomolecules (peptides, polysaccharides) and the mineral phase / modern experimental methods for studying BM phenomena / inter-, intra, extra- and epicellular BM / organic templates and matrices for BM / structure of bone, teeth (vertebrates and invertebrates) and mollusk shells / calcification / silification in diatoms, radiolarians and plants / calcium and iron storage / impact of BM on lithosphere and atmosphere / evolution / taxonomy of organisms.

1. Introduction and overview
2. Biominerals and their functions
3. Chemical control of biomineralization
4. Control of morphology: Organic templates and additives
5. Modern methods of investigation of BM
6. BM in matrices: bone and nacre
7. Vertebrate teeth
8. Invertebrate teeth
9. BM within vesicles: calcite of coccoliths
10. Silica
11. Iron storage and mineralization

### Lecture notes

Script with more than 600 pages with many illustrations will be distributed free of charge.

### Literature


### Prerequisites / notice

No special requirements are needed for attending. Basic knowledge in chemistry and cell biology is expected.

### Course Details

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<th>Course Code</th>
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<th>Credits</th>
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<tbody>
<tr>
<td>376-1103-00L</td>
<td>Frontiers in Nanotechnology</td>
<td>6 credits</td>
<td>Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers. Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within manmade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies. The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries. Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations. Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges. All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.</td>
</tr>
<tr>
<td>402-0674-00L</td>
<td>Physics in Medical Research: From Atoms to Cells</td>
<td>6 credits</td>
<td>Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.</td>
</tr>
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</table>
Objective

The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X-rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

<table>
<thead>
<tr>
<th>535-0423-00L</th>
<th>Drug Delivery and Drug Targeting</th>
<th>W</th>
<th>2 credits</th>
<th>1.5V</th>
<th>J.-C. Leroux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria. The students dispose of an overview on current principles and systems for the controlled delivery and targeting of drugs. The focus of the course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines. The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems. Constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines. Selected lecture notes, documents and supporting material will be directly provided or may be downloaded from the course website.</td>
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Further references will be provided in the course.

<table>
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<tr>
<th>551-0307-00L</th>
<th>Molecular and Structural Biology I: Protein Structure and Function</th>
<th>W</th>
<th>3 credits</th>
<th>2V</th>
<th>R. Glockshuber, K. Locher, E. Weber-Ban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNA, current topics in protein biophysics and structural biology. Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics. Scripts on the individual topics can be found under <a href="http://www.mol.biol.ethz.ch/teaching">http://www.mol.biol.ethz.ch/teaching</a>.</td>
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Abstract
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective
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Content

Lecture notes
Handout during the course.
MAS in Future Transport Systems
Four-semester, part-time MAS programme.


Major in Systemic Aspects of Future Transport
The Major in "Systemic Aspects of Future Transport" takes place every 1.5 years according to the program website.

Course duration: Six months part time

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<tr>
<td>166-0100-00L</td>
<td>Transport Systems: Dynamics and Future Developments</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
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</table>

Abstract
Interrelationships and dynamic change and the impact of these on mobility and transportation are being investigated in this module. The module addresses desirable future development of urban transport systems in Switzerland by covering and critically examining authentic, existing transport scenarios (e.g. ARE) in an exercise setting which deploys backcasting.

Objective
Participants
- understand the complexity of the transport system status quo as a whole, and are able to describe it qualitatively and create an operational and/or working context (K1).
- understand the development of transport systems and future transport scenarios over time, and can infer objectives from the latter (K2).
- understand the dynamics between spacial quality and mobility behavior and can evaluate how measures to promote active mobility can contribute to a more sustainable transport system (K3).
- understand how digitalisation drives new mobility services (mobility as a service), and are able to qualitatively estimate the changes these bring to transport systems as a whole (K4).
- are able to pinpoint the challenges and potential of the transition to autonomous transport forms (K5).

Content
- Deepen understanding of complex transport systems and their dynamics past – status quo – future
- Consolidate a foundation in the dynamics of transport systems: elements and their interrelationships
- Overview and selection of methods/approaches for the development and analysis of scenarios
- Future perspectives (ARE), target scenarios
- Transformation and change in systems
- Transport policy and the potential of regulation
- Excursion: "Infrastructure to support active mobility: Bike capital Bern"

Methods selected
- System analysis, scenario analysis, foresight, indicators for sustainable mobility, Case studies, reading and discussion of thesis papers and scientific publications

Lecture notes Distributed at start of module
Literature Distributed at start of module
Prerequisites / notice Announced to students of the of the MAS / CAS at the beginning of the term

166-0101-00L Development and Assessment of Transport Scenarios O 3 credits 3G

Abstract
This module familiarises participants with current methods of developing and evaluating transport scenarios. These include analysis of the interrelationship of space and traffic; traffic modelling methods; and evaluation according to economic and planning criteria.

Objective
Participants
- are familiar with suitable methods for developing transport scenarios and how to analyse and evaluate them. In particular, they know how to address the challenges of evaluating future forms of transport;
- are able to select a suitable method and determine an evaluation concept with relation to a specific problem.

Content
- Methodological foundations of traffic modelling (44-level model, activity-based model, agent-based simulation)
- Design and evaluation of transport scenarios using MATSim (traffic simulation) with a focus on transport with autonomous vehicles
- Interrelationship of space and traffic (accessibility measurement, settlement density and mixed usage) and what to consider in designing and evaluating transport scenarios
- Approaches to evaluation of traffic scenarios (cost-benefit analyses and their foundations, methodological limits), analysis of effects taking into account user group and space type
- Ecobalancing with Life Cycle Assessment (LCA) in addressing passenger and goods transport issues
- Development of case studies on shared transport and mobility with an activity- and agent-based transport simulation model

Methods
- Aggregated and activity-based transport demand models
- Agent-based simulation
- Cost-benefit analysis
- Accessibility analysis

Case studies
- Shared mobility
- Autonomous mobility
- Densified settlement development and slow forms of mobility

Lecture notes Distributed at start of module
Literature Distributed at start of module
Prerequisites / notice Announced to students of the of the MAS / CAS at the beginning of the term.
Participants are able...

- to understand the economic and social-sciences fundamentals of innovation and change processes in the area of transportation;
- to analyse the foundations, opportunities and challenges of disruption in mobility systems;
- to set this concepts and frameworks in context to pathways towards more sustainable mobility;
- and to set these concepts and frameworks constructively in context to their own work practice.

In this module, innovation, change and transitions in transportation systems on different levels are discussed from different complementary perspectives. Both economic and social science approaches to the analysis, anticipation and governance of innovation processes are presented, discussed and applied to current issues. Topics are:
- Respective theories and methods;
- Innovation as an economic discovery process, measuring innovation;
- Emerging trends as new opportunities for innovation;
- Innovation today in the transportation/mobility system: theoretical basis and concrete examples;
- Transition of socio-technical systems, co-evolution of technical and societal dynamics;
- The relevance of social acceptance and ethical aspects for innovations in mobility.

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the of the MAS / CAS at the beginning of the term

166-0103-00L  System Aspects of Air and Shipping Traffic  ■  O  3 credits  2G  to be announced

Abstract
Air and shipping traffic cover a substantial part of human mobility, air traffic in passenger as well as freight transport, shipping mainly in freight transport. Students gain an overview, limit modes of mobility and learn to classify air and shipping traffic in the overall system of mobility.

Objective
Participants
- know the fundamental differences between air, shipping traffic compared to motorized individual transport and public transport.
- are able to deduce differences between air and shipping traffic.
- know the possibilities and limits as well as pros and cons of different valuation methods used for air and shipping transport.
- develop ideas for suitable indicators to evaluate scenarios in air and shipping traffic.

Content
- Key figures, development and trends in air and shipping traffic.
- Potentials for holistic improvement in air and shipping traffic.
- Life Cycle Assessment (LCA) for questions in air and shipping traffic.
- Overview on technologies and their potentials to improve sustainability in air and shipping transport.
- Berechnung und Interpretation von Kennzahlen.

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the of the MAS/CAS at the beginning of the term

166-0190-00L  CAS Thesis on System Aspects  ■  O  3 credits  5D  C. Onder, to be announced

Abstract
The participants deal with a current problem from the topics of CAS System Aspects.

Objective
Participants
- Deal with a specific problem from the CAS System Aspects subject area.
- Deepen selected content from module independently
- Be able to work interdisciplinary and across sectors, where appropriate together with relevant other parties.
- Communicate the results appropriately.

Content
In der CAS-Arbeit zeigen die Studierenden, dass sie in der Lage sind, eine fundiert aufbereitete Auseinandersetzung mit technischen und nicht-technischen Entwicklungen im Mobilitätssektor aufzubauen und zu analysieren. Die Teilnehmenden setzen sich dabei aktiv mit aktuellen und/oder zukünftig erwarteten Entwicklungen im Mobilitätssektor auseinander, übersetzen mögliche Entwicklungen in verkehrliche Parameter (=Zukunft der Mobilität); greifen auf Lerninhalte des Studiums zurück; entwickeln ausgewählte Themen selbständig weiter (bzw. im Rahmen einer Arbeitsgruppe) und setzen sich mit der Relevanz für die Praxis auseinander (Relevanz für Stakeholdergruppen wie z.B. politische Entscheidungsträger, Verkehrsuntemnehmen, Industrie, Umweltverbände, Energieversorger sowie auch andere gesellschaftliche Gruppen, z.B. für Menschen im Rentenalter).

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the of the MAS / CAS at the beginning of the term

▶ Major in Technology Potential

The Major in "Major in Technology Potential" takes place every 1.5 years according to the program website.

Course duration: Six months part time

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>166-0200-00L</td>
<td>Technology Potential: Powertrain, Systems and Energy Carriers</td>
<td>O</td>
<td>3.5</td>
<td>3G</td>
<td>C. Onder</td>
</tr>
</tbody>
</table>

Abstract
The module provides a foundation in the current situation and short- and middle-term development directions of powertrain and automotive engineering in the context of passenger & goods transport. Corresponding energy sources and resulting consequences for the energy system are addressed. Participants will be enabled to identify potentials of these technologies and apply them to concrete problems.

Objective
Familiarity with conventional and alternative powertrain and automotive systems for future sustainable mobility, and the ability to identify and deploy their potential to address concrete problems.

Content
- Drive component efficiency rates and core fields
- Drive and non-drive energy flow / Vehicle "driving resistance"
- Energy chains (operating power only) and CO2 emissions to primary energy

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the of the MAS / CAS at the beginning of the term

166-0201-00L  Potential of Spatial Information- and Communication Technologies  ■  O  3 credits  3G  M. Raubal

Announced to students of the of the MAS / CAS at the beginning of the term.
Abstract
The digital revolution, spatial information and communication systems in particular, have a significant influence on the development of new transport systems. Participants acquire an in-depth understanding of the functionality and application potential of spatial information systems and services and of communication technologies for deployment in future transport systems and applications.

Objective
Familiarity with information and communication technologies (ICT) and spatial information technologies, and the ability to identify and utilise their potential to address concrete problems.

Content
- Functionality and application of geographic information systems (GIS) to represent and analyse transport systems (acquire, model, analyse and visualise geodata)
- Deployment potentials of GIS and ICT for efficient transport solutions (tangible, non-tangible)
- Functionality and application of mobile spatial information technologies in future transport systems
- Methods of spatiotemporal analysis and geodata analysis
- Technical aspects of information and communication technologies (ICT)
- Modelling, simulation and assessment of traffic behaviour
- Basics of autonomous driving
- Legal aspects of geodata
- Applications: Traffic behaviour in Switzerland; location based services for energy-efficient behaviour; GIS for the Zurich traffic system (multimodal)

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the of the MAS / CAS at the beginning of the term.

166-0202-00L Integrated Assessment of Technologies and Transport Systems O 2 credits 1G

Abstract
The module provides a solid introduction to integrated technology assessment with regard to economic, ecological and social criteria. It introduces life cycle assessment (LCA), cost assessment, risk assessment and multi-criteria decision analysis. It also presents scenario analyses based upon energy-economic models which explicitly represent transport and energy-supply technologies.

Objective
An overview of suitable methods for analysing and evaluating technical systems (transport systems) and the ability to choose among them to address concrete problems

Content
(1) Introduction to and overview of integrated assessment
- Current status of transport in Switzerland and internationally
- Scope and goals of integrated assessment
- Sustainability: concept and practical implementation via criteria and indicators
- Overview of concepts and implementation methods

(2) Selected methods for assessing transport technologies and their application to current and future options
- Ecobalance / life cycle assessment (LCA)
- Location-specific assessment of health hazards and environmental pollution
- Risk analysis
- Internal cost assessment
- External cost assessment

(3) Integrated assessment of transport technologies
- Overall costs (internal and external)
- Multi-criteria analysis

(4) Analysis of transport scenarios
- Scenarios, influencing factors, policy and sustainability
- Approaches to scenario modelling
- Global mobility scenarios: examples
- Transport scenarios for Switzerland using energy system models

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the of the MAS / CAS at the beginning of the term

166-0203-00L Energy Carrier for the Mobility of the Future O 3 credits 3G

Abstract
The module includes the supply of the road mobility of the future with renewable energy. The generation, transport, processing, transfer of energy to the vehicles (refueling, charging) and the energetic evaluation are presented. Electricity, hydrogen, biogenic and synthetic fuels are considered.

Objective
The aim of the module is a detailed energetic and technical understanding of the supply of road vehicles with renewable energy. Graduates know the primary energy production as well as the end energy processing of the different energy carrier concepts. In addition, they know the legal CO2 requirements for vehicle registration and are able to qualitatively assess the impact on the Swiss energy system.

Content
- The energy system of the future; biogenic and electric renewable primary energy
- End energy processing
- Transfer from the energy system to mobility and influences on the overall energy system

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the of the MAS / CAS at the beginning of the term

166-0290-00L CAS Thesis on Technology Potentials O 3 credits 5D C. Onder

Abstract
The participants, in heterogeneous teams, deal with a current problem from the topics of the CAS Technology Potentials. They are expected to deal with a specific problem from the CAS Technology Potentials subject area, be able to work interdisciplinary and across sectors, where appropriate together with relevant other parties. They should be able to communicate the results appropriately.

Objective
The participants, in heterogeneous teams, deal with a current problem from the topics of the CAS Technology Potentials.

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the of the MAS / CAS at the beginning of the term

Major in New Business Models
The "CAS in Future Transport Systems: New Business Models" takes place every 1.5 years according to the program website.

Course duration: Six months part time

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1715 of 2653
### Framework Conditions and Transport Behaviour

**Number:** 166-0300-00L  
**Title:** Framework Conditions and Transport Behaviour  
**ECTS:** 3.5 credits  
**Hours:** 3G  
**Lecturers:**

**Abstract**  
This module addresses the demand for new business models for future transport systems. Why and in what way do people wish to be mobile? What are the economic, social and legal framework conditions, and how will these develop? What approaches leading to new value propositions will follow?

**Objective**  
Participants
- can tell the difference between drivers of mobility which cannot really change and those which can change;
- are able to identify the effects of path dependence on transport systems and future transport systems;
- are familiar with the socio-psychological factors involved in transport vehicle acquisition and transport behaviour, and can apply them in ideas for new business models;
- are able to judge the significance of travel time, driving time and fixed costs and use this knowledge to identify new business models;
- are able to design incentives which will trigger maximum changes in behaviour and/or facilitate cooperative behaviour;
- are able to embed electric mobility conceptually such that its potential is realised and the associated risks are minimised;
- are familiar with the framework conditions and efficient drivers required to replace overland transport with air transport;
- are able to assemble combinations of political and market instruments on the basis of their efficiency profiles and side-effects in order to realise efficiency potentials and changes in behaviour;
- are able to design policy and market measures in such a way that they minimise rebound effects (including those in connection with automatic and fully autonomous vehicles);
- are able to recognise the properties of automatic and fully autonomous vehicles which are particularly suitable for new business models.

**Content**  
- Why are people mobile? What resources (time, money, space) do they invest in mobility?
- What are the various qualities of transport services (comfort/stress, risk/safety, plannability, multifunctionality)?
- What are the various resource and quality profiles of current transport services, and what mutual dependencies are there?
- What current mobility demands are unsated? Why are they unsated? What future key technologies might change this?
- What current forms of mobility might be substituted by other transport services? If they were substituted, how would the necessary resources and transport service qualities change?

**Methods**  
- Group work (groups of four and groups of two)
- Creative methods for generating value propositions
- Tasks in preparation for the fourth course day: design, implementation and analysis of a small survey of potential target clients regarding a not-yet-existing business model

**Lecture notes**  
Distributed at start of module.

**Literature**  
Distributed at start of module.

**Prerequisites / notice**  
Announced to students of the of the MAS | CAS at the beginning of the term.

### New Business Models for Future Transport Systems

**Number:** 166-0301-00L  
**Title:** New Business Models for Future Transport Systems  
**ECTS:** 3 credits  
**Type:** O  
**Hours:** 2G

**Abstract**  
This module addresses the implementation of (digital) strategies and innovative business models of the future and elucidates the drivers, inhibitors and challenges of business model innovation. Using suitable methods and procedures, participants in the module develop, evaluate and refine prototypes of sustainable future business models.

**Objective**  
Participants
- are able to understand and explain the core issues, concepts and strategies of business model innovation;
- are able to describe the relevance and the process of business model development;
- are able to translate a personally developed business case into a sustainable business model;
- are able to apply suitable design strategies to optimise a personally developed business model;
- are able to appropriately embed new business models into a corporate or business segment strategy;
- are able to assess the strengths, weaknesses, opportunities and risks of a business model;
- are able to convincingly present their own business case / business model in a structured manner to relevant stakeholder groups (investors, board members, clients, partners);
- are able to engage with and develop various points of view to assess business models;
- are able to shape a modelling process for themselves and reflect on it.
Content

Business model innovation:
- Conceptual foundations of business model innovation
- Drivers, inhibitors and challenges of business model innovation
- Business model innovation in established organisations and structures
- Case study and mini cases in the context of transport system / mobility business model innovation

Business modelling (essentials):
- Business model thinking and modelling
- The Business Model Canvas as a conceptual and methodological tool
  - Customer benefits / value propositions
  - Demand side
  - Supply side
- Business model patterns

Business modelling (application)
- Creation of a real business case for business modelling
- Business model prototyping (basis: Business Model Canvas)
- Evaluation and review/re-prototyping of participants' own business cases / business models

Incorporating new business models into corporate / business segment strategies
- Fit with strategic analysis
- Compliance with corporate or business segment strategy
- Contribution to strategy implementation

Presenting business models convincingly (basics/application)
- Basics of business model presentation
- Development of participants' own storylines and presentation structure (business value concept)
- Pitching of own business case / business model

Methods
- Blended learning elements to prepare for classroom sessions
- Case studies and examples; group work (4-person and 2-person groups)
- Classroom discussions to introduce relevant concepts and instruments
- Homework for the 4th and 5th NG-2 course days: Develop a structured presentation of a personally developed business case (business model) for delivery to relevant stakeholder groups (investors, board members, clients, partners)

Case studies
- Reciprocal presentations of personally developed business cases

Lecture notes
Distributed at start of module.

Literature
Distributed at start of module.

Prerequisites / notice
Announced to students of the MAS | CAS at the beginning of the term.

166-0302-00L Implementing New Strategies and Business Models for Future Transport Systems
O 3 credits 2G

Does not take place this semester.

Abstract
In order to be successful, new strategies / innovative business models have to be implemented in the market as well as in the company itself. This requires proactively managed transition processes. This module deals with such transition processes on three levels: change management theory – best-practice examples – one’s own practice.

Objective
Participants...
- know and understand selected classic and current theories regarding change (management) in systems
- know how to design and initiate participative transition processes
- are familiar with / know how to apply selected tools of change management
- have discussed best-practice cases with responsible managers within the mobility/transportation sector
- have reflected theory and best-practice cases in regard to their own practice
- have developed management options and approaches for their own practice

Content
- Classic and current change management approaches
- Communication in transition processes
- Participation: integration of stakeholders
- Dealing with resistances
- Discussions with guests from practice regarding the management of transition processes related to the implementation of new strategies / business models

Methods
- Selected change management methods and tools

Case studies
- Various good/best practice cases within the mobility sector
- Change cases of students

Lecture notes
Distributed at start of module.

Literature
Distributed at start of module.

Prerequisites / notice
Announced to students of the MAS | CAS at the beginning of the term.
166-0303-00L  Agile and User-Centered Innovation  ■  O  2.5 credits  2G

Does not take place this semester.

Abstract  For companies it is essential to realise products quickly, economically and in a customer-oriented way. In this context, approaches to agile and user-centred product development such as Scrum and Design Thinking are increasing in importance. Compared to traditional product development methods, agile methods promise higher quality and customer satisfaction coupled with reduced expenditure.

Objective  Design and realisation of product development projects for future transport systems: Participants are familiar with the methods and procedures of agile and user-centred product development and are able to apply them profitably in their enterprises.

Content  Participants define an innovation theme themselves in groups, and a selection of topics is then drawn from this theme for module group work. The module takes participants through the whole process, from the analysis of target groups and their requirements through project conception and planning to implementation in example form. The course is practical and uses concrete examples. At the end of the module, participants will have deployed the methods of agile and user-centred product development to work very practically through a theme they have developed themselves, and will have become familiar with the typical application scenarios, advantages and hurdles associated with these methods.

Lecture notes  Distributed at start of module.

Literature  Distributed at start of module.

Prerequisites / notice  Announced to students of the MAS/CAS at the beginning of the term.

Competencies

<table>
<thead>
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<th>Competencies</th>
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<th>Methods-specific Competencies</th>
<th>Social Competencies</th>
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<td>Concepts and Theories</td>
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<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Decision-making</td>
<td>Customer Orientation</td>
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<tr>
<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Leadership and Responsibility</td>
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<td>Problem-solving</td>
<td>Self-presentation and Social Influence</td>
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<td>Self-presentation</td>
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<tr>
<td>Project Management</td>
<td>fostered</td>
<td></td>
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<td>Negotiation</td>
</tr>
</tbody>
</table>

166-0390-00L  CAS Project: New Business Models  ■  O  3 credits  5D  C. Onder

Does not take place this semester.

Abstract  The participants, in heterogeneous teams, deal with a current problem from the topics of the CAS New Business Models.

Objective  - Deal with a specific problem from the CAS New Business Models subject area.
- Be able to work interdisciplinary and across sectors, where appropriate together with relevant other parties.
- Communicate the results appropriately.

Lecture notes  Distributed at start of module.

Literature  Distributed at start of module.

Prerequisites / notice  Announced to students of the MAS | CAS at the beginning of the term.

Additional Task MAS|CAS

Depending on the need, the "Additional task MAS|CAS" Module takes place every Semester.

Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<tbody>
<tr>
<td>166-0490-00L</td>
<td>MAS Thesis</td>
<td>O</td>
<td>15</td>
<td>27D</td>
<td>C. Onder</td>
</tr>
</tbody>
</table>

Note: The previous course title until HS23 "Master's Thesis".

Abstract  Individually and independently, students address a practice-related problem in the area of future transport systems. To do this they deploy, under the supervision of an expert, what they have learned in the MAS programme. They set out the problem, the procedure and the solution in a written report which they present and defend in front of a specialist audience.

Objective  - Ability to draw up solutions in the context of future transport systems.
- Ability to communicate these solutions in a manner suited to a particular target audience.
Content
- Introductory colloquium: Working scientifically and presenting a project idea
- Individual and independent work on a problem selected by the participant
- Interim colloquium: Presentation of the status quo
- Individual supervision by the lecturer
- Compilation of the written thesis and preparation of the presentation
- Examination colloquium: Presentation and defence

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the of the MAS at the beginning of the term.

MAS in Future Transport Systems - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Key for Credits</th>
</tr>
</thead>
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</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr Suitable for doctorate</td>
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Key for Hours

<table>
<thead>
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<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
MAS in Spatial Development
Four-semester, part-time MAS programme.

Start of the next course: Autumn Semester 2023

Introduction

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>135-0001-00L</td>
<td>Einführung: Grundlagen der Raumentwicklung</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>S. Kissling, A. Rupf, J. Van Wezemael</td>
</tr>
</tbody>
</table>

Abstract
Orientation and preparation for further education in the field of spatial planning and development. Introduction to the Spatial Planning Act and its instruments, assessment of participants' knowledge. Completion through mandatory assessment.

Spatial Development and Planning Practice

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>135-0100-00L</td>
<td>Module 1: Spatial Planning</td>
<td>O</td>
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</table>

Abstract
Overview of current and future tasks of spatial planning, discussion of formal and informal instruments, and introduction to a methodical way of action-oriented planning. (Tasks, methods and instruments).

<table>
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<tr>
<th>Number</th>
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<th>Type</th>
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<td>135-0101-00L</td>
<td>Module 2: Space as a Complex Situation</td>
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Abstract
Introduction to the nature and pitfalls of complex situations, methods and processes for treatment. Introduction to spatial planning and planning actions in multi-actor networks. (Perceiving, acting and arguing in complex situations).

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<th>Number</th>
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<tr>
<td>135-0102-00L</td>
<td>Module 3: Integrated Urban Design</td>
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Abstract
Inputs for the integrated development of livable urban spaces in connection with central aspects and mechanics of mobility, open spaces, and social spaces. (In the tension field of mobility, open space, and society).

<table>
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<tr>
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<td>Module 4: Functional Regions</td>
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Abstract
Discussion of the development of large-scale and cross-border spaces. Designing and planning in multi-actor networks, spatial concepts as a basis for cooperation and coordination tasks. (Designing and developing large-scale tasks).

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<td>135-0104-00L</td>
<td>Module 5: Shaping Transformation</td>
<td>O</td>
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<td>further lecturers</td>
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Abstract
Exploration of current and future questions of planning law and discussion of the further development of planning instruments and processes. (Law, process, and instruments II).

<table>
<thead>
<tr>
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</table>

Abstract
Module 1-5: Introduction of the task and excursion, integrated location assessment, development of viable action options and interim critique, overall concept and in-depth study, finalization and final critique.

Spatial Development and Process Design

<table>
<thead>
<tr>
<th>Number</th>
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Abstract
Introduction to the nature and pitfalls of complex situations, methods and processes for treatment. Introduction to spatial planning and planning actions in multi-actor networks. (Perceiving, acting and arguing in complex situations).

Future of Spatial Development

<table>
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<tr>
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<th>Hours</th>
<th>Lecturers</th>
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<td>135-0107-00L</td>
<td>Module 7: Future</td>
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Abstract
Discussion of the development of large-scale and cross-border spaces. Designing and planning in multi-actor networks, spatial concepts as a basis for cooperation and coordination tasks. (Designing and developing large-scale tasks).

Master's Thesis

<table>
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<tr>
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<th>Lecturers</th>
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<td>135-0108-00L</td>
<td>Thesis</td>
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Abstract
Exploration of current and future questions of planning law and discussion of the further development of planning instruments and processes. (Law, process, and instruments II).

MAS in Spatial Development - Key for Type

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<th>Key</th>
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<td>Courses outside the curriculum</td>
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<tr>
<td>E-</td>
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<td>Dr</td>
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Key for Hours

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</tr>
<tr>
<td>R</td>
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</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
MAS in Technology and Public Policy
Two-semester full time- or four-semester part-time programme.

More information at: https://tpp.ethz.ch/tpp-degrees/mas-tpp.html

► Compulsory Modules

►► Policy Process
The Module is offered two-yearly in spring semester. The module is offered again in the spring semester of 2025.

►► Impact Analysis
The Module is offered two-yearly in spring semester. The module is offered again in the spring semester of 2026.

► Electives
MAS students can choose from the Science in Perspective course offer or related courses. Enrollment only after agreement with the TPP Programme Leadership.

► Master’s Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
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<td>Master’s Thesis</td>
<td>O</td>
<td>15 credits</td>
<td>32D</td>
<td>Lecturers</td>
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</table>

Abstract
The MAS students focus on a specific policy problem and carry out a policy analysis either within an ETH research group or with a project partner from the public, private or civic sector. In either case, the policy analysis project requires an ETH professor as supervisor, who is also responsible for grading the thesis.

Objective
Apply the policy analysis skills acquired throughout the MAS TPP programme.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
<td>fostered</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Method-specific Competencies</th>
<th>Analytical Competencies</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td>Decision-making</td>
<td>fostered</td>
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<tr>
<td>Problem-solving</td>
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</table>

<table>
<thead>
<tr>
<th>Personal Competencies</th>
<th>Critical Thinking</th>
<th>assessed</th>
</tr>
</thead>
</table>

MAS in Technology and Public Policy - Key for Type

| O    | Compulsory    | E- | Recommended, not eligible for credits |
| W+   | Eligible for credits and recommended | Z   | Courses outside the curriculum |
| W    | Eligible for credits | Dr  | Suitable for doctorate |

Key for Hours

| V    | lecture       | P   | practical/laboratory course |
| G    | lecture with exercise | A   | independent project |
| U    | exercise       | D   | diploma thesis |
| S    | seminar        | R   | revision course / private study |
| K    | colloquium     |     |                            |

ECTS
European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
MAS in Urban and Territorial Design

The MAS in Urban and Territorial Design requires one year of full-time postgraduate study for a 60 ECTS joint degree, the “MAS ETH EPF UTD”. It is taught in English and held at the two Swiss schools, EPFL (Autumn) and ETH Zurich (Spring).

### Design Studio and Postproduction

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>078-0100-00L</td>
<td>Core Design and Research Studio I (EPFL)</td>
<td>O</td>
<td>17G</td>
<td>17G</td>
<td>external organisers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Lecturers: P. Viganò with C. Fivet, L. Rossi and guests. The Core Studio will reflect on the “transition”, assuming its multiple dimensions (ecological, social and economic) and developing transcalar design operations in concrete territories. The territory of Greater Geneva will be the test-bed for radical design explorations of possible futures.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Different urban conditions will be considered in order to understand, read and manage the thick complexity of the contemporary habitat where densities, distances, relations and practices shape heterogeneous spaces and ecologies. Conceived as a place of interaction among disciplines, the studio also constitutes the main tool to develop interdisciplinarity within the design practice.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>A series of lectures will deal with ecology; the organism and its environment; population and community ecology; and biodiversity. Others lectures on design as knowledge production and on representation—GIS, video and photography—will be embedded within the activities of the studio. Fieldwork is integral to the design studio.</td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Postproduction I (EPFL)</th>
<th>O</th>
<th>2G</th>
<th>2G</th>
<th>external organisers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Lecturer: P. Viganò. The last period of the semester in January will consist of a post-production session, related to the results at EPFL. It mainly concerns the products of the Core Studio, but will also be implemented by the associated teaching.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>All research and design materials produced during the studio, courses and sessions (e.g. texts, maps, drawings, etc.) will be evaluated, edited and curated in a “Semester Report” by the core teaching team and a graphic designer. At the end, the “Report” will be available online.</td>
<td></td>
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</table>

### Interdisciplinary Courses

<table>
<thead>
<tr>
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<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>078-0200-00L</td>
<td>City, Habitat and Mobility (EPFL)</td>
<td>O</td>
<td>2G</td>
<td>3G</td>
<td>external organisers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Lecturers: V. Kaufmann with L. Pattaroni. The course aims to understand the political and social conditions of urban lifestyles and mobilities patterns in order to explore the levers of action available to professionals to support the critical emergence of renewed urban models.</td>
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<tr>
<td>Objective</td>
<td>Taking the form of a course - seminar, the proposed teaching aims to show the interest of methodologies from the social sciences of the city to develop critical urban and territorial design. Planned to last 12 weeks, it proposes to take up each week a theme related to the relation between city, habitat and mobility.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Each session is organized in two parts: (1) a presentation by one of the students of an article on the week’s theme, followed by a discussion, and (2) a presentation by the teaching team to identify the knowledge and debates of social sciences related to urban and territorial design issues. Two sessions will be devoted to field visits.</td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Circularity, Materials &amp; Flows (EPFL)</th>
<th>O</th>
<th>2G</th>
<th>3G</th>
<th>external organisers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Lecturer: C. Fivet. The circular economy consists in maintaining the value of products as long as possible by extending or renewing their service life while minimizing resource depletion, waste and greenhouse gas emissions. The integration of these principles in the construction industry has many facets that often contradict each other.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>While introducing students to the concept of the circular economy and its applications to building design, the class provides ready-to-use techniques and aims at developing a critical mindset towards their use. Following a “flipped classroom” methodology, the class devolves into recent literature and practice by means of adversarial open debates. Examination consists in the writing of a short personal essay on a chosen topic and its oral defence.</td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Landscapes &amp; Ecosystems (EPFL)</th>
<th>O</th>
<th>3G</th>
<th>2G</th>
<th>external organisers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Lecturer: L. Rossi. This course addresses water management from a global point of view, including in particular the impacts of rain discharges on receiving environments. The qualitative aspects (risk of contamination) are considered as a priority, in parallel with the quantitative risks (floods).</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The course aims to understand the means and issues of management and maintenance of sewerage systems, finalized to the control of impacts in receiving environments, and more generally to raise the importance of hydraulic management in the urban and territorial project.</td>
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</tr>
<tr>
<td>Content</td>
<td>General introduction - Legislative aspects related to urban hydrology - Simplified design methods and technical solutions: from source control to solutions at the end of the network - Field visits</td>
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### Urban Theory Sessions

<table>
<thead>
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<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>078-0300-00L</td>
<td>Urban &amp; Environmental Theory Session (EPFL)</td>
<td>O</td>
<td>2G</td>
<td>2G</td>
<td>external organisers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Lecturers: S. Marot and guests. As a guiding principle that remains to be defined, the transition can be critically confronted with broader histories of the environment. The various and even very opposite hypotheses it contains will be differentiated and deepened in the module. In particular that of autonomy will be discuss regarding to the so-called “secession” scenario.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Objective</td>
<td>This session aims to understand how and to what extent environmental concerns can influence urban and territorial design. From a critical point of view, it also intends to question the notion of transition under the prism of its antecedents in ecological thinking.</td>
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</table>

MAS in Urban and Territorial Design - Key for Type

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<tbody>
<tr>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1722 of 2653
### Key for Hours

<table>
<thead>
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<th>Key</th>
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<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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#### ECTS
- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
# MAS Mediation in Peace Processes

## Modules

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
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<tbody>
<tr>
<td>868-0001-00L</td>
<td>Module 1: Mediation in Context</td>
<td>O</td>
<td>10 credits</td>
<td>9G</td>
<td>A. Wenger, L.-E. Cederman</td>
</tr>
<tr>
<td></td>
<td>Does not take place this semester.</td>
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</table>

**Abstract**

This module defines and contextualises peace mediation in relation to other conflict resolution approaches. The module focuses heavily on conflict analysis, introducing the students to the latest knowledge about conflict typologies, trends, and causes in addition to providing them with various opportunities to practice conflict analysis using diverse methods.

**Objective**

This module defines and contextualises peace mediation in relation to other conflict resolution approaches. The module focuses heavily on conflict analysis, introducing the students to the latest knowledge about conflict typologies, trends, and causes in addition to providing them with various opportunities to practice conflict analysis using diverse methods.

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<th>Number</th>
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<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>868-0004-00L</td>
<td>Module 4: Mediation Process Design</td>
<td>O</td>
<td>10 credits</td>
<td>9G</td>
<td>A. Wenger</td>
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</table>

**Abstract**

Mediators help the parties reach a peace agreement by designing and structuring the process. This module covers the basic elements of process design and how they differ. Important to process design is the reflection on theory and practice in sequencing the content to be examined. The module then explores the implications and challenges facing the implementation of peace agreements for mediators.

**Objective**

Mediators help the parties reach a peace agreement by designing and structuring the process. This module covers the basic elements of process design and how they differ. Important to process design is the reflection on theory and practice in sequencing the content to be examined. The module then explores the implications and challenges facing the implementation of peace agreements for mediators.

### MAS Mediation in Peace Processes - Key for Type

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<thead>
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<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E+</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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### Key for Hours

<table>
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<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
**Mechanical Engineering Bachelor**

➤ Bachelor Studies (Programme Regulations 2022)

➤➤ First Year Compulsory Courses

➤➤➤ First Year Examinations

➤➤➤➤ First Year Examination Block A

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-0261-00L</td>
<td>Analysis I</td>
<td>O</td>
<td>7 credits</td>
<td>5V+2U</td>
<td>A. Steiger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Functions; Differential and integral calculus for functions of one variable; power series. The mathematical methods are applied in a large number of examples from mechanics, physics and other areas which are basic to engineering.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Introduction to the mathematical foundations of engineering sciences, as far as concerning differential and integral calculus in one variable,</td>
<td></td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>U. Stammbach: Analysis I/II</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Exercises and online quizzes are an important aspect of this course. Attempts at solving these problems will be honored with a bonus on the final grade. See &quot;Performance assessment&quot; for more information.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<tr>
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<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<tr>
<td>151-0501-03L</td>
<td>Mechanics I</td>
<td>O</td>
<td>6 credits</td>
<td>3V+2U+1K</td>
<td>R. Hofp. E. Mazza</td>
</tr>
<tr>
<td>Abstract</td>
<td>Basics: Position of a material point, velocity, kinematics of rigid bodies, forces, reaction principle, mechanical power</td>
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</tr>
<tr>
<td>Objective</td>
<td>Statics: Groups of forces, moments, equilibrium of rigid bodies, reactions at supports, parallel forces, center of gravity, statics of systems, principle of virtual power, trusses, frames, forces in beams and cables, friction.</td>
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<tr>
<td>Content</td>
<td>The understanding of the fundamentals of statics for engineers and their application in simple settings</td>
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<tr>
<td>Lecture notes</td>
<td>Übungsblätter</td>
<td></td>
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<tr>
<td>Literature</td>
<td>Sayir, M.B., Dual J., Kaufmann S., Mazza E., Ingenieurmechanik 1: Grundlagen und Statik, Springer</td>
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<tr>
<td>252-0832-00L</td>
<td>Computer Science I</td>
<td>O</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>C. Cotrini Jimenez, R. Sasse</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.</td>
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<tr>
<td>Objective</td>
<td>Primary educational objective is to learn programming with C++. When successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens &quot;behind the scenes&quot; when a program is translated and executed.</td>
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<tr>
<td>Content</td>
<td>Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking of a computer scientist.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture slides and all other material will be made available for download on the course web page.</td>
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<tr>
<td>Literature</td>
<td>Bjarne Stroustrup, Einführung in die Programmierung mit C++, Pearson Studium, 2010</td>
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<td>Competencies</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<tr>
<td>151-0909-00L</td>
<td>Chemistry I</td>
<td>O</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>D. J. Norris</td>
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<tr>
<td>Abstract</td>
<td>This is a general chemistry course aimed at first-year bachelor students in the Department of Mechanical and Process Engineering.</td>
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<tr>
<td>Objective</td>
<td>The aims of the course are:</td>
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<tr>
<td></td>
<td>1) To provide a thorough understanding of the basic principles of chemistry and its application,</td>
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<td>2) To develop an understanding of the atomic and molecular nature of matter and of the chemical reactions that describe its transformations, and</td>
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<td>3) To emphasize areas considered most relevant in an engineering context.</td>
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<tr>
<td>Content</td>
<td>Electronic structure of atoms, chemical bonding, molecular geometry and bonding theories, intermolecular forces, gases, thermodynamics, chemical thermodynamics, chemical kinetics, equilibria, liquids and solutions, acids and bases, redox- and electrochemistry.</td>
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<tr>
<td>Lecture notes</td>
<td>The instructor's lecture notes will be available prior to every lecture and can be downloaded from Moodle.</td>
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</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1725 of 2653
### Content
Systems of linear equations, Gaussian elimination, solution space, matrices, LR decomposition, Determinants, structure of linear spaces, normed vector spaces, inner products, method of least squares, QR decomposition, introduction to MATLAB, applications

### Literature
* K. Meyberg / P. Vachenauer, Höhere Mathematik 1, Springer 2003

### Prerequisites / notice
Active participation in the exercises is part of this course. It is expected, that students submit 3/4 of all exercises for control.

### Additional First Year Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0321-00L</td>
<td>Engineering Design and Material Selection ■</td>
<td>O</td>
<td>4</td>
<td>4G</td>
<td>K. Shea, T. Stankovic</td>
</tr>
</tbody>
</table>

#### Abstract
This course provides an introduction to engineering design. Through hands-on, practice-oriented exercises, students learn about and experience the fundamentals of engineering design, including concept design, technical drawing, CAD, material selection, manufacturing process selection and sustainability. Three case studies in healthcare, mobility and sustainable materials are explored.

#### Objective
The lecture and exercises teach the fundamentals of engineering design, technical drawing and CAD as well as material selection. After taking the course, students will be able to tackle simple design tasks, generate and evaluate concepts, accurately create technical drawings of parts and assemblies as well as read them. Students will also be able to create models of parts and assemblies in a 3D, feature-based CAD system. They will understand the links between engineering design, sustainability, material selection and manufacturing process selection.

#### Content
- Introduction to Engineering Design
  - design requirements
  - concept generation and selection
  - prototyping
- Design Representations
  - Sketching in Engineering Design
  - Technical Drawing:
    - projections, views and cuts
    - dimensioning
    - assemblies
  - CAD:
    - CAD modeling operations
    - parametric design and feature-based modeling
    - assemblies
    - creating 2D drawings from 3D part models
- Fabrication and Additive manufacturing
- Design for the Environment
- Material and Manufacturing Process Selection
  - materials and their properties, with emphasis on sustainable materials
  - basic mechanics
  - material selection processes
  - manufacturing process selection

Three case studies in healthcare, mobility and sustainable materials

#### Lecture notes
Lecture slides and exercise handouts are available on the course Moodle website: https://moodle-app2.let.ethz.ch/course/view.php?id=17403

#### Literature
All literature will be given on the Moodle website: https://moodle-app2.let.ethz.ch/course/view.php?id=17403

#### Prerequisites / notice
This course is given as a lecture (1h/week) and an exercise (3h/week). Students are split into working groups for the exercises with a maximum of 20 students per group.

#### Semester Fee
A fee is charged for printed copies of the course handouts and 3D printing.

### Competencies

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</table>
**Additional Project**

ONLY for Mechanical Engineering BSc, Programme Regulations 2022.

Enrollment only in consultation with the D-MAVT student administration.

**Abstract**

Additional Project

**Objective**

Compensation of missing credit points due to transition between regulations.

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### Second and Third Year Compulsory Courses

#### Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0503-00L</td>
<td>Mechanics III</td>
<td>O</td>
<td>6 credits</td>
<td>4V+2U</td>
<td>D. Kochmann</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Dynamics of particles, rigid bodies, and deformable bodies: Motion of a single particle, motion of systems of particles, 2D and 3D motion of rigid bodies, vibrations, waves.</td>
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</tr>
<tr>
<td><strong>Objective</strong></td>
<td>This course enables students to apply the concepts and laws governing the kinematics and kinetics of particles, rigid bodies, and elastic bodies in order to identify, formulate, and solve dynamical engineering problems. Specifically, students will be able to describe, analyze, and predict the motion of particles and bodies in space over time and to relate their motion to the applied forces for applications in (not only) mechanical and civil engineering.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Students of mechanical and civil engineering learn the fundamental concepts of the dynamics of mechanical systems. By studying the motion of a single particle, systems of particles, rigid bodies, and of deformable bodies, we introduce essential concepts such as kinematics, kinetics, work and energy, equations of motion, and forces and torques. Further topics include the stability of equilibria and vibrations as well as an introduction to the dynamics of deformable bodies and waves in elastic rods. Throughout the course, application-oriented examples help students acquire a proficient background in engineering dynamics, further to learn and embrace problem-solving techniques for dynamical engineering problems, gain cross-disciplinary expertise (by linking concepts from, among others, mechanics, mathematics, and physics), and prepare students for advanced courses and work on engineering applications. The detailed syllabus includes:</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Lecture notes (a complete scriptum) is available on Moodle. Students are encouraged to take their own notes during class.</td>
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</tr>
<tr>
<td><strong>Literature</strong></td>
<td>Lecture notes (a complete scriptum) is available on Moodle. Further reading materials are suggested but not required for this class.</td>
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</tr>
<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>For students in the bachelor's degree programme in mechanical engineering: Precondition for this course unit are passed first year examination blocks A and B.</td>
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<tr>
<td><strong>Competencies</strong></td>
<td>All course materials (including lecture notes, exercise problems, etc.) are available on Moodle.</td>
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<thead>
<tr>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>151-0591-00L</td>
<td>Control Systems I</td>
<td>O</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>E. Frazzoli</td>
</tr>
</tbody>
</table>

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Objective

The course addresses dynamic control systems, i.e., systems that (i) evolve over time, and (ii) have control inputs and measured outputs. The main objective is to learn how to design the control inputs in such a way that the measured outputs have some desirable properties. For example, for an advanced driver assistance system, how to control acceleration so that the speed remains constant, and how to control the steering angle so that the car remains in the center of the lane.

In order to pursue this objective, the course is organized into three main parts:

1) Modeling: learn how to represent a dynamic control system in such a way that it can be treated effectively using computational and mathematical tools. This will include learning how to use computer tools like Matlab to simulate dynamic control systems.

2) Analysis: understand the basic characteristics of a system, such as its (internal and external) stability, performance, and robustness, and how the input affects the output. We will also learn to analyze systems obtained as interconnections (e.g., feedback) of two or more other systems. In particular, we will focus on tools that allow to understand how a system will behave under feedback control (i.e., closed-loop behavior), based only on its open-loop behavior.

3) Synthesis: the last part of the course will concentrate on how to design feedback control laws, in order to change the behavior of the system in a desirable way.

In this course, we will concentrate on systems that can be modeled by Ordinary Differential Equations (ODEs), and that satisfy certain other technical conditions, such as linearity and time-invariance. In addition, we will focus on systems with a Single Input and a Single Output (SISO).

This will allow us to use “classical control” tools that are very powerful and easy to use (i.e., mostly graphical), and which are really laying the foundation of any follow-up work on more challenging control problems.

In addition to paper-and-pencil techniques, we will leverage modern computational tools for control design, such as Matlab.

Lecture notes

Lecture slides and additional material will be posted online.

Literature

There is no required textbook.

A nice introductory book on feedback control, available online for free, is:

Feedback Systems: An Introduction for Scientists and Engineers
Karl J. Astrom and Richard M. Murray

http://www.cds.caltech.edu/~murray/amwiki/index.php/First_Edition

Prerequisites / notice

Basic knowledge of (complex) analysis and linear algebra.
Familiarity with Matlab is recommended.

For students in the bachelor's degree programme in mechanical engineering:
Precondition for this course unit are passed first year examination blocks A and B.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Analytical Competencies assessed

Method-specific Competencies

Abstract

Introduction to the fundamentals of technical thermodynamics.

Objective

Introduction to the fundamentals of technical thermodynamics.

Content

1. Konzepte und Definitionen
2. Der erste Hauptsatz, der Begriff der Energie und Anwendungen für geschlossene Systeme
3. Eigenschaften reiner kompressibler Substanzen, quasistatische Zustandsänderungen
4. Elemente der kinetischen Gastheorie
5. Der erste Hauptsatz in offenen Systemen - Energieanalyse in einem Kontrollvolumen
6. Der zweite Hauptsatz - Der Begriff der Entropie
7. Nutzbarkeit der Energie - Exergie
8. Thermodynamische Beziehungen für einfache, kompressible Substanzen.

Lecture notes

available

Literature


Prequisites / notice

For students in the bachelor's degree programme in mechanical engineering:
Precondition for this course unit are passed first year examination blocks A and B.

Abstract

Basic course in electrical engineering with the following topics: Concepts of voltage and currents; Analyses of dc and ac networks; Series and parallel resistive circuits, circuits including capacitors and inductors; Kirchhoff's laws and other network theorems; Transient responses; Basics of electrical and magnetic fields;

Objective

Understanding of the basic concepts in electrical engineering with focus on network theory. The successful student knows the basic components of electrical circuits and the network theorems after attending the course.
Diese Vorlesung vermittelt Grundlagenkenntnisse im Fachgebiet Elektrotechnik. Ausgehend von den grundlegenden Konzepten der Spannung und des Stroms wird die Analyse von Netzwerken bei Gleich- und Wechselstrom behandelt. Dabei werden folgende Themen behandelt:

Kapitel 1 Das elektrostatische Feld
Kapitel 2 Das stationäre elektrische Strömungsfeld
Kapitel 3 Einfache elektrische Netzwerke
Kapitel 4 Halbleiterbauelemente (Dioden, der Transistor)
Kapitel 5 Das stationäre Magnetfeld
Kapitel 6 Das zeitlich veränderliche elektromagnetische Feld
Kapitel 7 Der Übergang zu den zeitabhängigen Strom- und Spannungsformen
Kapitel 8 Wechselspannung und Wechselstrom

Die Vorlesungsfolien werden auf Moodle bereitgestellt.

Als ausführliches Skript wird das Buch "Manfred Albach. Elektrotechnik, Person Verlag, Ausgabe vom 1.8.2011" empfohlen.

Für das weitergehende Studium werden in der Vorlesung verschiedene Bücher vorgestellt.

For students in the bachelor's degree programme in mechanical engineering:

Precondition for this course unit are passed first year examination blocks A and B.

### Analysis III

**Abstract**

Introduction to partial differential equations. Differential equations which are important in applications are classified and solved. Elliptic, parabolic and hyperbolic differential equations are treated. The following mathematical tools are introduced: Laplace transforms, Fourier series, separation of variables, methods of characteristics.

**Objective**

Mathematical treatment of problems in science and engineering. To understand the properties of the different types of partial differential equations.

**Content**

- Laplace Transforms:
  - Laplace Transform, Inverse Laplace Transform, Linearity, s-Shifting
  - Transforms of Derivatives and Integrals, ODEs
  - Unit Step Function, t-Shifting
  - Short Impulses, Dirac's Delta Function, Partial Fractions
  - Convolution, Integral Equations
  - Differentiation and Integration of Transforms

- Fourier Series, Integrals and Transforms:
  - Fourier Series
  - Functions of Any Period p=2L
  - Even and Odd Functions, Half-Range Expansions
  - Forced Oscillations
  - Approximation by Trigonometric Polynomials
  - Fourier Integral
  - Fourier Cosine and Sine Transform

- Partial Differential Equations:
  - Basic Concepts
  - Modeling: Vibrating String, Wave Equation
  - Solution by separation of variables; use of Fourier series
  - D’Alembert Solution of Wave Equation, Characteristics
  - Heat Equation: Solution by Fourier Series
  - Heat Equation: Solutions by Fourier Integrals and Transforms
  - Modeling Membrane: Two Dimensional Wave Equation
  - Laplacian in Polar Coordinates; Circular Membrane, Fourier-Bessel Series
  - Solution of PDEs by Laplace Transform

**Lecture notes**

Lecture notes by Prof. Dr. Alessandra Iozzi:

https://polybox.ethz.ch/index.php/s/D3K0TayQXvpCAA

**Literature**


For reference/complement of the Analysis I/II courses:

Christian Blatter: Ingenieur-Analysis

https://people.math.ethz.ch/~blatter/dlp.html

**Prerequisites / notice**

For students in the bachelor's degree programme in mechanical engineering:

Precondition for this course unit are passed first year examination blocks A and B.

#### Examination Block 2

*Offered in the spring semester only*

#### Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0300-10L</td>
<td>Innovation Project</td>
<td>O</td>
<td>3</td>
<td>3U</td>
<td>M. Meboldt</td>
</tr>
</tbody>
</table>

**Abstract**

The students are going through a product development process starting with the first idea to the functional product. The participants will learn to work on a complex development task in a team (5 pers.), to structure a given problem, to generate and evaluate ideas as well as the design and realization of the product with subsequent verification.

**Objective**

The students learn and experience the principles of product development. In addition to acquiring development methodical responsibilities, the main focus is on working together as a team. The participants are taught how to structure a complex development objective and how to achieve this objective in team work. In the end, the students will master the basics of development processes and development methodical tools.
**Electives**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0221-00L</td>
<td>Introduction to Modeling and Optimization of Sustainable Energy Systems</td>
<td>W</td>
<td>4</td>
<td>4G</td>
<td>G. Sansavini, A. Bardow, S. Moret</td>
</tr>
</tbody>
</table>

**Abstract**

This course introduces the fundamentals of energy system modeling for the analysis and the optimization of the energy system design and operations.

**Objective**

At the end of this course, students will be able to:

- define and quantify the key performance indicators of sustainable energy systems;
- select and apply appropriate models for conversion, storage and transport of energy;
- develop mathematical models for the analysis, design and operations of multi-energy systems and solve them with appropriate mathematical tools;
- select and apply methodologies for the uncertainty analysis on energy systems models;
- apply the acquired knowledge to tackle the challenges of the energy transition.

**Content**

In the course "Introduction to Modeling and Optimization of Sustainable Energy Systems", the competencies of process understanding, system understanding, modeling, concept development, data analysis & interpretation and measurement methods are taught, applied and examined. Programming is applied.

**Lecture notes**

Lecture slides and supplementary documentation will be available online. Reference to appropriate book chapters and scientific papers will be provided.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0533-00L</td>
<td>Introduction to Computing</td>
<td>W</td>
<td>4</td>
<td>2+2U</td>
<td>L. De Lorenzis</td>
</tr>
</tbody>
</table>

**Abstract**

The course provides a broad introduction to modern techniques in scientific computing, useful for tasks ranging from data analysis to model building to engineering computations. For each topic, a solid theoretical foundation is combined with extensive exposure to practical multidisciplinary examples and with coding exercises.

**Objective**

After taking this class, students will be able to apply numerical techniques including interpolation, transforms, differentiation, integration and solution techniques for linear and non-linear equation systems to extract fundamental information from data and to model, approximate and solve a number of complex problems in engineering and across disciplines.

**Lecture notes**

Lecture notes will be provided, however, students are also encouraged to take their own notes.

**Literature**

Relevant references will be provided.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>151-0575-01L</td>
<td>Signals and Systems</td>
<td>W</td>
<td>4</td>
<td>2+2U</td>
<td>A. Carron</td>
</tr>
</tbody>
</table>

**Abstract**

Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to signals and produce other signals. In this course, we explore how signals can be represented and manipulated, and their effects on systems. We further explore how we can discover basic system properties by exciting a system with various types of signals.

**Objective**

Master the basics of signals and systems. Apply this knowledge to problems in the homework assignments and programming exercise.

**Content**


**Lecture notes**

Lecture notes available on course website.

**Prerequisites / notice**

Control Systems I is helpful but not required.

<table>
<thead>
<tr>
<th>Number</th>
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</tr>
</thead>
<tbody>
<tr>
<td>151-0700-00L</td>
<td>Manufacturing</td>
<td>W</td>
<td>4</td>
<td>2+2U</td>
<td>M. Bambach, M. Afsani</td>
</tr>
</tbody>
</table>

**Abstract**

Fundamental terms of production engineering, plastic deformation, machining, Lasermachining, Mechatronic in the productions machine construction, Quality assurance, Process chain planning.

**Objective**

- Knowledge of principal terms of manufacturing engineering
- Basic knowledge of some processes, their mode of operation and design (forming, separative processes, Laser techniques)
- Knowledge of product defining properties and limitations of applications
- In competition of processes make the right decisions
- Procedure for process chain planning
- Basic knowledge for quality assurance

**Content**

Explanation of basic principles of manufacturing techniques and insight into the functionality of a manufacturing shop. Plastic deformation and separative-manufacturing processes, as well as laser machining (welding and cutting), and their layouts, product defining properties and limitations of applications such as the associated workshop facilities, will be introduced in different details. Further basic principles of the industrial measurement technique and mechatronics concepts in machine tool construction will be discussed.

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>151-0851-00L</td>
<td>Robot Dynamics</td>
<td>W</td>
<td>4</td>
<td>2+2U</td>
<td>M. Hutter, R. Siegwart, J. Tordesillas Torres</td>
</tr>
</tbody>
</table>

**Abstract**

We will provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing.

**Objective**

The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems. The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

**Content**

The course consists of three parts: First, we will refresh and deepen the student's knowledge in kinematics, dynamics, and rotations of multi-body systems. In this context, the learning material will build upon the courses for mechanics and dynamics available at ETH, with the particular focus on their application to robotic systems. The goal is to foster the conceptual understanding of similarities and differences among the various types of robots. In the second part, we will apply the learned material to classical robotic arms as well as legged systems and discuss kinematic constraints and interaction forces. In the third part, focus is put on modeling fixed wing aircraft, along with related design and control concepts. In this context, we also touch aerodynamics and flight mechanics to an extent typically required in robotics. The last part finally covers different helicopter types, with a focus on quadrotors and the coaxial configuration which we see today in many UAV applications. Case studies on all main topics provide the link to real applications and to the state of the art in robotics.

**Prerequisites / notice**

The contents of the following ETH Bachelor lectures or equivalent are assumed to be known: Mechanics and Dynamics, Control, Basics in Fluid Dynamics.

<table>
<thead>
<tr>
<th>Number</th>
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</tr>
</thead>
<tbody>
<tr>
<td>151-0913-00L</td>
<td>Introduction to Photonics</td>
<td>W</td>
<td>4</td>
<td>2+2U</td>
<td>R. Quidant, J. Ortega Arroyo</td>
</tr>
</tbody>
</table>

**Abstract**

This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.
Objective

Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.

Content

I- BASICS OF WAVE THEORY
1) General concepts
2) Differential wave equation
3) Wavefront
4) Plane waves and Fourier decomposition of optical fields
5) Spherical waves and Huygens-Fresnel principle

II- ELECTROMAGNETIC WAVES
1) Maxwell equations
2) Wave equation for EM waves
3) Dielectric permittivity
4) Refractive index
5) Nonlinear optics
6) Polarisation and polarisation control

III- PROPAGATION OF LIGHT
1) Waves at an interface
2) The Fresnel coefficients
3) Total internal reflection
4) Evanescent waves
5) Dispersion diagram

IV- INTERFERENCES
1) General considerations
2) Temporal and spatial coherence
3) The Young double slit experiment
4) Diffraction gratings
5) The Michelson interferometer
6) Multi-wave interference
7) Antireflecting coating and interference filters
8) Optical holography

V- LIGHT MANIPULATION
1) Optical waveguides
2) Photonic crystals
3) Metamaterials and metasurfaces
4) Optical cavities

VI- OPTICAL FORCES AND OPTICAL TWEEZERS
1) History of optical forces
2) Theory of optical trapping
3) Atom cooling
4) Optomechanics
5) Applications of optical tweezers

VII- INTRODUCTION TO OPTICAL MICROSCOPY
1) Basic concepts
2) Direct and Fourier imaging
3) Image formation
4) Fluorescence microscopy
5) Scattering-based microscopy
6) Digital holography
7) Computational imaging

Lecture notes

Class notes and handouts

Literature

Optics (Hecht) - Pearson

Prerequisites / notice

Physics

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

151-0917-00L Mass Transfer W 4 credits 2V+2U M. Tibbitt, V. Mavrantzas, C.-J. Shih

Abstract

This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore, the application of these principles to important engineering problems is demonstrated.

Objective

This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore, the application of these principles to important engineering problems is demonstrated.

Content

Fick's laws; application and significance of mass transfer; comparison of Fick's laws with Newton's and Fourier's laws; derivation of Fick's 2nd law; diffusion in dilute and concentrated solutions; rotating disk; dispersion; diffusion coefficients, viscosity and heat conduction (Pr and Sc numbers); Brownian motion; Stokes-Einstein equation; mass transfer coefficients (Nu and Sh numbers); mass transfer across interfaces; Analogies for mass-, heat-, and momentum transfer in turbulent flows; film-, penetration-, and surface renewal theories; simultaneous mass, heat and momentum transfer (boundary layers); homogeneous and heterogeneous reversible and irreversible reactions; diffusion-controlled reactions; mass transfer and first order heterogeneous reaction. Applications.

Literature

We teach the fundamentals of process engineering using practical examples as well as concrete process engineering problems in the fostered areas of process control and balancing, thermal separation processes, mechanical separation processes and reaction engineering.

**Course Information**

**Code:** 151-0973-00L

**Title:** Introduction to Process Engineering

**Objective:**
Overview of process engineering; fundamentals of process engineering; processes and balances; overview of thermal separation processes and multiphase systems; introduction to reaction engineering, reactors and residence times.

**Content:**
- Overview of process engineering; fundamentals of process engineering; processes and balances; overview of thermal separation processes and multiphase systems; introduction to reaction engineering, reactors and residence times.
- In addition to teaching basic theoretical knowledge, the focus is on solving typical problems in various subdisciplines of process engineering.

**Lecture notes:**
A script is provided (German language).

**Literature:**
- Further literature will be announced during the course. For the successful completion of the course, the lecture notes, the slides of the lecture and the exercise materials are sufficient.

**Competencies**

**Subject-specific Competencies:**
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

**Method-specific Competencies:**
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed

**Personal Competencies:**
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

**Focus Project**

*In addition to the focus project, 8 ECTS must be acquired as focus courses. Choose these subjects in consultation with the professor responsible for your focus project from the categories of “Electives” and “Focus Specialization”.*

**Number**

**Title**

**Type**

**ECTS**

**Hours**

**Lecturers**

151-0073-10L

MONKEE

This course is part of a one-year course. The 20 credit points will be issued at the end of FS2025 with new enrolling for the same Focus Project in FS2025.
Prerequisites for the focus projects:

a. First year examinations successfully passed.
b. Block 1 and 2 successfully passed.

Abstract

Students develop and build a product from A-Z! They work in teams and independently, learn to structure problems, to identify solutions, system analysis and simulations, as well as presentation and documentation techniques. They build the product with access to a machine shop and state of the art engineering tools (Matlab, Simulink, etc).

Objective

The various objectives of the Focus Project are:
- Synthesizing and deepening the theoretical knowledge from the basic courses of the 1. - 4. semester
- Team organization, work in teams, increase of interpersonal skills
- Independence, initiative, independent learning of new topic contents
- Problem structuring, solution identification in indistinct problem definitions, searches of information
- System description and simulation
- Presentation methods, writing of a document
- Ability to make decisions, implementation skills
- Workshop and industrial contacts
- Learning and recess of special knowledge
- Control of most modern engineering tools (Matlab, Simulink, CAD, CAE, PDM)

Prerequisites / notice

Participation in the Focus Rollout is part of the Focus Project.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-direction and Self-management

Autumn Semester 2024
Objective
The various objectives of the Focus Project are:
- Synthesizing and deepening the theoretical knowledge from the basic courses of the 1. - 4. semester
- Team organization, work in teams, increase of interpersonal skills
- Independence, initiative, independent learning of new topic contents
- Problem structuring, solution identification in indistinct problem definitions, searches of information
- System description and simulation
- Presentation methods, writing of a document
- Ability to make decisions, implementation skills
- Workshop and industrial contacts
- Learning and recess of special knowledge
- Control of most modern engineering tools (Matlab, Simulink, CAD, CAE, PDM)

Prerequisites / notice
Participation in the Focus Rollout is part of the Focus Project.

151-0073-50L Underwater Swarm Robotics W 0 credits 21A M. Zeilinger
This course is part of a one-year course. The 20 credit points will be issued at the end of FS2025 with new enrolling for the same Focus Project in FS2025.

For MAVT BSc and ITET BSc only.

Prerequisites for the focus projects:
a. First year examinations successfully passed.
b. Block 1 and 2 successfully passed.

Abstract
Students develop and build a product from A-Z! They work in teams and independently, learn to structure problems, to identify solutions, system analysis and simulations, as well as presentation and documentation techniques. They build the product with access to a machine shop and state of the art engineering tools (Matlab, Simulink, etc).

Objective
The various objectives of the Focus Project are:
- Synthesizing and deepening the theoretical knowledge from the basic courses of the 1. - 4. semester
- Team organization, work in teams, increase of interpersonal skills
- Independence, initiative, independent learning of new topic contents
- Problem structuring, solution identification in indistinct problem definitions, searches of information
- System description and simulation
- Presentation methods, writing of a document
- Ability to make decisions, implementation skills
- Workshop and industrial contacts
- Learning and recess of special knowledge
- Control of most modern engineering tools (Matlab, Simulink, CAD, CAE, PDM)

Prerequisites / notice
Participation in the Focus Rollout is part of the Focus Project.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Customer Orientation assessed
Leadership and Responsibility assessed
Self-presentation and Social Influence assessed

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-direction and Self-management assessed

151-0075-10L Modular Evolving Industrial Robots W 0 credits 21A M. Bambach
This course is part of a one-year course. The 20 credit points will be issued at the end of FS2025 with new enrolling for the same Focus Project in FS2025.

For MAVT BSc and ITET BSc only.

Prerequisites for the focus projects:
a. First year examinations successfully passed.
b. Block 1 and 2 successfully passed.

Abstract
Students develop and build a product from A-Z! They work in teams and independently, learn to structure problems, to identify solutions, system analysis and simulations, as well as presentation and documentation techniques. They build the product with access to a machine shop and state of the art engineering tools (Matlab, Simulink, etc).

Objective
The various objectives of the Focus Project are:
- Synthesizing and deepening the theoretical knowledge from the basic courses of the 1. - 4. semester
- Team organization, work in teams, increase of interpersonal skills
- Independence, initiative, independent learning of new topic contents
- Problem structuring, solution identification in indistinct problem definitions, searches of information
- System description and simulation
- Presentation methods, writing of a document
- Ability to make decisions, implementation skills
- Workshop and industrial contacts
- Learning and recess of special knowledge
- Control of most modern engineering tools (Matlab, Simulink, CAD, CAE, PDM)

Prerequisites / notice
Participation in the Focus Rollout is part of the Focus Project.
**Formula Student Electric - Chassis**

This course is part of a one-year course. The 20 credit points will be issued at the end of FS2025 with new enrolling for the same Focus Project in FS2025.

For MAVT BSc and ITET BSc only.

**Prerequisites for the focus projects:**
- First year examinations successfully passed.
- Block 1 and 2 successfully passed.

**Abstract**

Students develop and build a product from A-Z! They work in teams and independently, learn to structure problems, to identify solutions, system analysis and simulations, as well as presentation and documentation techniques. They build the product with access to a machine shop and state of the art engineering tools (Matlab, Simulink, etc).

**Objective**

The various objectives of the Focus Project are:
- Synthesizing and deepening the theoretical knowledge from the basic courses of the 1. - 4. semester
- Team organization, work in teams, increase of interpersonal skills
- Independence, initiative, independent learning of new topic contents
- Problem structuring, solution identification in indistinct problem definitions, searches of information
- System description and simulation
- Presentation methods, writing of a document
- Ability to make decisions, implementation skills
- Workshop and industrial contacts
- Learning and recess of special knowledge
- Control of most modern engineering tools (Matlab, Simulink, CAD, CAE, PDM)

**Prerequisites / notice**

Participation in the Focus Rollout is part of the Focus Project.

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**Formula Student Electric - Drivetrain**

This course is part of a one-year course. The 20 credit points will be issued at the end of FS2025 with new enrolling for the same Focus Project in FS2025.

For MAVT BSc and ITET BSc only.

**Prerequisites for the focus projects:**
- First year examinations successfully passed.
- Block 1 and 2 successfully passed.

**Abstract**

Students develop and build a product from A-Z! They work in teams and independently, learn to structure problems, to identify solutions, system analysis and simulations, as well as presentation and documentation techniques. They build the product with access to a machine shop and state of the art engineering tools (Matlab, Simulink, etc).

**Objective**

The various objectives of the Focus Project are:
- Synthesizing and deepening the theoretical knowledge from the basic courses of the 1. - 4. semester
- Team organization, work in teams, increase of interpersonal skills
- Independence, initiative, independent learning of new topic contents
- Problem structuring, solution identification in indistinct problem definitions, searches of information
- System description and simulation
- Presentation methods, writing of a document
- Ability to make decisions, implementation skills
- Workshop and industrial contacts
- Learning and recess of special knowledge
- Control of most modern engineering tools (Matlab, Simulink, CAD, CAE, PDM)

**Prerequisites / notice**

Participation in the Focus Rollout is part of the Focus Project.

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**The Way of Water**

This course is part of a one-year course. The 20 credit points will be issued at the end of FS2025 with new enrolling for the same Focus Project in FS2025.

For MAVT BSc and ITET BSc only.

**Prerequisites for the focus projects:**
- First year examinations successfully passed.
- Block 1 and 2 successfully passed.

**Abstract**

Students develop and build a product from A-Z! They work in teams and independently, learn to structure problems, to identify solutions, system analysis and simulations, as well as presentation and documentation techniques. They build the product with access to a machine shop and state of the art engineering tools (Matlab, Simulink, etc).

**Objective**

The various objectives of the Focus Project are:
- Synthesizing and deepening the theoretical knowledge from the basic courses of the 1. - 4. semester
- Team organization, work in teams, increase of interpersonal skills
- Independence, initiative, independent learning of new topic contents
- Problem structuring, solution identification in indistinct problem definitions, searches of information
- System description and simulation
- Presentation methods, writing of a document
- Ability to make decisions, implementation skills
- Workshop and industrial contacts
- Learning and recess of special knowledge
- Control of most modern engineering tools (Matlab, Simulink, CAD, CAE, PDM)

**Prerequisites / notice**

Participation in the Focus Rollout is part of the Focus Project.

---

**CELLSIUS Project H2**

This course is part of a one-year course. The 20 credit points will be issued at the end of FS2025 with new enrolling for the same Focus Project in FS2025.

For MAVT BSc and ITET BSc only.
Prerequisites for the focus projects:
a. First year examinations successfully passed.
b. Block 1 and 2 successfully passed.

Abstract
Students develop and build a product from A-Z! They work in teams and independently, learn to structure problems, to identify solutions, system analysis and simulations, as well as presentation and documentation techniques. They build the product with access to a machine shop and state of the art engineering tools (Matlab, Simulink, etc).

Objective
The various objectives of the Focus Project are:
- Synthesizing and deepening the theoretical knowledge from the basic courses of the 1. - 4. semester
- Team organization, work in teams, increase of interpersonal skills
- Independence, initiative, independent learning of new topic contents
- Problem structuring, solution identification in indistinct problem definitions, searches of information
- System description and simulation
- Presentation methods, writing of a document
- Ability to make decisions, implementation skills
- Workshop and industrial contacts
- Learning and recession of special knowledge
- Control of most modern engineering tools (Matlab, Simulink, CAD, CAE, PDM)

Prerequisites / notice
Participation in the Focus Rollout is part of the Focus Project.

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**151-0079-10L ARGOS**
This course is part of a one-year course. The 20 credit points will be issued at the end of FS2025 with new enrolling for the same Focus Project in FS2025.

For MAVT BSc and ITET BSc only.

Prerequisites for the focus projects:
a. First year examinations successfully passed.
b. Block 1 and 2 successfully passed.

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**151-0079-20L Development of a High Performance Cryogenic Rocket Engine**
This course is part of a one-year course. The 20 credit points will be issued at the end of FS2025 with new enrolling for the same Focus Project in FS2025.

For MAVT BSc and ITET BSc only.

Prerequisites for the focus projects:
a. First year examinations successfully passed.
b. Block 1 and 2 successfully passed.

---

**151-0079-30L Swissloop**
This course is part of a one-year course. The 20 credit points will be issued at the end of FS2025 with new enrolling for the same Focus Project in FS2025.

For MAVT BSc and ITET BSc only.

Prerequisites for the focus projects:
a. First year examinations successfully passed.
b. Block 1 and 2 successfully passed.

---

Abstract
Students develop and build a product from A-Z! They work in teams and independently, learn to structure problems, to identify solutions, system analysis and simulations, as well as presentation and documentation techniques. They build the product with access to a machine shop and state of the art engineering tools (Matlab, Simulink, etc).
Objective: The various objectives of the Focus Project are:
- Synthesizing and deepening the theoretical knowledge from the basic courses of the 1. - 4. semester
- Team organization, work in teams, increase of interpersonal skills
- Independence, initiative, independent learning of new topic contents
- Problem structuring, solution identification in indistinct problem definitions, searches of information
- System description and simulation
- Presentation methods, writing of a document
- Ability to make decisions, implementation skills
- Workshop and industrial contacts
- Learning and recess of special knowledge
- Control of most modern engineering tools (Matlab, Simulink, CAD, CAE, PDM)

Prerequisites / notice: Participation in the Focus Rollout is part of the Focus Project.

### Focus Specialization

#### Sustainable Energy and Processes

**Focus Coordinator: Prof. Mark Tibbitt**

*In order to achieve the required 20 credit points for the Focus Specialization Sustainable Energy and Processes you need to pass at least 2 core courses (W+) and at least 2 of the elective courses, according to the presentation of the Focus Specialization. An additional course, if needed, can be selected among the courses offered by D-MAVT (151-…).*

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0917-00L</td>
<td>Mass Transfer</td>
<td>W+</td>
<td>4</td>
<td>2V+2U</td>
<td>M. Tibbitt, V. Mavrantzas, C.-J. Shih</td>
</tr>
</tbody>
</table>

**Abstract**

This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore, the application of these principles to important engineering problems is demonstrated.

**Objective**

This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore, the application of these principles to important engineering problems is demonstrated.

**Content**

Fick's laws; application and significance of mass transfer; comparison of Fick's laws with Newton's and Fourier's laws; derivation of Fick's 2nd law; diffusion in dilute and concentrated solutions; rotating disk; dispersion; Brownian motion; Stokes-Einstein equation; mass transfer coefficients (Nu and Sh numbers); mass transfer across interfaces; Analogies for mass-, heat-, and momentum transfer in turbulent flows; film-, penetration-, and surface renewal theories; simultaneous mass, heat and momentum transfer (boundary layers); homogeneous and heterogeneous reversible and irreversible reactions; diffusion-controlled reactions; mass transfer and first order heterogeneous reaction. Applications.

**Literature**


**Prerequisites / notice**

Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: fostered
- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: fostered
- **Social Competencies**
  - Communication: fostered
  - Cooperation and Teamwork: fostered
  - Sensitivity to Diversity: fostered
- **Personal Competencies**
  - Adaptability and Flexibility: fostered
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

<table>
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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0973-00L</td>
<td>Introduction to Process Engineering</td>
<td>W+</td>
<td>4</td>
<td>2V+2U</td>
<td>F. Donat, C. Müller</td>
</tr>
</tbody>
</table>

**Abstract**

Overview of process engineering: fundamentals of process engineering; processes and balances; overview of thermal separation processes and multiphase systems; overview of mechanical separation processes and granular systems; introduction into reaction engineering, reactors and residence times.

**Objective**

We teach the fundamentals of process engineering using practical examples as well as concrete process engineering problems in the areas of process control and balancing, thermal separation processes, mechanical separation processes and reaction engineering.

**Content**

Overview of process engineering: fundamentals of process engineering; processes and balances; overview of thermal separation processes and multiphase systems; overview of mechanical separation processes and granular systems; introduction into reaction engineering, reactors and residence times. In addition to teaching basic theoretical knowledge, the focus is on solving typical problems in various subdisciplines of process engineering.

**Lecture notes**

A script is provided (German language).

**Literature**

Further literature will be announced during the course. For the successful completion of the course, the lecture notes, the slides of the lecture and the exercise materials are sufficient.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0123-00L</td>
<td>Experimental Methods for Engineers</td>
<td>W+</td>
<td>4</td>
<td>2V+2U</td>
<td>D. J. Norris, F. Coletti, M. Lukatskaya, A. Manera, O. Supponen, M. Tibbitt</td>
</tr>
</tbody>
</table>

**Abstract**

The course presents an overview of measurement tasks in engineering environments. Different concepts for the acquisition and processing of typical measurement quantities are introduced. Following an initial in-class introduction, laboratory exercises from different application areas (especially in thermofluidics, energy, and process engineering) are attended by students in small groups.
Objective
Introduction to various aspects of measurement techniques, with particular emphasis on thermo-fluidic, energy, and process-engineering applications.

Understanding of various sensing technologies and analysis procedures.
Exposure to typical experiments, diagnostics hardware, data acquisition, and processing.

Content
Study of applications in the laboratory. Fundamentals of scientific documentation and reporting.

In-class introduction to representative measurement techniques in the research areas of the participating institutes (fluid dynamics, energy technology, and process engineering).

Student participation in ~6 laboratory experiments (study groups of ~3 students, dependent on the number of course participants and available experiments).

Lab reports for all attended experiments have to be submitted by the study groups.

Lecture notes
Presentations, handouts, and instructions are provided for each experiment.

Literature

Prerequisites / notice
Basic understanding in the following areas:
- fluid mechanics, thermodynamics, heat and mass transfer
- electrical engineering / electronics
- numerical data analysis and processing (e.g. using MATLAB)

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving fostered
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork assessed
Leadership and Responsibility fostered

Personal Competencies
Critical Thinking fostered
Self-direction and Self-management fostered

151-0109-00L Turbulent Flows W 4 credits 2V+1U P. Jenny

Abstract
Laminar and turbulent flows, instability and origin of turbulence - Statistical description: averaging, turbulent energy, dissipation, closure problem - Scalings. Homogeneous isotropic turbulence, correlations, Fourier representation, energy spectrum - Free turbulence: wake, jet, mixing layer - Wall turbulence: Channel and boundary layer - Computation and modelling of turbulent flows

Objective
Basic physical phenomena of turbulent flows, quantitative and statistical description, basic and averaged equations, principles of turbulent flow computation and elements of turbulence modelling

Content
- Properties of laminar, transitional and turbulent flows.
- Origin and control of turbulence. Instability and transition.
- Statistical description, averaging, equations for mean and fluctuating quantities, closure problem.
- Scalings, homogeneous isotropic turbulence, energy spectrum.
- Turbulent free shear flows. Jet, wake, mixing layer.
- Wall-bounded turbulent flows.
- Turbulent flow computation and modeling.

Lecture notes
Lecture notes are available

Literature

151-0125-00L Hydrodynamics and Cavitation W 4 credits 3G O. Supponen

Abstract
This course builds on the foundations of fluid dynamics to describe hydrodynamic flows and provides an introduction to cavitation.

Objective
The main learning objectives of this course are:
1. Identify and describe dominant effects in liquid fluid flows through physical modelling.
2. Identify and predict the onset of hydrodynamic instabilities.
3. Describe acoustic wave behaviour in liquids.
4. Explain tension, nucleation and phase-change in liquids.
5. Predict the behaviour of a gas bubble subject to changes in surrounding liquid pressure.
6. Describe hydrodynamic cavitation and its consequences in physical terms.
7. Recognise experimental techniques and industrial and medical applications for cavitation.
8. Read and evaluate research papers on recent research on cavitation and bubble dynamics and communicate the content orally to a multidisciplinary audience.

Content
The course gives an overview on the following topics: basics of hydrodynamics, capillarity, hydrodynamic instabilities, liquid fragmentation. Acoustics in liquids, tension in liquids, phase change. Cavitation and bubble dynamics: single bubbles (nucleation, dynamics, collapse), bubble clouds and cavitation flows. Industrial applications and measurement techniques.

Lecture notes
Class notes and handouts

Literature
Literature will be provided in the course material.

Prerequisites / notice
Fluid dynamics I & II or equivalent

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Social Competencies
Communication assessed

Personal Competencies
Cooperation and Teamwork fostered

Critical Thinking assessed

151-0163-00L Nuclear Energy Conversion W 4 credits 2V+1U A. Manera

Abstract

Objective

Content

Competencies

Notice

Prerequisites / notice

Lab reports for all attended experiments have to be submitted by the study groups.

Lecture notes

Literature
This course is proposed for Master and PhD students interested in getting knowledge in acoustics. Students will be able to understand, describe analytically and interpret sound generation, absorption and propagation.

First, magnitudes characterizing sound propagation are reviewed and the constitutive equations for acoustics are derived. Then the different types of sources (monopole/dipole/quadrupole, punctual, non-compact) are introduced and linked to the noise generated by turbulent flows, coherent vortical structures or fluctuating heat release. The scattering of sound by rigid bodies is given in basic configurations. Analytical, experimental and numerical methods used to analyze sound in ducts and rooms are presented (Green functions, Galerkin expansions, Helmholtz solvers).

The second part covers elastic wave phenomena, such as dispersion and vibration modes, in infinite and finite structures.

Lecture notes
Hand-outs will be distributed during the class.

Literature
Books will be recommended for each chapter.

Abstract
- define and quantify the key performance indicators of sustainable energy systems;
- select and apply appropriate models for conversion, storage and transport of energy;
- develop mathematical models for the analysis, design and operations of multi-energy systems and solve them with appropriate mathematical tools;
- select and apply methodologies for the uncertainty analysis on energy systems models;
- apply the acquired knowledge to tackle the challenges of the energy transition.

In the course "Introduction to Modeling and Optimization of Sustainable Energy Systems", the competencies of process understanding, system understanding, modeling, concept development, data analysis & interpretation and measurement methods are taught, applied and examined. Programming is applied.

The global energy transition: Key performance indicators of sustainable energy systems; Optimization models; Heat integration and heat exchanger networks; Life-cycle assessment; Models for conversion, storage and transport technologies; Multi-energy systems; Design, operations and analysis of energy systems; Uncertainties in energy system modeling.

Lecture notes
Lecture slides and supplementary documentation will be available online. Reference to appropriate book chapters and scientific papers will be provided.

Abstract
This course provides an introduction to acoustics. It focuses on fundamental phenomena of airborne and structure-borne sound waves. The lecture combines theoretical principles with practical insights and interpretations.

Content
The second part covers elastic wave phenomena, such as dispersion and vibration modes, in infinite and finite structures.

Lecture notes
Hand-Outs will be distributed. Additional literature and information will be provided.

Literature

R. L. Murray: Nuclear Energy (Sixth Edition), An Introduction to the Concepts, Systems, and Applications of Nuclear Processes, Elsevier

151-0215-00L Fundamentals of Acoustics W+ 4 credits N. Noiray, B. Van Damme

Objective
This course is proposed for Master and PhD students interested in getting knowledge in acoustics. Students will be able to understand, describe analytically and interpret sound generation, absorption and propagation.

Content
First, magnitudes characterizing sound propagation are reviewed and the constitutive equations for acoustics are derived. Then the different types of sources (monopole/dipole/quadrupole, punctual, non-compact) are introduced and linked to the noise generated by turbulent flows, coherent vortical structures or fluctuating heat release. The scattering of sound by rigid bodies is given in basic configurations. Analytical, experimental and numerical methods used to analyze sound in ducts and rooms are presented (Green functions, Galerkin expansions, Helmholtz solvers).

The second part covers elastic wave phenomena, such as dispersion and vibration modes, in infinite and finite structures.

Lecture notes
Hand-outs will be distributed during the class.

Literature
No. Noiray

151-0221-00L Introduction to Modeling and Optimization of Sustainable Energy Systems W+ 4 credits G. Sansavini, A. Bardow, S. Moret

Objective
At the end of this course, students will be able to:
- define and quantify the key performance indicators of sustainable energy systems;
- select and apply appropriate models for conversion, storage and transport of energy;
- develop mathematical models for the analysis, design and operations of multi-energy systems and solve them with appropriate mathematical tools;
- select and apply methodologies for the uncertainty analysis on energy systems models;
- apply the acquired knowledge to tackle the challenges of the energy transition.

In the course "Introduction to Modeling and Optimization of Sustainable Energy Systems", the competencies of process understanding, system understanding, modeling, concept development, data analysis & interpretation and measurement methods are taught, applied and examined. Programming is applied.

The global energy transition: Key performance indicators of sustainable energy systems; Optimization models; Heat integration and heat exchanger networks; Life-cycle assessment; Models for conversion, storage and transport technologies; Multi-energy systems; Design, operations and analysis of energy systems; Uncertainties in energy system modeling.

Lecture notes
Lecture slides and supplementary documentation will be available online. Reference to appropriate book chapters and scientific papers will be provided.

Abstract
This course will provide an introduction to the fundamentals and the applications of combustion in energy conversion and nanoparticles synthesis. The content is highly relevant for technologies which cannot be electrified such as long distance aviation and shipping, and which will more and more rely on carbon-neutral synthetic fuels.

Objective
The main learning objectives of this course are: 1. Understand the thermodynamic, fluid-dynamic and chemical kinetics fundamentals of combustion processes. 2. Predict relevant parameters for combustion systems, such as laminar and turbulent flame speeds, adiabatic flame temperature or quenching distance. 3. Understand the causal relations of relevant combustion parameters such as the pressure influence on the laminar flame speed. 4. Analyze the challenges of developing sustainable combustion technologies based on carbon-neutral synthetic fuels.

Content

Lecture notes
No script available. Instead, material will be provided in lecture slides and the following text book (which can be downloaded for free) will be followed:


Teaching language, assignments and lecture slides in English

Literature

151-0913-00L Introduction to Photonics W 4 credits R. Quidant, J. Ortega Arroyo

Abstract
This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

151-0293-00L Combustion and Reactive Processes in Energy and Materials Technology W 4 credits N. Noiray, B. Van Damme

Objective
This course will provide an introduction to the fundamentals and the applications of combustion in energy conversion and nanoparticles synthesis. The content is highly relevant for technologies which cannot be electrified such as long distance aviation and shipping, and which will more and more rely on carbon-neutral synthetic fuels.

Objective
The main learning objectives of this course are: 1. Understand the thermodynamic, fluid-dynamic and chemical kinetics fundamentals of combustion processes. 2. Predict relevant parameters for combustion systems, such as laminar and turbulent flame speeds, adiabatic flame temperature or quenching distance. 3. Understand the causal relations of relevant combustion parameters such as the pressure influence on the laminar flame speed. 4. Analyze the challenges of developing sustainable combustion technologies based on carbon-neutral synthetic fuels.

Content

Lecture notes
No script available. Instead, material will be provided in lecture slides and the following text book (which can be downloaded for free) will be followed:

Objective

Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.

Content

I- BASICS OF WAVE THEORY
1) General concepts
2) Differential wave equation
3) Wavefront
4) Plane waves and Fourier decomposition of optical fields
5) Spherical waves and Huygens-Fresnel principle

II- ELECTROMAGNETIC WAVES
1) Maxwell equations
2) Wave equation for EM waves
3) Dielectric permittivity
4) Refractive index
5) Nonlinear optics
6) Polarisation and polarisation control

III- PROPAGATION OF LIGHT
1) Waves at an interface
2) The Fresnel coefficients
3) Total internal reflection
4) Evanescent waves
5) Dispersion diagram

IV- INTERFERENCES
1) General considerations
2) Temporal and spatial coherence
3) The Young double slit experiment
4) Diffraction gratings
5) The Michelson interferometer
6) Multi-wave interference
7) Antireflecting coating and interference filters
8) Optical holography

V- LIGHT MANIPULATION
1) Optical waveguides
2) Photonic crystals
3) Metamaterials and metasurfaces
4) Optical cavities

VI- OPTICAL FORCES AND OPTICAL TWEEZERS
1) History of optical forces
2) Theory of optical trapping
3) Atom cooling
4) Optomechanics
5) Applications of optical tweezers

VII- INTRODUCTION TO OPTICAL MICROSCOPY
1) Basic concepts
2) Direct and Fourier imaging
3) Image formation
4) Fluorescence microscopy
5) Scattering-based microscopy
6) Digital holography
7) Computational imaging

Lecture notes

Class notes and handouts

Literature

Optics (Hecht) - Pearson

Prerequisites / notice

Physics

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Problem-solving

Personal Competencies

Creative Thinking

Critical Thinking

151-0941-00L Molecular Sensors: From Fundamentals to Health and Environmental Applications W 4 credits 2V+2U A. Günther, P. Gerber

Note: previous course title until HS23 "Molecular Health Sensors and Devices"

Abstract

Molecular sensors are used in everyday life in health care, environmental monitoring, food safety, space and other fields. Sources of molecular information, its transport and fundamental concepts of molecular sensing will be discussed. In the scope of group projects, the acquired knowledge will be applied and deepened in case studies.

Data: 15.06.2024 12:39 Autumn Semester 2024
After the course, the students will:

- know the requirements and merits of molecular sensors for health, environmental and other emerging applications (e.g. space)
- understand transport phenomena of molecular information & surface interactions and know how to quantitatively describe these
- understand fundamental sensing concepts for the detection and quantification of molecular analytes
- know concepts of signal processing
- be capable to apply the learnt knowledge to conceive and engineer sensor concepts and systems
- know how to investigate sensor-related literature and present scientific data

This course consists of a theoretical and a project-based learning block. In the first 10 semester weeks, theoretical knowledge will be provided through lectures and deepened in corresponding exercises. In the last 4 weeks, the students will apply the learned concepts through group projects to investigate case studies. The outcome will be present.

Content

Transport of Molecular Information; Surface Interactions; Sensor Fundamentals; Chemoresistive Sensing; Electrochemical Sensing; Mass-sensitive; Capacitive Sensing; Signal Processing; Medical Requirements for Molecular Sensing

Lecture notes

Hand-outs will be provided to each lecture including the exercises and their solutions.

Materials

Lecture notes available on course website.

Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices

Prerequisites / notice

Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.

Objective

The course will provide you with the fundamentals of the new and exciting field of ultrasound-based microrobots to treat various diseases.

Content

- Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices
- Microrobots for applications in medicine and additive manufacturing.
- Furthermore, we will explore how ultrasound can be used in additive manufacturing for tissue constructs and robotics.
- This course consists of a theoretical and a project-based learning block. In the first 10 semester weeks, theoretical knowledge will be provided through lectures and deepened in corresponding exercises. In the last 4 weeks, the students will apply the learned concepts through group projects to investigate case studies. The outcome will be present.

Materials

Lecture notes available on course website.

Number

151-0509-00L

Title

Acoustics in Fluid Media: From Robotics to Additive Manufacturing

Type

W

ECTS

4 credits

Hours

3G

Lecturers

D. Ahmed

Abstract

The course will provide you with the fundamentals of the new and exciting field of ultrasound-based microrobots to treat various diseases. Furthermore, we will explore how ultrasound can be used in additive manufacturing for tissue constructs and robotics.

Objective

The course is designed to equip students with skills in the design and development of ultrasound-based manipulation devices and microrobots for applications in medicine and additive manufacturing.

Content

- Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices
- Microrobots for applications in medicine and additive manufacturing.
- Furthermore, we will explore how ultrasound can be used in additive manufacturing for tissue constructs and robotics.

Materials

Lecture notes available on course website.

Number

151-0575-01L

Title

Signals and Systems

Type

W

ECTS

4 credits

Hours

2V+2U

Lecturers

A. Carron

Abstract

Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to signals and produce other signals. In this course, we explore how signals can be represented and manipulated, and their effects on systems. We further explore how we can discover basic system properties by exciting a system with various types of signals.

Objective

Master the basics of signals and systems. Apply this knowledge to problems in the homework assignments and programming exercise.

Content

- Master the basics of signals and systems. Apply this knowledge to problems in the homework assignments and programming exercise.

Materials

Lecture notes available on course website.
Overview of Mechatronics topics and study subjects. Identification of minimum 10 pertinent refereed articles or works in the literature in
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

Students are introduced to the fundamentals of semiconductors, the basics of micromachining and silicon process technology and will learn about the fabrication of microsystems and -devices by a sequence of defined processing steps (process flow).

The students are familiar with the challenges of the fascinating and interdisciplinary field of Mechatronics and Mikrosystems. They are introduced in the basics of independent non-experimental scientific research and are able to summarize and to present the results efficiently.

Handouts (available online)

- S.M. Sze: Semiconductor Devices, Physics and Technology
- W. Menz, J. Mohr, O. Paul: Microsystem Technology
- Hong Xiao: Introduction to Semiconductor Manufacturing Technology
- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications

Prerequisites / notice

The lecture will be taught in English.

151-0621-00L Microsystems I: Process Technology and Integration

Abstract

Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystem devices by the combination of unit process steps (= process flow).

Objective

- Introduction to microsystems technology (MST) and micro electro mechanical systems (MEMS)
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.
- Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties.

Application of selected technologies will be demonstrated on case studies.

Lecture notes

Handouts (available online)

Prerequisites / notice

Prerequisites: Physics I and II

151-0640-00L Studies on Mechatronics

The supervising professors can be selected in myStudies during registration of the course. For exceptions please contact the focus coordinator and info@mavt.ethz.ch.

This course is not available to incoming exchange students.

Abstract

Overview of Mechatronics topics and study subjects. Identification of minimum 10 pertinent refereed articles or works in the literature in consultation with supervisor or instructor. After 4 weeks, submission of a 2-page proposal outlining the value, state-of-the art and study plan based on these articles. After feedback on the substance and technical writing by the instructor, project commences.

Objective

The students should make their first experiences in the use of computer-based simulation.

Content

- Application and application areas of the event-driven simulation
- Application in the context of Industry 4.0 (digital twin)
- Exemplary application of a software tool (Technomatix-Simulation-Software)
- Internal organization and functionality of simulation tools
- Procedure for application: optimizing, experimental design planning, analysis, data preparation
- Controlling philosophies, emergency concepts, production in sequence, line production, rescheduling
- Application on the facilities projecting
- Applications of Virtual and Mixed Reality

The knowledge is enhanced by practice-oriented exercises and an excursion. A guest speaker will present a practical example.

Lecture notes

Will be sent by email before the lecture (pdf).

Prerequisites / notice

Recommended for all Bachelor-Students in the 5th semester and Master-Students in the 7th semester (MAVT, MTEC, PhD students in material sciences) and for all with interest in production (e.g., MTEC, HEST, etc.)

151-0703-00L Operational Simulation of Production Lines

Abstract

The students learn the application of the event-based and computer-based simulation for layout and improvement of production facilities by means of practical examples and by using the so-called «Digital Twin» within the context of «Industry 4.0». They learn how virtual and mixed reality tools can be used together with the Digital Twin to plan and support the operation of a production line.

Objective

- Application and application areas of the event-driven simulation
- Application in the context of Industry 4.0 (digital twin)
- Exemplary application of a software tool (Technomatix-Simulation-Software)
- Internal organization and functionality of simulation tools
- Procedure for application: optimizing, experimental design planning, analysis, data preparation
- Controlling philosophies, emergency concepts, production in sequence, line production, rescheduling
- Application on the facilities projecting
- Applications of Virtual and Mixed Reality

Further, the lecture gives insights into the methods-time measurement (MTM) for evaluating human work places as basis for the simulation and work planning. The students should make their first experiences in the use of computer-based simulation. Further, the lecture gives insights into the methods-time measurement (MTM) for evaluating human work places as basis for the simulations and work planning. The students should make their first experiences in the use of computer-based simulation.
We will provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, and multi-body systems. In this context, the learning material will build upon the courses for mechanics and dynamics available at ETH, with the particular focus on their application to robotic systems. The goal is to foster the conceptual understanding of similarities and differences among the various types of robots. In the second part, we will apply the learned material to classical robotic arms as well as legged systems and discuss kinematic constraints and interaction forces. In the third part, focus is put on modeling fixed wing aircraft, along with related design and control concepts. In this context, we also touch aerodynamics and flight mechanics to an extent typically required in robotics. The last part finally covers different helicopter types, with a focus on quadrotors and the coaxial configuration which we see today in many UAV applications. Case studies on all main topics provide the link to real applications and to the state of the art in robotics.

The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

Nothing works without electronics! Typical products in mechanical engineering such as machine tools, as well as any kind of vehicle contain a significant amount of electric or electronic components of more than 60%. Thus, it is important to master the value added process sequence for electric and electronic components.

The lecture follows the value added process sequence of electric and electronic components. It contains: Development of electric and electronic circuits, design of electronic circuits on printed circuit boards as well as in hybrid technology, integrated test technology, planning of production lines, production of highly integrated electronic on a wafer as well as recycling.

The lecture concludes with an excursion to a large manufacturing company. Here, students can see the application and realization of the manufacturing of electric and electronic devices. The lecture is partly given by experts from industry. It is supplemented by an excursion to one of the industry partners.

The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems. The focus is on their application to robotic systems. The goal is to foster the conceptual understanding of similarities and differences among the various types of robots. In the second part, we will apply the learned material to classical robotic arms as well as legged systems and discuss kinematic constraints and interaction forces. In the third part, focus is put on modeling fixed wing aircraft, along with related design and control concepts. In this context, we also touch aerodynamics and flight mechanics to an extent typically required in robotics. The last part finally covers different helicopter types, with a focus on quadrotors and the coaxial configuration which we see today in many UAV applications. Case studies on all main topics provide the link to real applications and to the state of the art in robotics.

The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

The lecture concludes with an excursion to a large manufacturing company. Here, students can see the application and realization of the manufacturing of electric and electronic devices. The lecture is partly given by experts from industry. It is supplemented by an excursion to one of the industry partners.

The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems. The focus is on their application to robotic systems. The goal is to foster the conceptual understanding of similarities and differences among the various types of robots. In the second part, we will apply the learned material to classical robotic arms as well as legged systems and discuss kinematic constraints and interaction forces. In the third part, focus is put on modeling fixed wing aircraft, along with related design and control concepts. In this context, we also touch aerodynamics and flight mechanics to an extent typically required in robotics. The last part finally covers different helicopter types, with a focus on quadrotors and the coaxial configuration which we see today in many UAV applications. Case studies on all main topics provide the link to real applications and to the state of the art in robotics.

The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.
I- BASICS OF WAVE THEORY
1) General concepts
2) Differential wave equation
3) Wavefront
4) Plane waves and Fourier decomposition of optical fields
5) Spherical waves and Huygens-Fresnel principle

II- ELECTROMAGNETIC WAVES
1) Maxwell equations
2) Wave equation for EM waves
3) Dielectric permittivity
4) Refractive index
5) Nonlinear optics
6) Polarisation and polarisation control

III- PROPAGATION OF LIGHT
1) Waves at an interface
2) The Fresnel coefficients
3) Total internal reflection
4) Evanescent waves
5) Dispersion diagram

IV- INTERFERENCES
1) General considerations
2) Temporal and spatial coherence
3) The Young double slit experiment
4) Diffraction gratings
5) The Michelson interferometer
6) Multi-wave interference
7) Antireflecting coating and interference filters
8) Optical holography

V- LIGHT MANIPULATION
1) Optical waveguides
2) Photonic crystals
3) Metamaterials and metasurfaces
4) Optical cavities

VI- OPTICAL FORCES AND OPTICAL TWEEZERS
1) History of optical forces
2) Theory of optical trapping
3) Atom cooling
4) Optomechanics
5) Applications of optical tweezers

VII- INTRODUCTION TO OPTICAL MICROSCOPY
1) Basic concepts
2) Direct and Fourier imaging
3) Image formation
4) Fluorescence microscopy
5) Scattering-based microscopy
6) Digital holography
7) Computational imaging

Lecture notes
Class notes and handouts

Literature
Optics (Hecht) - Pearson

Prerequisites / notice
Physics

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed

Method-specific Competencies
Analytical Competencies
assessed

Personal Competencies
Creative Thinking
Problem-solving
assessed

Critical Thinking
assessed

151-0941-00L Molecular Sensors: From Fundamentals to Health and Environmental Applications
W 4 credits 2V+2U A. Güntner, P. Gerber

Abstract
Molecular sensors are used in everyday life in health care, environmental monitoring, food safety, space and other fields. Sources of molecular information, its transport and fundamental concepts of molecular sensing will be discussed. In the scope of group projects, the acquired knowledge will be applied and deepened in case studies.

Objective
After the course, the students will:

• know the requirements and merits of molecular sensors for health, environmental and other emerging applications (e.g. space)
• understand transport phenomena of molecular information & surface interactions and know how to quantitatively describe these
• understand fundamental sensing concepts for the detection and quantification of molecular analytes
• know concepts of signal processing
• be capable to apply the learnt knowledge to conceive and engineer sensor concepts and systems
• know how to investigate sensor-related literature and present scientific data

This course consists of a theoretical and a project-based learning block. In the first 10 semester weeks, theoretical knowledge will be provided through lectures and deepened in corresponding exercises. In the last 4 weeks, the students will apply the learned concepts through group projects to investigate case studies. The outcome will be present.

Content
Transport of Molecular Information; Surface Interactions; Sensor Fundamentals; Chemoresistive Sensing; Electrochemical Sensing; Mass-sensitive; Capacitive Sensing; Signal Processing; Medical Requirements for Molecular Sensing

Lecture notes
Hand-outs will be provided to each lecture including the exercises and their solutions.
Competencies

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving

Social Competencies

Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Sensitivity to Diversity

Personal Competencies

Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection

227-0113-00L Power Electronics

W 6 credits 4G J. Huber

Abstract

Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

Objective

Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

Content

Fields of application and application examples of power electronic converters, basic concept of switch-mode voltage and current conversion, pulse-width modulation (PWM); derivation and operating modes (continuous and discontinuous current mode) of DC/DC converter topologies, buck / boost / buck-boost converter; extension to DC/AC conversion using differences of unipolar output voltages varying over time; single-phase diode rectifier; boost-type PWM rectifier featuring sinusoidal input current; tolerance band AC current control and cascaded output voltage control with inner constant switching current control; local and global averaging of switching frequency discontinuous quantities for calculation of component stresses; three-phase AC/DC conversion, center-tap rectifier with impressed output current, thyristor function, thyristor center-tap and full-bridge converter, rectifier and inverter operation, control angle and recovery time, inverter operation limit; basics of inductors and single-phase transformers, design based on scaling laws; Isolated DC/DC converter, flyback and forward converter, single-switch and two-switch circuit; single-phase DC/AC conversion, four-quadrant converter, unipolar and bipolar modulation, fundamental frequency model of AC-side operating behaviour; three-phase DC/AC converter with star-connected three-phase load, zero sequence (common-mode) and current forming differential-mode output voltage components, fundamental frequency modulation and PWM with single triangular carrier and individual carrier signals of the phases.

Lecture notes

Lecture notes and associated exercises including correct answers, simulation program for interactive self-learning including visualization/animation features.

Prerequisites

Prerequisites: Basic knowledge of electrical engineering / electric circuit analysis and signal theory.

Competencies

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving

Social Competencies

Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Sensitivity to Diversity

Personal Competencies

Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection

227-0124-00L Embedded Systems

W 6 credits 4G M. Magno

Abstract

An embedded system is a combination of hardware and software, either fixed in function or programmable, that is designed for a specific application scenario or for a specific task within a larger system. They are part of industrial machines such as agricultural and manufacturing equipment, automotive systems, medical equipment, household appliances, sensor networks, and the Internet of Things.

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Objective

Understanding the specific requirements and problems that arise in embedded system applications.

Understanding the hardware structure of a microcontroller and an embedded system; memory architecture and memory map, internal and external peripherals, low-power and low-energy design as well as instruction sets and computational accelerators.

Understanding the firmware structure of a microcontroller and an embedded system; low-level instruction set, hardware-software interfaces, communication between components, embedded real-time operating systems, real-time scheduling, shared resources, low-power and low-energy programming as well as computational accelerators.

Using formal models and methods for designing and optimizing embedded systems.

Gaining experience with practical applications of the C programming language, embedded real-time operating systems, and debug functionalities of the associated design environment to design, implement, and verify embedded firmware.

Through project-based activities, students will gain substantial experience in applying the C programming language in the context of embedded systems. Projects will involve developing and implementing firmware, utilizing embedded real-time operating systems, and exploring the debugging functionalities within design environments. This hands-on approach aims to bridge the gap between theoretical knowledge and practical application, allowing students to experience the full lifecycle of embedded system development from design to implementation and verification.

Content

This lecture focuses on the design of embedded systems using formal models and methods.

Besides the theoretical lecture, the course contains laboratory sessions where students transfer the learned theoretical aspects into praxis by programming a microcontroller and interfacing it with sensors and actuators. Students will be exposed to a commercial microcontroller, and the development board extend with a custom-designed embedded systems educational platform.

Specifically, the following topics will be covered in the course: hardware and software structures of embedded systems, low-level instruction set, memory architecture and memory map, peripherals, hardware-software interfaces, communication between components, firmware design methodologies, firmware design using the C programming language, embedded real-time operating systems, real-time scheduling, shared resources, low-power, and low-energy designs as well as computational accelerators.

Lecture notes

Lecture material, publications, exercise sheets, and laboratory documentation will be available on the course’s Moodle page.

Literature


Prerequisites / notice

Prerequisites: C programming, circuit theory, digital logic, binary number representations.

Recommended: basic knowledge of assembly programming and computer architecture.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

assessed

assessed

227-0517-10L Fundamentals of Electric Machines W 6 credits 4G D. Bortis

Abstract

This course introduces to different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.

Objective

The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are to evaluate machine types for given specifications and to acquire the ability to perform a rough design of an electrical machine while considering the versatile aspects with respect to magnetic, electrical, mechanical and thermal limitations. Exercises are used to consolidate the presented theoretical concepts.

Content

- Fundamentals in magnetic circuits and electromechanical energy conversion.
- Force and torque calculation.
- Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine).
- Complex space vector notation, rotating coordinate system (dq-transformation).
- Loss components in electric machines, scaling laws of electromechanical actuators.
- Mechanical and thermal modelling.

Lecture notes

Lecture notes and associated exercises including correct answers

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

assessed

assessed

Method-specific Competencies

Analytical Competencies

Decision-making

Problem-solving

fostered

fostered

376-1504-00L Physical Human Robot Interaction (pHRI) W 4 credits 2V+2U O. Lambercy, P. Wolf

Abstract

This course focuses on the emerging, interdisciplinary field of physical human-robot interaction, bringing together themes from robotics, real-time control, human factors, haptics, virtual environments, interaction design and other fields to enable the development of human-oriented robotic systems.
The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and design safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1) Identify critical human factors in physical human-robot interaction and use these to derive design requirements;
2) Compare and select mechatronic components that optimally fulfill the defined design requirements;
3) Derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;
4) Design control hardware and software and implement and test human-interactive control strategies on the physical setup;
5) Characterize and optimize such systems using both engineering and psychophysical evaluation metrics;
6) Investigate and optimize one aspect of the physical setup and convey and defend the gained insights in a technical presentation.

This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in device design for humans such as transparency and stability analysis, safety hardware and procedures. The course is organized into lectures that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical human-robot interaction, laboratory sessions and lab visits.

Students will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. Here the salient features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic platform (https://relab.ethz.ch/telesystems/openhardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

Will be distributed on Moodle before the lectures.


Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Problem-solving assessed
Project Management assessed

Social Competencies
Communication assessed
Cooperation and Teamwork assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking assessed
Self-direction and Self-management fostered

Techniques and Technologies assessed

Media and Digital Technologies fostered
Problem-solving assessed

Decision-making fostered

Leadership and Responsibility fostered
Self-presentation and Social Influence assessed
Sensitivity to Diversity fostered

Negotiation fostered
Integrity and Work Ethics assessed
Self-direction and Self-management assessed

Micro- and Nanosystems Technology
Focus Coordinator: Prof. Christofer Hierold

151-0621-00L  Microsystems I: Process Technology and Integration W+ 6 credits 3V+2U M. Haluska, C. Hierold

Abstract
Students are introduced to the fundamentals of semiconductors, the basics of micromachining and silicon process technology and will learn about the fabrication of microsystems and -devices by a sequence of defined processing steps (process flow).

Objective
Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystem devices by the combination of unit process steps (= process flow).

Content
- Introduction to microsystems technology (MST) and micro electro mechanical systems (MEMS)
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.
- Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties.

Application of selected technologies will be demonstrated on case studies.

Lecture notes
Handouts (available online)

Literature
- S.M. Sze: Semiconductor Devices, Physics and Technology
- W. Menz, J. Mohr, O.Paul: System Technology
- Hong Xiao: Introduction to Semiconductor Manufacturing Technology
- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications

Prerequisites / notice
Prerequisites: Physics I and II

151-0509-00L  Acoustics in Fluid Media: From Robotics to Additive Manufacturing W 4 credits 3G D. Ahmed

Abstract
The course will provide you with the fundamentals of the new and exciting field of ultrasound-based microrobots to treat various diseases. Furthermore, we will explore how ultrasound can be used in additive manufacturing for tissue constructs and robotics.

Objective
The course is designed to equip students with skills in the design and development of ultrasound-based manipulation devices and microrobots for applications in medicine and additive manufacturing.

Content
Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices

Lecture notes

Literature

Prerequisites / notice
Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions ( both compulsory) and hand in homework.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence assessed
Sensitivity to Diversity fostered

Personal Competencies
Critical Thinking fostered
Integrity and Work Ethics assessed
Self-direction and Self-management assessed

151-0604-00L  Microrobotics W 4 credits 3G B. Nelson

Abstract
Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Objective
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microrobots

The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

The lecture will be taught in English.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Supervisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0643-00L</td>
<td>Studies on Micro and Nano Systems</td>
<td>W</td>
<td>5</td>
<td>11A</td>
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</tbody>
</table>

Abstract:
The students get familiarized with the challenges of the fascinating and interdisciplinary field of Micro- and Nanosystems. They are introduced to the basics of independent non-experimental scientific research and are able to summarize and to present the results efficiently.

Objective:
The students get familiarized with the challenges of the fascinating and interdisciplinary field of Micro- and Nanosystems. They are introduced to the basics of independent non-experimental scientific research and are able to summarize and to present the results efficiently.

Content:
Students work independently on a study of selected topics in the field of Micro- and Nanosystems. They start with a selection of scientific papers, and continue with an independent literature research. The results (e.g. state-of-the-art, methods) are evaluated with respect to predefined criteria. Then the results are presented in an oral presentation and summarized in a report, which takes the discussion of the presentation into account.

<table>
<thead>
<tr>
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<th>Credits</th>
<th>Type</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0913-00L</td>
<td>Introduction to Photonics</td>
<td>W</td>
<td>4 credits</td>
<td>R. Quidant, J. Ortega Arroyo</td>
</tr>
</tbody>
</table>

Abstract:
This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

Objective:
Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.
## I- BASICS OF WAVE THEORY
1) General concepts
2) Differential wave equation
3) Wavefront
4) Plane waves and Fourier decomposition of optical fields
5) Spherical waves and Huygens-Fresnel principle

## II- ELECTROMAGNETIC WAVES
1) Maxwell equations
2) Wave equation for EM waves
3) Dielectric permittivity
4) Refractive index
5) Nonlinear optics
6) Polarisation and polarisation control

## III- PROPAGATION OF LIGHT
1) Waves at an interface
2) The Fresnel coefficients
3) Total internal reflection
4) Evanescent waves
5) Dispersion diagram

## IV- INTERFERENCES
1) General considerations
2) Temporal and spatial coherence
3) The Young double slit experiment
4) Diffraction gratings
5) The Michelson interferometer
6) Multi-wave interference
7) Antireflecting coating and interference filters
8) Optical holography

## V- LIGHT MANIPULATION
1) Optical waveguides
2) Photonic crystals
3) Metamaterials and metasurfaces
4) Optical cavities

## VI- OPTICAL FORCES AND OPTICAL TWEEZERS
1) History of optical forces
2) Theory of optical trapping
3) Atom cooling
4) Optomechanics
5) Applications of optical tweezers

## VII- INTRODUCTION TO OPTICAL MICROSCOPY
1) Basic concepts
2) Direct and Fourier imaging
3) Image formation
4) Fluorescence microscopy
5) Scattering-based microscopy
6) Digital holography
7) Computational imaging

### Lecture notes
- Class notes and handouts
- Optics (Hecht) - Pearson

### Literature
- Optics

### Prerequisites / notice
- Physics

### Competencies
- Subject-specific Competencies: Concepts and Theories assessed
- Method-specific Competencies: Analytical Competencies assessed
- Personal Competencies: Problem-solving assessed

### 151-0941-00L Molecular Sensors: From Fundamentals to Health and Environmental Applications
- W 4 credits
- A. Güntner, P. Gerber

### Abstract
Molecular sensors are used in everyday life in health care, environmental monitoring, food safety, space and other fields. Sources of molecular information, its transport and fundamental concepts of molecular sensing will be discussed. In the scope of group projects, the acquired knowledge will be applied and deepened in case studies.

### Objective
After the course, the students will:
- know the requirements and merits of molecular sensors for health, environmental and other emerging applications (e.g. space)
- understand transport phenomena of molecular information & surface interactions and know how to quantitatively describe these
- understand fundamental sensing concepts for the detection and quantification of molecular analytes
- know concepts of signal processing
- be capable to apply the learnt knowledge to conceive and engineer sensor concepts and systems
- know how to investigate sensor-related literature and present scientific data

This course consists of a theoretical and a project-based learning block. In the first 10 semester weeks, theoretical knowledge will be provided through lectures and deepened in corresponding exercises. In the last 4 weeks, the students will apply the learned concepts through group projects to investigate case studies. The outcome will be present.

### Content
- Transport of Molecular Information; Surface Interactions; Sensor Fundamentals; Chemoresistive Sensing; Electrochemical Sensing; Mass-sensitive; Capacitive Sensing; Signal Processing; Medical Requirements for Molecular Sensing

### Lecture notes
Hand-outs will be provided to each lecture including the exercises and their solutions.

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Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

**Social Competencies**
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Sensitivity to Diversity: fostered

**Personal Competencies**
- Adaptability and Flexibility: assessed
- Critical Thinking: assessed
- Creativity: assessed
- Integrity and Work Ethics: fostered
- Leadership: fostered
- Sensitivity to Diversity: fostered

**Competencies**

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

**Personal Competencies**
- Adaptability and Flexibility: assessed
- Critical Thinking: assessed
- Creativity: assessed
- Integrity and Work Ethics: fostered
- Leadership: fostered
- Sensitivity to Diversity: fostered

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### Additional Case for the Focus Specialization

**151-0135-00L**

**Title:** Additional Case for the Focus Specialization

**Type:** W

**ECTS:** 1 credit

**Lecturers:** Professors

**Objective:**

Independent studies on a defined field within the selected Focus Specialization.

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### Solid State Electronics and Optics

**227-0145-00L**

**Title:** Solid State Electronics and Optics

**Type:** W

**ECTS:** 6 credits

**Lecturers:** N. Yazdani, V. Wood

**Objective:**

Understand the fundamental physics behind the mechanical, thermal, electric, magnetic, and optical properties of materials.

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### Applied Analysis of Variance and Experimental Design

**401-0625-01L**

**Title:** Applied Analysis of Variance and Experimental Design

**Type:** W

**ECTS:** 5 credits

**Lecturers:** L. Meier

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### Engineering for Health

**Focus Coordinator:** Prof. Bradley Nelson

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### Data

**Autumn Semester 2024**

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### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

**Social Competencies**
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Sensitivity to Diversity: fostered

**Personal Competencies**
- Adaptability and Flexibility: assessed
- Critical Thinking: assessed
- Creativity: assessed
- Integrity and Work Ethics: fostered
- Leadership: fostered
- Sensitivity to Diversity: fostered

---

### Additional Case for the Focus Specialization

**151-0135-00L**

**Title:** Additional Case for the Focus Specialization

**Type:** W

**ECTS:** 1 credit

**Lecturers:** Professors

**Objective:**

Independent studies on a defined field within the selected Focus Specialization.

---

### Solid State Electronics and Optics

**227-0145-00L**

**Title:** Solid State Electronics and Optics

**Type:** W

**ECTS:** 6 credits

**Lecturers:** N. Yazdani, V. Wood

**Objective:**

Understand the fundamental physics behind the mechanical, thermal, electric, magnetic, and optical properties of materials.

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### Applied Analysis of Variance and Experimental Design

**401-0625-01L**

**Title:** Applied Analysis of Variance and Experimental Design

**Type:** W

**ECTS:** 5 credits

**Lecturers:** L. Meier

---

### Engineering for Health

**Focus Coordinator:** Prof. Bradley Nelson

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### Data

**Autumn Semester 2024**

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Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence

Personal Competencies

- Critical Thinking
- Integrity and Work Ethics
- Self-direction and Self-management

**151-0524-00L Continuum Mechanics I**

**Objective**

After successful completion of the course students are able to

- explain basic theories for solving continuum mechanics problems
- proficiently apply these theories by solving application-related academic examples
- relate the theories and examples to real engineering applications and challenges
- distinguish between different mechanical behaviors of materials
- systematically select appropriate constitutive theories suitable to analyze and model these materials

Content

- Anisotropic Elasticity
- Linear Elastic and Linear Viscous Material Behavior
- Viscoelasticity
- Micro-Macro Modelling
- Laminate Theory
- Plasticity
- Viscoplasticity
- Examples of Engineering Applications
- Comparison with Experiments

Lecture notes

- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies
- Personal Competencies: Critical Thinking

**151-0604-00L Microrobotics**

Objective

The objective of this course is to expose students to the fundamentals aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

Content

- Main topics of the course include:
  - Scaling laws at micro/nano scales
  - Electrostatics
  - Electromagnetism
  - Low Reynolds number flows
  - Observation tools
  - Materials and fabrication methods
  - Applications of biomedical microrobots

Lecture notes

- The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

**151-0621-00L Microsystems I: Process Technology and Integration**

Abstract

Students are introduced to the fundamentals of micromachining and silicon process technology and will learn about the fabrication of microsystems and devices by a sequence of defined processing steps (process flow).

Objective

Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystem devices by the combination of unit process steps (= process flow).

Content

- Introduction to microsystems technology (MST) and micro electro mechanical systems (MEMS)
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.
- Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties.

Lecture notes

- Literature: Microsystem Technology
- Literature: Micromachining Technology
- Literature: Microfabrication and Nanotechnology

Prerequisites / notice

- The student is responsible to find a project offered and supervised by ETH Professor in the area of Engineering

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1752 of 2653
for Health. Once received the approval of the ETH professor the student should forward the approval and the content of the project to the Student Administration info@mavt.ethz.ch for the enrolment.

This course is not available to incoming exchange students.

### Abstract
Overview of Engineering for Health topics. Identification of minimum 10 pertinent refereed articles or works in the literature in consultation with supervisor or instructor. After 4 weeks, submission of a 2-page proposal outlining the value, state-of-the art and study plan based on these articles. After feedback on the substance and technical writing by the instructor, project commences.

### Objective
The students are familiar with the challenges of the fascinating and interdisciplinary field of Engineering for Health. They are introduced in the basics of independent non-experimental scientific research and are able to summarize and to present the results efficiently.

### Content
The students work independently on a study of selected topics in the field of Studies on Engineering for Health. They start with a selection of scientific papers to continue literature research. The results (e.g. state-of-the-art, methods) are evaluated with respect to predefined criteria. Then the results are presented in an oral presentation and summarized in a report, which takes the discussion of the presentation into account.

### Literature
Will be available.

<table>
<thead>
<tr>
<th>151-0941-00L</th>
<th>Molecular Sensors: From Fundamentals to Health and Environmental Applications</th>
</tr>
</thead>
</table>

**Abstract**
Molecular sensors are used in everyday life in health care, environmental monitoring, food safety, space and other fields. Sources of molecular information, its transport and fundamental concepts of molecular sensing will be discussed. In the scope of group projects, the acquired knowledge will be applied and deepened in case studies.

**Objective**
After the course, the students will:
- know the requirements and merits of molecular sensors for health, environmental and other emerging applications (e.g. space)
- understand transport phenomena of molecular information & surface interactions and know how to quantitatively describe these
- understand fundamental sensing concepts for the detection and quantification of molecular analytes
- know concepts of signal processing
- be capable to apply the learnt knowledge to conceive and engineer sensor concepts and systems
- know how to investigate sensor-related literature and present scientific data

This course consists of a theoretical and a project-based learning block. In the first 10 semester weeks, theoretical knowledge will be provided through lectures and deepened in corresponding exercises. In the last 4 weeks, the students will apply the learned concepts through group projects to investigate case studies. The outcome will be present.

**Content**
Transport of Molecular Information; Surface Interactions; Sensor Fundamentals; Chemoresistive Sensing; Electrochemical Sensing; Mass-sensitive; Capacitive Sensing; Signal Processing; Medical Requirements for Molecular Sensing

**Lecture notes**
Hand-outs will be provided to each lecture including the exercises and their solutions.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
<td></td>
</tr>
</tbody>
</table>

| Method-specific Competencies          | Analytical Competencies | assessed |
|                                     | Decision-making        | assessed |
|                                     | Media and Digital Technologies | assessed |
|                                     | Problem-solving        | assessed |
|                                     | Project Management     | assessed |

| Social Competencies                  | Communication         | assessed |
|                                     | Cooperation and Teamwork | assessed |
|                                     | Customer Orientation   | fostered |
|                                     | Leadership and Responsibility | fostered |
|                                     | Sensitivity to Diversity | fostered |

| Personal Competencies                | Adaptability and Flexibility | assessed |
|                                     | Creative Thinking         | assessed |
|                                     | Critical Thinking         | assessed |
|                                     | Integrity and Work Ethics | fostered |
|                                     | Self-awareness and Self-reflection | fostered |

<table>
<thead>
<tr>
<th>151-8101-00L</th>
<th>International Engineering: from Hubris to Hope</th>
</tr>
</thead>
</table>

**Abstract**
Since Europe surrendered their colonial assets, engineers from rich countries have returned to the African continent to address the real and perceived ills that they felt technology could solve. And yet, 70 years on, the promise of technology has largely failed to deliver widespread, substantive improvements in the quality of life. Why?

**Objective**
This course is meant for engineers who are interested in pursuing an ethical and relevant career internationally, and who are willing to examine the complex role that well-meaning foreigners have played and continue to play in the disappointing health outcomes that characterize much of the African continent.

After completing the course, participants will be able to
- critique the jargon and terms used by the international community, i.e. “development”, “aid”, “cooperation”, “assistance” “third world” “developing” “global south” “low and middle-income” and justify their own chosen terminology
- recognize the role of racism and white-supremacy in the development of the Aid industry
- understand the political, financial, and cultural reasons why technology and infrastructure have historically failed
- Debate the merits of international engineering in popular culture and media
- Propose improved SDG indicators that address current shortcomings of cross-disciplinary engineering
- Compare the engineering curricula of different countries to identify relative strengths and shortcomings
- Explain the inherent biases of academic publishing and its impact on engineering failure
- Analyse linkages between the rise of philanthropy and strategic priority areas
- Recommend equitable, just funding models to achieve more sustainable outcomes
- Formulate a vision for the international engineer of the future
Role of international engineering during colonialism
Transition of international engineering following colonialism
White saviourism and racism in international engineering
International engineering in popular culture
The missing role of Engineering Education
Biases in academic publishing
The emerging role in Global Philanthropy
The paradox of international funding


J. Vörös

M. F. Yanik

Content

227-0385-10L

Biomedical Imaging

W 6 credits

S. Kozerke, K. P. Prüssmann

Abstract

Introduction to diagnostic medical imaging based on electromagnetic and acoustic fields including X-ray planar and tomographic imaging, radio-tracer based nuclear imaging techniques, magnetic resonance imaging and ultrasound-based procedures.

Objective

Upon completion of the course students are able to:

- Explain the physical and mathematical foundations of diagnostic medical imaging systems
- Characterize system performance based on signal-to-noise ratio and transfer function
- Design a basic diagnostic imaging system chain including data acquisition and data reconstruction
- Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications

Content

- Introduction (intro, overview, history)
- Signal theory and processing (foundations, transforms, filtering, signal-to-noise ratio)
- X-rays (production, tissue interaction, contrast, modular transfer function)
- Magnetic Resonance (Magnetic moment, spin transitions, excitation, relaxation, detection)
- Magnetic Resonance (plane wave encoding, Fourier reconstruction, pulse sequences)
- Magnetic Resonance (contrast mechanisms, gradient- and spin-echo, applications)
- Ultrasound (mechanical wave generation, propagation in tissue, reflection, transmission)
- Ultrasound (spatial and temporal resolution, phased arrays)
- Ultrasound (Doppler shift, implementations, applications)
- Summary, example exam questions

Lecture notes

Lecture notes and handouts

Literature

Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

Prerequisites / notice

Analysis, Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies

Communication fostered
Cooperation and Teamwork fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies

Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

227-0393-10L

Bioelectronics and Biosensors

W 6 credits

J. Vörös, M. F. Yanik

Abstract

The course introduces bioelectricity and the sensing concepts that enable obtaining information about neurons and their networks. The sources of electrical fields and currents in the context of biological systems are discussed. The fundamental concepts and challenges of measuring bioelectric signals and the basic concepts to record optogenetically modified organisms are introduced.

Objective

During this course the students will:
- learn the basic concepts in bioelectronics including the sources of bioelectric signals and the methods to measure them
- be able to solve typical problems in bioelectronics
- learn about the remaining challenges in this field

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies

Communication assessed
Cooperation and Teamwork assessed
Leadership and Responsibility assessed
Self-presentation and Social Influence assessed
Negotiation assessed

Personal Competencies

Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-direction and Self-management fostered
Content

Lecture topics:

1. Introduction
2. Membrane and Transport
3-4. Action potential and Hodgkin-Huxley

Measuring bioelectronic signals
5. Detection and Noise
6. Measuring currents in solutions, nanopore sensing and patch clamp pipettes
7. Measuring potentials in solution and core conductance model
8. Measuring electronic signals with wearable electronics, ECG, EEG
9. Measuring mechanical signals with bioelectronics

In vivo stimulation and recording
10. Functional electric stimulation
11. In vivo electrophysiology

Optical recording and control of neurons (optogenetics)
12. Measuring neurons optically, fundamentals of optical microscopy
13. Fluorescent probes and scanning microscopy, optogenetics, in vivo microscopy

14. Measuring biochemical signals

Lecture notes
A detailed script is provided to each lecture including the exercises and their solutions.

Literature
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites / notice
The course requires an open attitude to the interdisciplinary approach of bioelectronics. In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Abstract
Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Objective
Students are able to describe the human body as a mechanical system. They analyse and describe human movement according to the laws of mechanics.

Content
Movement- and sports biomechanics deals with the attributes of the human body and their link to mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.

Lecture notes
Is available within the Moodle

376-0021-00L Materials and Mechanics in Medicine W 4 credits 3G M. Zenobi-Wong, J. G. Snedeker

376-0203-00L Movement and Sport Biomechanics W 4 credits 3G W. R. Taylor, R. List

376-1504-00L Physical Human Robot Interaction (pHRI) W 4 credits 2V+2U O. Lambercy, P. Wolf
Abstract
This course focuses on the emerging, interdisciplinary field of physical human-robot interaction, bringing together themes from robotics, real-time control, human factors, haptics, virtual environments, interaction design and other fields to enable the development of human-oriented robotic systems.

Objective
The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and de-sign safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1) Identify critical human factors in physical human-robot interaction and use these to derive design requirements;
2) Compare and select mechatronic components that optimally fulfill the defined design requirements;
3) Derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;
4) Design control hardware and software and implement and test human-interactive control strategies on the physical setup;
5) Characterize and optimize such systems using both engineering and psychophysical evaluation metrics;
6) Investigate and optimize one aspect of the physical setup and convey and defend the gained insights in a technical presentation.

Content
This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in device design for humans such as transparency and stability analysis, safety hardware and procedures. The course is organized into lectures that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical human-robot interaction, laboratory sessions and lab visits.

Students will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. Here the salient features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic paddle (https://relab.ethz.ch/downloads/open-hardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

Lecture notes
Will be distributed on Moodle before the lectures.

Literature

Prerequisites / notice

Notice:
The registration is limited to 26 students
There are 4 credit points for this lecture.
The lecture will be held in English.
The students are expected to have basic control knowledge from previous classes.
http://www.relab.ethz.ch/education/courses/phri.html

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### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed
- Project Management: assessed

**Social Competencies**
- Communication: assessed
- Cooperation and Teamwork: assessed

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Self-direction and Self-management: fostered

### 376-1714-00L Biocompatible Materials

**Abstract**
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

**Objective**
The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

**Content**
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Lecture notes**
Handouts are deposited online (moodle).

**Literature**

(available online via ETH library)

**Design, Mechanics and Manufacturing**

**Focus Coordinator:** Prof. Dennis Kochmann

To achieve the required 20 credit points for the Focus Specialization Design, Mechanics and Manufacturing, all of the courses listed can be selected. If you wish to take a Master level course, you must obtain the consent of the responsible lecturer. After approval by the focus coordinator, an additional course to the listed courses can be requested. There are recommended lectures for the "Design" track, the "Mechanics" track and the "Manufacturing" track. For recommended courses and further information, please visit the MAVT website for Focus Specialization (https://mavt.ethz.ch/studies/bachelor/focus/foocus-specialization.html).

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0364-00L</td>
<td>Lightweight Structures Laboratory</td>
<td>W</td>
<td>4 credits</td>
<td>5A</td>
<td>M. Zogg</td>
</tr>
</tbody>
</table>

**Abstract**
Teams of 2 to 3 students have to design, size, and manufacture a lightweight structure complying with given specifications. An aircraft wing spar prototype as well as later a second improved spar will be tested and assessed regarding to design and to structural mechanical criteria.

**Objective**
To develop the skills to identify and solve typical problems of the structure mechanics on a real application. Other important aspects are to foster team work and team spirit, to link theoretical knowledge and practice, to gather practical experiences in various fields related to lightweight structures such as design, different CAE-methods and structural testing.

**Content**
The task of each team (typically 2-3 students) is the realization of a reduced-scale aircraft wing spar, a typical load-carrying structure, with selected materials. The teams are free to develop and implement their own ideas. In this context, specified requirements include information about loads, interface to the surrounding structures.

The project is structured as described below:
- Concept development
- design of the component including FEM simulation and stability checks
- manufacturing and structural testing of a prototype in the lab
- manufacturing and structural testing of an improved component in the lab
- cost assessment
- Report

The practical project work is supported by selected teaching units.

**Lecture notes**
Handouts for selected topics are available.
Analytical Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management

Social Competencies
Communication
Cooperation and Teamwork
Leadership and Responsibility
Negotiation

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Subject-specific Competencies
Concepts and Theories

Abstract
The course will provide you with the fundamentals of the new and exciting field of ultrasound-based microrobots to treat various diseases. Furthermore, we will explore how ultrasound can be used in additive manufacturing for tissue constructs and robotics.

Objective
The course is designed to equip students with skills in the design and development of ultrasound-based manipulation devices and microrobots for applications in medicine and additive manufacturing.

Content
Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobots to surface acoustic wave devices.

Lecture notes

Literature

Prerequisites / notice
Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management

Social Competencies
Communication
Cooperation and Teamwork
Leadership and Responsibility

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Subject-specific Competencies
Concepts and Theories

Abstract
The lecture deals with constitutive models that are relevant for the design and analysis of components and structures. These include anisotropic linear elasticity, linear viscoelasticity, plasticity and viscoplasticity. The basic concepts of homogenization and laminate theory are introduced. Theoretical models are complemented by examples of engineering applications and experiments.

Objective
After successful completion of the course students are able to
- explain basic theories for solving continuum mechanics problems
- proficiently apply these theories by solving application-related academic examples
- relate the theories and examples to real engineering applications and challenges
- distinguish between different mechanical behaviors of materials
- systematically select appropriate constitutive theories suitable to analyze and model these materials

Content
Anisotropic Elasticity, Linear Elastic and Linear Viscoelastic Material Behavior, Viscoelasticity, Micro-Macro Modelling, Laminate Theory, Plasticity, Viscoplasticity, Examples of Engineering Applications, Comparison with Experiments

Lecture notes
yes

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving

Personal Competencies
Adaptability and Flexibility
Creative Thinking

Subject-specific Competencies
Concepts and Theories

Abstract
Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

Objective
This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.
The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

Prerequisites / notice
- Prerequisites: Analysis, linear algebra and a basic course in differential equations.

<table>
<thead>
<tr>
<th>151-0544-00L</th>
<th>Metal Additive Manufacturing - Mechanical Integrity and Process Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Note: The previous course title until HS22 &quot;Metal Additive Manufacturing - Mechanical Integrity and Numerical Analysis&quot;</td>
<td></td>
</tr>
</tbody>
</table>

Abstract
An introduction to Metal Additive Manufacturing (MAM) (e.g. different techniques, the metallurgy of common alloy-systems, existing challenges) will be given. The focus of the lecture will be on the employment of different simulation approaches to address MAM challenges and to enable exploiting the full advantage of MAM for the manufacture of structures with desired property and functionality.

Objective
The main objectives of this lecture are:
- Acknowledging the possibilities and challenges for MAM (with a particular focus on mechanical integrity aspects),
- Understanding the importance of material science and metallurgical considerations in MAM,
- Appreciating the importance of thermal, fluid, mechanical and microstructural simulations for efficient use of MAM technology,
- Using commercial analysis tools (e.g. ABAQUS) for simulation of the MAM process.

Content
- Introduction to MAM (concept, application examples, pros & cons),
- Powder-bed and powder-blown metal additive manufacturing,
- Thermo-fluid analysis of additive manufacturing,
- Continuum-based thermal modelling and experimental validation techniques,
- Residual stress and distortion simulation and verification methods,
- Microstructural simulation (basics, analytical, kinetic Monte Carlo, cellular automata, phase-field),
- Mechanical property prediction for MAM,
- Microstructure and mechanical response of MAM material (stainless steel, Ti6Al4V, Inconel 718),
- Design for additive manufacturing
- Artificial intelligence for AM

Exercise sessions use ABAQUS for analysis of MAM process. Detailed video instructions will be provided to enable students to set up their own simulations. Students can install the packages on their own systems.

Handouts of the presented slides.

No textbook is available for the course (unfortunately), since it is a dynamic and relatively new topic. In addition to the material presented in the course slides, suggestions/recommendations for additional literature/publications will be given (for each individual topic).

Prerequisites / notice
A basic knowledge of mechanical analysis, metallurgy, thermodynamics is recommended.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

<table>
<thead>
<tr>
<th>151-0741-00L</th>
<th>Sustainable Materials</th>
</tr>
</thead>
</table>

Abstract
The lecture addresses the issue of sustainability in manufacturing, focussing on materials. The most used materials, their production and transformation into a product are analysed in terms of energy consumption and emissions. Emphasis is then placed on alternative design strategies which reduce the use of materials and innovative processes which lower energy consumption and emissions.

Objective
After this lecture students will be able to:
- Develop a critical thinking of published sustainability data and facts
- Explain where the materials that we use come from, what emissions arise from the different steps of raw material production and product manufacturing
- Determine where significant changes can be brought
- Develop feasible solutions towards a more sustainable use of materials

Content
- Introduction : what is sustainability, which industrial sectors are responsible for the most CO2 (and other) emissions
- The "real" numbers: where to find reliable data and how one can play with the figures
- Basics of life cycle analysis
- CO2 and other emissions
- The most used materials
  - The 5 most used materials today, their key properties and what they are used for
  - Evolution of production, consumption and resources
  - Production, recyclability and new processing routes for Al and steel
  - Use less material by design
  - Re-use of materials & prolonging products life
  - Production of cement, new developments & alternatives
  - Presentation of students' projects

Lecture notes
Slides distributed and available on Moodle

References given in the lecture

<table>
<thead>
<tr>
<th>151-0763-00L</th>
<th>Practical Course of CAD and CAE Application in Projects</th>
</tr>
</thead>
</table>

Note: Previous course title until HS23 "Practice Course to Focus Projects on CAD and CAE Based on Siemens NX"
This course provides comprehensive input to ongoing Focus Projects teams in the areas of CAD and CAE mit Siemens NX.
Participants will receive tips, hints and background information from experienced tutors applicable to current projects.

CAD with Siemens NX
- 2 day of intensive training (2x4h, 1x8L)

CAE mit Siemens NX
- 2 separate days of intensive training (2x8L)

Lecture notes and documentation will be electronically available.
- Max. 3 Students by one Focus Team allowed
- Course is only useful and recommended for students using CAD and CAE Tools for their duty within the project itself
- Feel free to contact us, if there are open questions: martin.schuetz@mavt.ethz.ch
- Only for students participating in a Focus Project in the same semester
- Use of Siemens NX CAD/CAE in the corresponding Focus Project required

151-0833-00L Applied Finite Element Analysis W 4 credits 2V+2U B. Berisha, D. Mohr

Abstract
Most problems in engineering are of nonlinear nature. The nonlinearities are caused basically due to the nonlinear material behavior, contact conditions and instability of structures. The principles of the nonlinear Finite-Element-Method (FEM) will be introduced for treating such problems. The finite element program ABAQUS is introduced to investigate real engineering problems.

Objective
The goal of the lecture is to provide the students with the fundamentals of the nonlinear Finite Element Method (FEM). The lecture focuses on the principles of the nonlinear Finite-Element-Method based on explicit and implicit formulations. Typical applications of the nonlinear Finite-Element-Methods are simulations of:
- Crash
- Collapse of structures
- Material behavior (metals and rubber)
- General forming processes

Content
- Introduction into FEM
- Fundamentals of continuum mechanics to characterize large plastic deformations
- Elasto-plastic material models
- Lagrange and Euler approaches
- FEM implementation of constitutive equations
- Element formulations
- Implicit and explicit FEM methods
- FEM formulations of coupled thermo-mechanical problems
- Modeling of tool contact and the influence of friction
- Solvers and convergence
- Instability problems

Special attention will be paid to the modeling of the nonlinear material behavior, thermo-mechanical processes and processes with large plastic deformations. The ability to independently create a virtual model which describes the complex nonlinear systems will be acquired through accompanying exercises. These will include the Matlab programming of important model components such as constitutive equations. The FEM Program ABAQUS will be introduced to investigate real engineering problems.

Lecture notes
Lecture slides

Literature

151-3204-00L Coaching Innovation Projects W 2 credits 2V I. Goller, K. Weiss

Abstract
The course is building up skills and experience in coaching engineering teams. To gain experience and to reflect real coaching situations, the participants of the course have the role of teaching assistance of the innovation project (151-0300-00L). In this framework the participants coach teams and professionalize the knowledge in the area product development methods.

Objective
- Critical thinking and reasoned judgements
- Basic knowledge about role and mindset of a coach
- Understanding the challenges of engineering projects and design teams
- Development of personal skills to apply and train product development methods
- Knowledge and know-how about applying methods
- Reflection and exchange of experiences about personal coaching situations
- Inspiration and learning from good cases regarding organizational and team management aspects
- Decision-making under uncertainty

Content
- Kick-off & Experience Exchange
- Coaching Role
- Active Listening
- Giving and Receiving Feedback
- Team Building & Psychological Safety
- Building Hypotheses in the coaching process
- Conflict resolution and motivation

In addition to the content topics, one-on-one coaching will be provided and classes will reflect on current, practical issues derived from coaching of the innovation teams.

Prerequisites / notice
Only for participants (Bachelor Students, Master Students) who are teaching assistants in the innovation project).

Competencies
- Subject-specific Competencies
  - Concepts and Theories
  - Analytical Competencies
  - Problem-solving
- Method-specific Competencies
  - Communication
  - Cooperation and Teamwork
  - Leadership and Responsibility
  - Self-presentation and Social Influence
- Social Competencies
  - Adaptability and Flexibility
  - Critical Thinking
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

151-3207-00L Lightweight Structures W 4 credits 2V+2U T. Tancogne-Dejean

Abstract
The goal of the lecture is to provide the students with the fundamentals of the nonlinear Finite Element Method (FEM). The lecture focuses on the principles of the nonlinear Finite-Element-Method based on explicit and implicit formulations. Typical applications of the nonlinear Finite-Element-Methods are simulations of:
- Crash
- Collapse of structures
- Material behavior (metals and rubber)
- General forming processes

Content
- Introduction into FEM
- Fundamentals of continuum mechanics to characterize large plastic deformations
- Elasto-plastic material models
- Lagrange and Euler approaches
- FEM implementation of constitutive equations
- Element formulations
- Implicit and explicit FEM methods
- FEM formulations of coupled thermo-mechanical problems
- Modeling of tool contact and the influence of friction
- Solvers and convergence
- Instability problems

Special attention will be paid to the modeling of the nonlinear material behavior, thermo-mechanical processes and processes with large plastic deformations. The ability to independently create a virtual model which describes the complex nonlinear systems will be acquired through accompanying exercises. These will include the Matlab programming of important model components such as constitutive equations. The FEM Program ABAQUS will be introduced to investigate real engineering problems.

Lecture notes
Lecture slides

Literature
The Bachelor's Thesis is the culmination of the program. The thesis corresponds to a workload of 480 hours and can be done in part- or full-time. The students develop, enhance and demonstrate their methodological abilities to independently tackle and solve a given research problem. The topics for the Bachelor's Thesis are published by the professorship or they can be set in consultation between the professors and the student.

The Bachelor's Thesis with Focus Project is offered to students who wish to work on a project that is closely related to an industrial application. Students are required to work with an industrial partner on a project that is relevant to their area of interest.

The Bachelor's Thesis with Focus Specialization is a course that is designed to provide students with a deeper understanding of a specific topic within mechanical engineering. This course includes a project component that allows students to apply their knowledge and skills to a real-world problem.

The Integrative Ski Building Workshop consists of planning, designing, engineering and building your own alpine ski or snowboard. Students learn and execute all the needed steps in the process, such as engineering design, CAD, material selection, analysis of the mechanical properties of a composite layup, fabrication, routing wood cores, 3D printing of plastic protectors, milling side walls from wood or ABS plastic, laying up the fibers from carbon, glass, basalt or flax, laminating with resins, sanding and finishing, as well as laser engraving and veneer wood inlays.

The elective course Lightweight includes numerical methods for the analysis of the load carrying and failure behavior of lightweight structures, as well as construction methods and design principles for lightweight design. The goal of this course is to convey substantiated background for the understanding and the design and sizing of modern lightweight structures in mechanical engineering, vehicle and airplane design.
The Bachelor's Thesis is the culmination of the program. The thesis corresponds to a work load of 240 hours and can be done in part- or full-time.

The students develop, enhance and demonstrate their methodological abilities to independently tackle and solve a given research problem.

The topics for the Bachelor's Thesis are published by the professorship or can be set in consultation between the professors and the students. Thesis projects in cooperation with the industry are also possible.

The Bachelor's Thesis can be only started when the First Year Examinations, the Additional First Year Courses, the Examination Block 1 and 2 are passed. It is insistently recommended for students to only begin the Bachelor's Thesis if 150 credit points have been achieved.

The Bachelor's Thesis is the culmination of the program. The thesis corresponds to a work load of 240 hours and can be done in part- or full-time.

The students develop, enhance and demonstrate their methodological abilities to independently tackle and solve a given research problem.

The topics for the Bachelor's Thesis are published by the professorship or can be set in consultation between the professors and the students. Thesis projects in cooperation with the industry are also possible.

The Bachelor's Thesis can be only started when the First Year Examinations, the Additional First Year Courses, the Examination Block 1 and 2 are passed. It is insistently recommended for students to only begin the Bachelor's Thesis if 150 credit points have been achieved.

The declaration of originality is an integral part of the Bachelor's Thesis. This course must be chosen by students which have selected a focus project in their third year.

### Bachelor Studies (Programme Regulations 2010)

#### Electives

#### Engineering Tools

*The Engineering Tools courses are for MAVT Bachelor's degree students only.*

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0059-10L</td>
<td>Engineering Tool: CAD-Methodology and PDM-Technology in the Focus Project</td>
<td>W</td>
<td>0.4 credits</td>
<td>1K</td>
<td>M. Schütz</td>
</tr>
<tr>
<td>151-0061-10L</td>
<td>Engineering Tool: Scientific Writing with LaTeX and Vector Graphics</td>
<td>W</td>
<td>0.4 credits</td>
<td>1K</td>
<td>O. Lambercy</td>
</tr>
<tr>
<td>151-0062-10L</td>
<td>Engineering Tool: Computer-Aided Design Methods</td>
<td>W</td>
<td>0.4 credits</td>
<td>1K</td>
<td>T. Stankovic, K. Shea</td>
</tr>
</tbody>
</table>

#### Prerequisites / notice

- at least two students of a Focus-Team should sign in for this course, if the use of Siemens Teamcenter PLM is given for the Team.
- only for students participating in a Focus Project in the same semester

### Abstract

The participants learn about the procedures and tools that are necessary to develop technical products. The focus is on computer-based design and development and the management in an integrated software environment.

### Objective

The participants will deepen their existing CAD knowledge and learn new PDM knowledge, so that these may be directly applied and used in the focus project.

- CAD refresh (Modelling, Assembling, Drafting, etc.) and CAD mythology for construction (Top-Down modelling)
- Introduction to the Team Center (Siemens PDM System)
- CAD refresher and top down modelling

### Content

1. Afternoon: CAD refresher and top down modelling
   - To refresh already existing knowledge of CAD functionality.
   - Sketch and features as well as manipulation and optimizing models.
   - Assembling
   - Drafting.
   - Organisation, working methods, conventions.

2. Afternoon: Introduction to TC (Team Center)
   - Introduction: Short introduction to PLM (What is the idea of PLM? PLM is more than the pure management of drawings!).
   - Lesson 1 - Team Center Rich Client Interface
   - Lesson 2 - TC data types
   - Lesson 3 - Construction from data in TC
   - Lesson 4 - Searching for and examining data.

3. Afternoon: TC application
   - Lesson 5 - Unit lists (PSE)
   - Lesson 6 - Cross-referencing
   - Lesson 7 - Data release
   - Lesson 8 - Product data examination

- only for students participating in a Focus Project in the same semester

### Prerequisites / notice

- at least two students of a Focus-Team should sign in for this course, if the use of Siemens Teamcenter PLM is given for the Team.
- only for students participating in a Focus Project in the same semester

#### Literature

http://www.relabor.ethz.ch/education/courses/engineering-tools-latex.html

#### Particular:

The exercises will be done on your personal laptop (at least one laptop per two students). The complete (full) LaTeX package, Inkscape and Gimp should be installed in advance.

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*Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1762 of 2653*
Participants will learn about the Computer-Aided Design fundamentals and methods that are necessary to model complex technical products. The focus will be placed on feature-based and parametric modeling that is common to all modern CAD tools used in mechanical engineering design.

**Objective**

CAD knowledge and skills will be further developed to enable students to recognize both the advantages and the limitations of current Computer-Aided Design tools. Examples of how to build feature-based and parametric models including design automation will be given along with common pitfalls. After taking the course students should be able to independently create effective feature-based and parametric models of mechanical parts.

**Content**

1. **CAD Methods and Feature-Based Design (2 afternoons):**
   - CAD in the context of the design process
   - Feature types and their relation to mechanical design
   - Strategies for building feature-based assemblies
   - Integration of digital part libraries
   - Common issues and difficulties with feature interaction

2. **CAD and Parametric Modeling (1 afternoon):**
   - Designing and building parametric models
   - Design automation to create design variants
   - Common issues and difficulties with parametric modeling

**Lecture notes**

Available on Moodle

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**151-0069-10L**

**Engineering Tool: Design Optimization and CAD**

* The Engineering Tools courses are for MAVT Bachelor's degree students only.

**Abstract**

Participants will learn about the Computer-Aided Engineering fundamentals and methods that are necessary to model complex technical products. The focus will be placed on the simulation-driven design in the context of product development process as well as on the fundamentals of the design optimization.

**Objective**

Basic Computer-Aided Engineering (CAE) knowledge and skills will be acquired to enable students to recognize both the advantages and the limitations of current CAE tools. Examples of how to build feature-based and parametric models for simulation-driven design automation will be given along with common pitfalls. The CAE environment will be the Siemens NX 8.5 which couples the simulation modeling (e.g. structural, thermal, flow, motion, and multiphysics) with design optimization and Feature-Based Design (FBD). After taking the course students should be able to independently create effective feature-based and parametric models to suit the requirements of simulation-driven design.

**Content**

1. **Computer-Aided Engineering (CAE) methods and tools in context of design process (2 afternoons):**
   - CAE in the context of the design process
   - Simulation-driven design
   - Introduction to design optimization
   - Features, parameterization and synchronous modeling technology
   - Basic design optimization examples
   - Introduction to Finite-Element Method (FEM) with basic examples

2. **Simulation-Driven Design with application to structural design (1 afternoon):**
   - Coupling simulation with structural design optimization and feature-based-design
   - Simulation driven design examples (single parts and assemblies)

**Lecture notes**

Handouts in the lecture

**Literature**

1. CAD NX:
2. CAE NX:

**Prerequisites / notice**

Max. 25 participants

---

### Workshop Training

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0003-00L</td>
<td>Workshop Training Placement of internships and request for recognition</td>
<td>O</td>
<td>5 credits</td>
<td>external organisers</td>
<td></td>
</tr>
</tbody>
</table>

**Abstract**

The main objective of the minimum five-week internship is to provide Bachelor's students with practical experience in producing components as well as knowledge and understanding about materials and their machining and finishing.

**Objective**

The main objective is to provide Bachelor's students with practical experience in producing components as well as knowledge and understanding about materials and their machining and finishing.

**Prerequisites / notice**

The minimum duration of the workshop training is five weeks.

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### Laboratory Practice

Students attend at least 10 Laboratory Practices during the 4th and 5th semester. 4 of them must be Physics laboratories. All laboratory works are graded "pass" or "fail". After completion of 10 laboratory training units, 2 credit points will be issued.

Please register online at www.mavt.ethz.ch/praktika

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>151-0029-10L</td>
<td>Laboratory Practice Enrollment is only possible under</td>
<td>O</td>
<td>2 credits</td>
<td>Lecturers</td>
<td></td>
</tr>
</tbody>
</table>

**Abstract**

Selected laboratory experiments in physics, mechanical and process engineering. With the Laboratory Training held during the fourth and fifth semester, the students learn how to handle and apply measurement methods and devices. Students are offered a diversified choice of laboratory experiments at least ten of which must be completed. Four of the chosen experiments must be in physics.

**Objective**

With the Laboratory Training held during the fourth and fifth semester, the students learn how to handle and apply measurement methods and devices.

**Prerequisites / notice**

Der Link zur Website, welche alle Informationen für das Physikpraktikum bietet: https://ap.phys.ethz.ch

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### Bachelor's Thesis

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1763 of 2653
### Bachelor's Thesis

**Number:** 151-0001-10L  
**Title:** Bachelor's Thesis  
**Type:** Only for Mechanical Engineering BSc, Programme Regulations 2010.  
**ECTS:** 14  
**Hours:** 30D  
**Lecturers:** Supervisors

**Abstract:** The Bachelor's Thesis is the culmination of the program. The thesis corresponds to a work load of 420 hours and can be done in part- or full-time.

**Objective:** The students develop, enhance and demonstrate their methodological abilities to independently tackle and solve a given research problem.

**Content:** The topics for the bachelor's thesis are published by the professorship or they can be set in consultation between the professors and the students. Thesis projects in cooperation with the industry are also possible.

**Prerequisites / notice:** The Bachelor's Thesis can only be started when the First Year Examinations, the Additional First Year Courses, the Examination Block 1 and 2 are passed. It is insistently recommended for students to only begin the Bachelor's Thesis if 150 credit points have been achieved. The declaration of originality is an integral part of the Bachelor's Thesis.

### Bachelor's Thesis (Focus Specialization Management, Technology and Economics)

**Number:** 151-3630-00L  
**Title:** Bachelor's Thesis (Focus Specialization Management, Technology and Economics)  
**Type:** Only for Mechanical Engineering BSc, Programme Regulations 2010.  
**ECTS:** 14  
**Hours:** 30D  
**Lecturers:** Professors

**Abstract:** The Bachelor's Thesis is the culmination of the program. The thesis corresponds to a work load of 420 hours and can be done in part- or full-time.

**Objective:** The students develop, enhance and demonstrate their methodological abilities to independently tackle and solve a given research problem.

**Content:** The topics for the bachelor's thesis are defined by the professorship or can be set in consultation between the professors and the students.

**Prerequisites / notice:** The Bachelor's Thesis can only be started when the First Year Examinations, the Additional First Year Courses, the Examination Block 1 and 2 are passed. Exclusively D-MAVT students who have enrolled for the Focus Specialization Management, Technology and Economy are eligible for this type of Bachelor's Thesis. It is strongly recommended for students to only begin the Bachelor's Thesis if 150 credit points have been achieved. The declaration of originality is an integral part of the Bachelor's Thesis.

### Science in Perspective

#### Science in Perspective

- See Science in Perspective: Type A: Enhancement of Reflection Capability

#### Recommended Science in Perspective (Type B) for D-MAVT

### Language Courses

- See Science in Perspective: Language Courses ETH/UZH

### Mechanical Engineering Bachelor - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Compulsory</th>
<th>Eligible for credits and recommended</th>
<th>Eligible for credits</th>
<th>Recommended, not eligible for credits</th>
<th>Courses outside the curriculum</th>
<th>Suitable for doctorate</th>
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<td>Dr</td>
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### Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

### ECTS

- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
## Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0105-00L</td>
<td>Imaging in Fluid Dynamics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>F. Coletti</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>This is a laboratory-based course on imaging techniques for the measurement of fluid flow properties. Modern approaches are presented, including particle image velocimetry and particle tracking velocimetry, applied in various experimental facilities. Students obtain first-hand experience with such techniques in laboratory sessions, using high-speed/high-resolution cameras in wind/water tunnels.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Knowledge of the working principles of modern flow imaging and velocimetry. Understanding of hardware and software requirements to achieve desired spatio-temporal resolution, ability to carry out imaging experiments in actual laboratory flows, and interpreting meaningfully the results.</td>
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</tr>
<tr>
<td><strong>Content</strong></td>
<td>Basics of optical diagnostics. Conception of laboratory flow experiment to be characterized by imaging, with focus on the spatial and temporal scales at play. Laboratory experiments including: - characterization of vortex shedding by wake visualization and liquid crystal thermography. - Eulerian flow field in turbulent flow by particle image velocimetry. - Lagrangian flow field in turbulent flow by particle tracking velocimetry. - fluid-structure interaction in wind tunnel by high-speed imaging.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Handouts will be made available.</td>
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</tr>
<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Prerequisites: Fluid Dynamics, basic programming skills.</td>
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<tr>
<td><strong>ECTS</strong></td>
<td>4 credits</td>
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</tr>
<tr>
<td><strong>Lecturers</strong></td>
<td>F. Coletti</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>151-0109-00L</td>
<td>Turbulent Flows</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>P. Jenny</td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>Basic physical phenomena of turbulent flows, quantitative and statistical description, basic and averaged equations, principles of turbulent flow computation and elements of turbulence modelling.</td>
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</tr>
<tr>
<td><strong>Lecture notes</strong></td>
<td>Lecture notes are available</td>
<td></td>
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</tr>
<tr>
<td>151-0125-00L</td>
<td>Hydrodynamics and Cavitation</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>O. Supponen</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>This course builds on the foundations of fluid dynamics to describe hydrodynamic flows and provides an introduction to cavitation. The main learning objectives of this course are:</td>
<td></td>
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</tr>
<tr>
<td><strong>Objective</strong></td>
<td>1. Identify and describe dominant effects in liquid fluid flows through physical modelling. 2. Identify and predict the onset of hydrodynamic instabilities. 3. Describe acoustic wave behaviour in liquids. 4. Explain tension, nucleation and phase-change in liquids. 5. Predict the behaviour of a gas bubble subject to changes in surrounding liquid pressure. 6. Describe hydrodynamic cavitation and its consequences in physical terms. 7. Recognise experimental techniques and industrial and medical applications for cavitation. 8. Read and evaluate research papers on recent research on cavitation and bubble dynamics and communicate the content orally to a multidisciplinary audience.</td>
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<tr>
<td><strong>Content</strong></td>
<td>The course gives an overview on the following topics: basics of hydrodynamics, capillarity, hydrodynamic instabilities, liquid fragmentation. Acoustics in liquids, tension in liquids, phase change. Cavitation and bubble dynamics: single bubbles (nucleation, dynamics, collapse), bubble clouds and cavitation flows. Industrial applications and measurement techniques.</td>
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</tr>
<tr>
<td><strong>Lecture notes</strong></td>
<td>Class notes and handouts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Literature</strong></td>
<td>Literature will be provided in the course material.</td>
<td></td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Fluid dynamics I &amp; II or equivalent.</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1765 of 2653
151-0163-00L Nuclear Energy Conversion  4 credits  2V+1U  A. Manera

Abstract
Physical fundamentals of the fission reaction and the sustainable chain reaction, thermal design, construction, function and operation of nuclear reactors and power plants, light water reactors and other reactor types, conversion and breeding

Objective
Students get an overview on energy conversion in nuclear power plants, on construction and function of the most important types of nuclear reactors with special emphasis to light water reactors. They obtain the mathematical/physical basis for quantitative assessments concerning most relevant aspects of design, dynamic behaviour as well as material and energy flows.

Content
Nuclear physics of fission and chain reaction. Thermodynamics of nuclear reactors. Design of the reactor core. Introduction into the dynamic behaviour of nuclear reactors. Overview on types of nuclear reactors, difference between thermal reactors and fast breeders. Construction and operation of nuclear power plants with pressurized and boiling water reactors, role and function of the most important safety systems, special features of the energy conversion. Development tendencies of reactor technology.

Lecture notes
Hand-outs will be distributed. Additional literature and information on the website of the lab: https://www.ethz.ch/content/specialinterest/mavt/energy-technology/lab-of-nuclear-energy-systems/en/studium/teaching-materials/151-0163-00l-nuclear-energy-conversion.html

Literature
R. L. Murray: Nuclear Energy (Sixth Edition), An Introduction to the Concepts, Systems, and Applications of Nuclear Processes, Elsevier

151-0204-00L Aerospace Propulsion  4 credits  2V+1U  R. S. Abhari, V. Irandidkht

Abstract
An introduction of working principals and design of airbreathing engines as well as rocket propulsion are presented. Key elements of the propulsion system as well as the design choices for the engineering of various components are examined.

Objective
Introduction of working principals and design of aircraft engines and the related background in aero- and thermodynamics. Engineering aspects of the component designs are examined.

Content
This course focuses on the fundamental concepts as well as the applied technologies for aerospace application, with a primary focus related to aviation. The systematic evolution of the aircraft propulsion engines, from turbojet to the modern high bypass ratio turbofan, including the operational limitations, are examined. Following the system analysis, the aero/thermo design of each component, including the inlet, fan, compressor, combustors, turbines and exhaust nozzles are presented. The mechanical and material limitations, as well as design choices related to manufacturing and operability of engines are also presented. The environmental aspects of propulsion (noise and emissions) are also presented. In the last part of the course, a basic introduction to the fundamentals of space propulsion is also presented.

Lecture notes
Lecture notes will be distributed. There will be NO recording of the lectures, nor the exercise sessions. Physical attendance in this course is advised.

Literature
Aircraft Engines and Gas Turbines, second edition
By Jack L. Kerrebrock

Prerequisites / notice
This course requires prior background in mechanical or aerospace engineering. Students must have already completed courses in basics of Thermodynamics (including cycles) as well as compressible Fluid Dynamics.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

Social Competencies
- Cooperation: fostered

Personal Competencies
- Critical Thinking: fostered

151-0209-00L Renewable Energy Technologies  4 credits  3G  A. Bardow, E. Casati

Abstract
The first part of the course covers the engineering aspects of the prominent renewable energy technologies: solar (PV and thermal), wind, hydro, geothermal and bioenergy. We further discuss energy storage, renewable transport and renewable heating & cooling. Finally, we introduce the key concepts of the economics of renewable energy and its integration in the energy system.

Objective
Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization.

Lecture notes
Lecture Notes containing copies of the presented slides

Prerequisites / notice
This course requires prior background in the fundamentals of engineering thermodynamics, equivalent to the material taught in the courses Thermodynamics I, II, and III of D-MAVT.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: fostered

Social Competencies
- Communication: fostered

Personal Competencies
- Critical Thinking: fostered

151-0213-00L Fluid Dynamics with the Lattice Boltzmann Method  4 credits  3G  I. Karlin

Abstract
The course provides an introduction to theoretical foundations and practical usage of the Lattice Boltzmann Method for fluid dynamics simulations.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: fostered

Personal Competencies
- Critical Thinking: fostered
Objective

Methods like molecular dynamics, DSMC, lattice Boltzmann etc are being increasingly used by engineers all over and these methods require knowledge of kinetic theory and statistical mechanics which are traditionally not taught at engineering departments. The goal of this course is to give an introduction to ideas of kinetic theory and non-equilibrium thermodynamics with a focus on developing simulation algorithms and their realizations.

During the course, students will be able to develop a lattice Boltzmann code on their own. Practical issues about implementation and performance on parallel machines will be demonstrated hands on.

Central element of the course is the completion of a lattice Boltzmann code (using the framework specifically designed for this course).

The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.

Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.

Content

The course builds upon three parts:

I Elementary kinetic theory and lattice Boltzmann simulations introduced on simple examples.
II Theoretical basis of statistical mechanics and kinetic equations.
III Lattice Boltzmann method for real-world applications.

The content of the course includes:

1. Background: Elements of statistical mechanics and kinetic theory; Particle's distribution function, Liouville equation, entropy, ensembles; Kinetic theory; Boltzmann equation for rarefied gas, H-theorem, hydrodynamic limit and derivation of Navier-Stokes equations, Chapman-Enskog method, Grad method, boundary conditions; mean-field interactions, Vlasov equation; Kinetic models: BGK model, generalized BGK model for mixtures, chemical reactions and other fluids.


3. Hands on: Development of the basic lattice Boltzmann code and its validation on standard benchmarks (Taylor-Green vortex, lid-driven cavity flow etc).

4. Practical issues of LBM for fluid dynamics simulations: Lattice Boltzmann simulations of turbulent flows; numerical stability and accuracy.

5. Microwaves: Rarefaction effects in moderately dilute gases; Boundary conditions, exact solutions to Couette and Poiseille flows; micro-channel simulations.

6. Advanced lattice Boltzmann methods: Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

7. Introduction to LB models beyond hydrodynamics: Relativistic fluid dynamics; flows with phase transitions.

Lecture notes

Lecture notes on the theoretical parts of the course will be made available. Selected original and review papers are provided for some of the lectures on advanced topics. Handouts and basic code framework for implementation of the lattice Boltzmann models will be provided.

Prerequisites / notice

The course addresses mainly graduate students (MSc/Ph D) but BSc students can also attend.

151-0215-00L Fundamentals of Acoustics W 4 credits 3G N. Noiray, B. Van Damme

Abstract

This course provides an introduction to acoustics. It focusses on fundamental phenomena of airborne and structure-borne sound waves. The lecture combines theoretical principles with practical insights and interpretations.

Objective

This course is proposed for Master and PhD students interested in getting knowledge in acoustics. Students will be able to understand, describe analytically and interpret sound generation, absorption and propagation.

Content

First, magnitudes characterizing sound propagation are reviewed and the constitutive equations for acoustics are derived. Then the different types of sources (monopole/dipole/quadrupole, punctual, non-compact) are introduced and linked to the noise generated by turbulent flows, coherent vortical structures or fluctuating heat release. The scattering of sound by rigid bodies is given in basic configurations. Analytical, experimental and numerical methods used to analyze sound in ducts and rooms are presented (Green functions, Galerkin expansions, Helmholtz solvers). The second part covers elastic wave phenomena, such as dispersion and vibration modes, in infinite and finite structures.

Lecture notes

Handouts will be distributed during the class

Literature

Books will be recommended for each chapter

151-0216-00L Wind Energy W 4 credits 2V+1U N. Chokani

Abstract

The objective of this course is to introduce the students to the fundamentals, technologies, modern day application, and economics of wind energy. These subjects are introduced through a discussion of the basic principles of wind energy generation and conversion, and a detailed description of the broad range of relevant technical, economic and environmental topics.

Objective

The objective of this course is to introduce the students to the fundamentals, technologies, modern day application, and economics of wind energy.

Content

This mechanical engineering course focuses on the technical aspects of wind turbines; non-technical issues are not within the scope of this technically oriented course. On completion of this course, the student shall be able to conduct the preliminary aerodynamic and structural design of the wind turbine blades. The student shall also be more aware of the broad context of drivetrains, dynamics and control, electrical systems, and meteorology, relevant to all types of wind turbines.

151-0221-00L Introduction to Modeling and Optimization of Sustainable Energy Systems W 4 credits 4G G. Sansavini, A. Bardow, S. Moret

Abstract

This course introduces the fundamentals of energy system modeling for the analysis and the optimization of the energy system design and operations.
Objective
At the end of this course, students will be able to:
- define and quantify the key performance indicators of sustainable energy systems;
- select and apply appropriate models for conversion, storage and transport of energy;
- develop mathematical models for the analysis, design and operations of multi-energy systems and solve them with appropriate mathematical tools;
- select and apply methodologies for the uncertainty analysis on energy systems models;
- apply the acquired knowledge to tackle the challenges of the energy transition.

In the course "Introduction to Modeling and Optimization of Sustainable Energy Systems", the competencies of process understanding, system understanding, modeling, concept development, data analysis & interpretation and measurement methods are taught, applied and examined. Programming is applied.

Content
The global energy transition; Key performance indicators of sustainable energy systems; Optimization models; Heat integration and heat exchanger networks; Life-cycle assessment; Models for conversion, storage and transport technologies; Multi-energy systems; Design, operations and analysis of energy systems; Uncertainties in energy system modeling.

Lecture notes
Lecture slides and supplementary documentation will be available online. Reference to appropriate book chapters and scientific papers will be provided.

Literature
Literature will be given during the course.

151-0225-00L Material Characterization by X-ray Techniques: W 4 credits 3G  P. M. Abdala, D. Piankova

Abstract
The determination of structure–property relationships in functional materials relies critically on structural characterization methods. This course introduces the basics of X-ray powder diffraction, pair distribution function (PDF) of X-ray total scattering and X-ray absorption spectroscopy analyses to determine the structure of inorganic functional materials.

Objective
Introduction basics of the structural characterization of materials using X-rays: covering the local and average structures. Specifically: X-ray, powder diffraction, total scattering and absorption spectroscopy.

Content
The course outlines experimental techniques based on X-rays to investigate the atomic structure of materials covering the local- and long-range order. It covers:
1- Overview of fundamentals of materials science and the structure of solids.
2- Overview of the different characterization methods to investigate the structure of functional materials, spanning the local to long-range order structure.
3- X-ray powder diffraction.
4- X-ray total scattering and pair distribution function analysis.
5- X-ray absorption spectroscopy.
6- Practical sessions on X-ray powder diffraction and PDF experiments.

Literature
Literature will be given during the course.

151-0227-00L Basics of Air Transport (Aviation I) W 4 credits 3G  P. Wild

Abstract
In general the course explains the main principles of air transport and elaborates on simple interdisciplinary topics. Working on broad 14 different topics like aerodynamics, manufacturers, airport operations, business aviation, business models etc. the students get a good overview in air transportation. The program is taught in English and we provide 11 different experts/lecturers.

Objective
The goal is to understand and explain basics, principles and contexts of the broader air transport industry. Further, we provide the tools for starting a career in the air transport industry. The knowledge may also be used for other modes of transport. Ideal foundation for Aviation II - Management of Air Transport.

Content
Weekly: 1h independent preparation; 2h lectures and 1 h training with an expert in the respective field

Concept: This course will be taught as Aviation I. A subsequent course - Aviation II - covers the "Management of Air Transport".

Content: Transport as part of the overall transportation scheme; Aerodynamics; Aircraft (A/C) Designs & Structures; A/C Operations; Aviation Law; Maintenance & Manufacturers; Airport Operations & Planning; Aviation Security; ATC & Airspace; Air Freight; General Aviation; Business Jet Operations; Business models within Airline Industry; Military Aviation.

Technical visit: This course includes a guided tour at Zurich Airport and Dubendorf Airfield (baggage sorting system, apron, Tower & Radar Simulator at Skyguide Dubendorf).

Lecture notes
Preparation materials & slides are provided prior to each class

Literature
Literature will be provided by the lecturers, respectively there will be additional Information upon registration (normally available in Moodle)

The lecture is planned as class teaching.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Customer Orientation: assessed
- Leadership and Responsibility: fostered
- Sensitivity to Diversity: assessed

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed

151-0245-00L Energy Systems Analysis: an Introduction and Overview with Applications W 4 credits 2V+2U  R. McKenna, P. Burgherr, E. Panos, R. Sacchi

Abstract
Introductory (advanced Bachelor or beginner Master level) course on Energy Systems Analysis, providing an overview of the field and methods. After an introduction to systems thinking and characterisation of technologies, three main blocks cover with Lifecycle Assessment (LCA, 3 units), bottom-up linear optimisation models (5 units) and Multi-Criteria Decision Analysis (MCDA, 3 units).

Objective
- Analyse energy technologies with respect to different criteria/characteristics
- Discuss and debate the pros and cons of different ESA models/approaches (for specific applications)
- Explain the system-level interdependencies/interconnections within the energy system
- Evaluate the effect of uncertainties and "the human dimension" on ESA and scenarios
The course provides an introduction and overview to the most well-established models and methods of energy systems analysis, in each case introducing students to the theory and assumptions of the method, strengths and weaknesses of the specific approach, and case studies for exemplary energy technologies and systems. The students are taught to understand and will be able to apply the basic principles of these methods in the context of targeted assignments relating to real-world energy systems.

No slides are provided before the lectures and videos recorded.

Will be provided during the course.

No specific prerequisites, some background in energy-related topics in the Bachelor would be beneficial.

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creativity Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

151-0251-00L Principles, Efficiency Optimization and Future Applications of IC Engines

W 4 credits 2V+1U Y. Wright, P. Soltic

Abstract

Objective
The students get familiar with operating characteristics and efficiency maximization methods of IC engines for propulsion and decentralized enterprises (SME). This could be for instance an enabling technology for net-based collaboration, the transmission of images and other data, their algorithms, and the applied methods are explained more in detail. Finally, future tasks of VR will be discussed and an outlook on ongoing international research is given.

Content
Introduction into Virtual Reality; basics of augmented reality; interaction with digital data, tangible user interfaces (TUI); basics of simulation; compression procedures of image-, audio-, and video signals; new materials for force feedback devices; introduction into data security; cryptography; definition of free-form surfaces; digital factory; new research fields of virtual reality.

Lecture notes
The handout is available in German and English.

Didactical concept
The course consists of lectures and exercises.

Prerequisites
No but slides are provided before the lectures and videos recorded.

Will be provided during the course.

151-0317-00L Visualization, Simulation and Interaction - Virtual Reality II

W 4 credits 3G A. Kunz

Abstract
This lecture provides deeper knowledge on the possible applications of virtual reality, its basic technology, and future research fields. The goal is to provide a strong knowledge on Virtual Reality for a possible future use in business processes.

Objective
Virtual Reality can only not be used for the visualization of 3D objects, but also offers a wide application field for small and medium enterprises (SME). This could be for instance an enabling technology for net-based collaboration, the transmission of images and other data, the interaction of the human user with the digital environment, or the use of augmented reality systems.

Content
Introduction into Virtual Reality; basics of augmented reality; interaction with digital data, tangible user interfaces (TUI); basics of simulation; compression procedures of image-, audio-, and video signals; new materials for force feedback devices; introduction into data security; cryptography; definition of free-form surfaces; digital factory; new research fields of virtual reality.

Lecture notes
The handout is available in German and English.

Didactical concept
The course consists of lectures and exercises.

Prerequisites
No but slides are provided before the lectures and videos recorded.

Will be provided during the course.

No specific prerequisites, some background in energy-related topics in the Bachelor would be beneficial.
This course is a hands-on introduction to self-driving cars using the Duckietown platform.

Each student is given a mobile wheeled robot and throughout the class must configure and program.

The objective of the class is to give the student a pragmatic view of what it takes to design and operate a fleet of self-driving cars or any other large robotic systems.

Perception, planning, modeling, and control, leveraging primarily on vision data.

Course notes will be provided in an electronic form.

Discrete planning, shortest path problems. Planning under uncertainty. Game-theoretic planning. Geometric Representations. Steering Script, handouts, exercises and additional material are available in PDF-format on the moodle page of the lecture.

The students will learn how to design and implement state-of-the-art algorithms for planning the motion of robots executing challenging tasks in complex environments.

Planning and Decision Making for Autonomous Robots

Planning safe and efficient motions for robots in complex environments, often shared with humans and other robots, is a difficult problem combining discrete and continuous mathematics, as well as probabilistic, game-theoretic, and ethical/regulatory aspects. This course will cover the algorithmic foundations of motion planning, with an eye to real-world implementation issues.

The students will learn how to design and implement state-of-the-art algorithms for planning the motion of robots executing challenging tasks in complex environments.

Each student is given a mobile wheeled robot and throughout the class must configure and program.

The course treats aspects related to elastic behavior of unidirectional and multidirectional laminates, micromechanics, failure and damage analysis, analysis and design of composite structures. The focus is on laminated fiber-reinforced polymer composites.

The course is addressing following topics:
- Introduction
- Elastic anisotropy
- Micromechanics & Homogenization
- Classical Laminate Theory (CLT)
- Strength, failure and damage analysis
- Thin ply composite shells & effects of material non-linearity
- Analysis and design of composite structures

Script, handouts, exercises and additional material are available in PDF-format on the moodle page of the lecture.

The lecture material is covered by a script/lecture notes compiled by CMASLab and further literature is referenced therein.
### Competencies

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<th>Subject-specific Competencies</th>
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<td>Project Management</td>
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| Social Competencies          | Communication          | fostered |
|------------------------------|                       |          |
| Cooperation and Teamwork     |                        | fostered |
| Customer Orientation         |                        | fostered |
| Leadership and Responsibility|                       | fostered |
| Self-presentation and Social Influence | | fostered |
| Sensitivity to Diversity     |                        | fostered |
| Negotiation                  |                        | fostered |

| Personal Competencies        | Adaptability and Flexibility | fostered |
|------------------------------|                            |          |
| Critical Thinking            |                            | fostered |
| Integrity and Work Ethics    |                            | fostered |
| Self-awareness and Self-reflection | | fostered |
| Self-direction and Self-management | | fostered |

### 151-0368-00L Aerodynamic

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<th>Lecture</th>
<th>W 4 credits 2V+1U</th>
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**Abstract**

Introduction to the basics and into the methods of Aerodynamic. An overview of the main static and dynamic phenomena arising from the interaction between structural and aerodynamic loads.

**Objective**

The course will provide a basic physical understanding of flow-structure interaction focused on lifting bodies such as wings. You will get to know the most important phenomena in the static and dynamic aerodynamics, as well as a presentation of the most relevant analytical and numerical prediction methods.

**Content**

- Introduction to steady and unsteady thin airfoil theory, extension to three dimension wing aerodynamics, strip theory, overview of numerical methods available (panel methods, CFD).
- Introduction to unsteady aerodynamics (theory): Theodorsen and Wagner functions. Unsteady aerodynamics observed from numerical experiments (CFD). Generation of simplified mathematical models.
- Presentation of steady aerodynamic: equations for equilibrium for the typical section, aeroelastic deformation, effectiveness of the aeroelastic system, stability (definition), divergence condition, role played by a control surface, control effectiveness, sweep angle, aeroelastic tailoring of bending-torsion coupling. Ritz model to model beams, use of FEM, modal condensation, choice of generalized coordinates.
- Numerical aerodynamic (Test Cases extracted from the latest AIAA Aerodynamic Prediction Workshops). Generation of Reduced Order Models from CFD data (in some cases though Machine Learning).
- Aerodynamic of modern aircraft: assessment of the effects induced by the control surfaces and control systems (Aeroservoelasticity), active controlled aircraft, flutter-suppression systems, certification (EASA, FAA).
- Planning and execution of Wind Tunnel experiments with aerodynamic models. Live-execution of an experiment in the WT of the ETH.
- Brief presentation of phenomena like Limit-Cycle Oscillations (LCO) and panel flutter.

**Lecture notes**

A script in English language is available.

**Literature**

- Bispilnghoff Ashley, Aerodynamic
- Abbott, Theory of Wing sections,

### 151-0371-00L Advanced Model Predictive Control

<table>
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<tr>
<th>Lecture</th>
<th>W 4 credits 2V+1U</th>
<th>M. Zeilinger, A. Carron, L. Hewing, J. Köhler</th>
</tr>
</thead>
</table>

**Abstract**

Model predictive control (MPC) has established itself as a powerful control technique for complex systems under state and input constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

**Objective**

Design, implement and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.

**Content**

- Nominal MPC for uncertain systems (nominal robustness)
- Robust MPC
- Stochastic MPC
- Review of regression methods
- Set-membership Identification and robust data-driven MPC
- Bayesian regression and stochastic data-driven MPC
- MPC as safety filter for reinforcement learning

**Lecture notes**

Lecture notes will be provided.
Prerequisites / notice
Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control in Spring Semester) strongly recommended.
Background in linear algebra and stochastic systems recommended.

**151-0409-00L Multiphysics Modeling and Simulation**

**Abstract**
This class introduces both theoretical and practical aspects related to the modeling and simulation of multiphysics systems. Students will learn how to set up multiphysics models systematically, and therefore reduce time-consuming trial-and-error. Comsol Multiphysics will be utilized to apply the concepts learned during the lectures to solve exercises.

**Objective**
As information technology continues its fast-paced evolution, solid-state devices and systems increase in complexity. Engineers and scientists are thus increasingly facing the need to model and simulate their problems numerically where analytic textbook solution cease to exist. Moreover, boundaries between traditional disciplines are harder to maintain, as a proper description of the system might involve phenomena from several domains. Examples include—but not limited to—mechatronics which relies on mechanical, electrical and electronic engineering, and transducers (sensors and actuators) which are by definition devices that convert signals from one physical domain to another. Simulation platforms such as Comsol Multiphysics have truly opened the way to easy multi-domain numerical simulation, offering tools that cover all operations from geometry definition, to meshing, to physics and boundary conditions setting to simulation and result post-processing and analysis in a unified, domain-independent fashion. However, this high degree of freedom has its price, as inexperienced users may face cryptic error messages, incomprehensible or even incorrect results. It is the mission of this course to show how to properly set up a problem by exposing some of the most common misconceptions and pitfalls in multiphysics modeling. Good practices will be taught that should simplify the modeling process and increase the likelihood of correct results. Examples will mainly come from the fields of mechanics (continuum solid mechanics), electromagnetism (electrostatics and conductive media), heat transfer (conductive not convective) and combinations of these domains.

**Content**
- Recap of ordinary and partial differential equations
- The Finite Element Method (and the Method of Lines)
- Numerical solvers
- Geometry simplification and discretization
- Continuous and discrete symmetries
- Approximate and simplified formulations; domains of applicability
- Boundary conditions and constraints
- Solution-appropriate discretization; hp-refinement, local/global adaptive meshing
- Ramping of nonlinearities and couplings
- Coupling and segregation of multiphysics

**Lecture notes**
Lecture handouts will be posted online.

**Competencies**

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Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

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**151-0509-00L Acoustics in Fluid Media: From Robotics to Additive Manufacturing**

**Abstract**
The course will provide you with the fundamentals of the new and exciting field of ultrasound-based microrobots to treat various diseases. Furthermore, we will explore how ultrasound can be used in additive manufacturing for tissue constructs and robotics.

**Objective**
The course is designed to equip students with skills in the design and development of ultrasound-based manipulation devices and microrobots for applications in medicine and additive manufacturing.

**Content**
Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity. Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices

**Lecture notes**

**Literature**

**Prerequisites / notice**
Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.
The course provides an introduction to non-linear finite element analysis. The treated sources of non-linearity are related to material properties (hyperelasticity, plasticity), kinematics (large deformations, instability problems) and boundary conditions (contact). To be able to address all major sources of non-linearity in theory and numerics, and to apply this knowledge to the solution of relevant problems in solid mechanics.

Lectures and computer labs concerned with the modeling of the deformation response and failure of engineering materials (metals, polymers and composites) subject to extreme loadings during manufacturing, crash, impact and blast events. Students will become familiar with important dynamic testing techniques to identify material model parameters from experiments. The ultimate goal is to provide the students with the knowledge and skills required to engineer modern multi-material solutions for high performance structures in automotive, aerospace and naval engineering.

Various books will be recommended pertaining to the topics covered. Lecture notes will be provided. Slides of the lectures, relevant journal papers and user manuals will be provided.

Prerequisites / notice
Course in continuum mechanics (mandatory), finite element method (recommended)

Competencies

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<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Critical Thinking</td>
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<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Negotiation</td>
<td>assessed</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
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<td>Problem-solving</td>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
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<td>Project Management</td>
<td>Leadership and Responsibility</td>
<td>fostered</td>
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<td>Customer Orientation</td>
<td>fostered</td>
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151-0529-00L Nonlinear FEA

Abstract
The course provides an introduction to non-linear finite element analysis. The treated sources of non-linearity are related to material properties (hyperelasticity, plasticity), kinematics (large deformations, instability problems) and boundary conditions (contact). To be able to address all major sources of non-linearity in theory and numerics, and to apply this knowledge to the solution of relevant problems in solid mechanics.

Lecture notes
Lecture notes will be provided. However, students are encouraged to take their own notes.
<table>
<thead>
<tr>
<th>Prerequisites / Objective</th>
<th>Nonlinear Dynamics and Chaos I</th>
<th>W</th>
<th>4 credits</th>
<th>4G</th>
<th>Q. Haller</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.</td>
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<tr>
<td><strong>Content</strong></td>
<td>(1) Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.</td>
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<td>(2) Near equilibrium dynamics: Linear and Lyapunov stability</td>
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<td>(3) Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations</td>
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<td>(4) Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.</td>
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<td></td>
<td>(5) Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>The lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>- Prerequisites: Analysis, linear algebra and a basic course in differential equations.</td>
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<thead>
<tr>
<th>Prerequisites / Objective</th>
<th>Optical Methods in Experimental Mechanics and Processing Technology</th>
<th>W</th>
<th>4 credits</th>
<th>3G</th>
<th>E. Mavrona</th>
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</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>The lecture introduces optical and imaging methods to assess structures and material parameters or validate numerical simulations. Selected fabrication technologies and their optical quality control methods are discussed, along with their strengths and limitations in industrial applications. The lecture includes two afternoons of hands-on experience at Empa in Dübendorf.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The students can describe the process of imaging and image acquisition. They know how to design simple experiments based on optical and imaging methods. They understand the working principle of the optical techniques. Specifically, they can explain how a mechanical measure such as shape, deformation, and strain is transformed into an optical signal such as an interference, a change of polarization state, or a change of surface temperature. They know the main application field of the individual techniques. They can choose the most appropriate method for solving a specific measurement task and estimate its expected resolution. In addition, they understand the basics of processing technologies from the clean room or 3D printing and how they can assess the quality of layers and structures. Through the hands-on experience, the students gain a more profound and sustained understanding by applying the theoretical foundations to tangible measurement tasks.</td>
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<td><strong>Content</strong></td>
<td>After introducing optics and image acquisition, the lecture explains how to transform mechanical quantities such as shape, deformation, strain, or stress into image content. Selected applications to clean room processes for the fabrication of layered structures are explained. The measurement techniques make use of basic principles such as:</td>
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<td>- Triangulation</td>
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<td>- Interference</td>
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<td>- Diffraction</td>
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<tr>
<td></td>
<td>- Birefringence</td>
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<tr>
<td></td>
<td>- Infrared radiation</td>
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<td></td>
<td>Imaging techniques rely on area detectors, most notably CCD cameras, infrared sensors, and micro-bolometers. Natural white light, halogen lamps, and coherent light sources such as lasers will be used and demonstrated. The topics of the lecture include:</td>
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<td></td>
<td>- Optics and imaging</td>
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<td>- Digital Image Correlation (DIC) in 2D and 3D</td>
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<td></td>
<td>- Diffraction and holography</td>
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<td>- Terahertz (THz) techniques</td>
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<td>- Simulations</td>
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<td>- Device fabrication and 3D printing</td>
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<td>- Photoelasticity and ellipsometry</td>
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<td>- Thermoelastic Stress Analysis</td>
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<td></td>
<td>- Validation of numerical models</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Copies of the presented slides will be made available in advance through Moodle. These slide copies allow the students to add their notes and explanations given during the lecture. We will strive to provide summary pages for each lesson. Each lecture includes a set of exercises. Standard solutions for the exercises will be posted with a time lag.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>A good overview on common optical methods is presented in the following text books:</td>
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<td>Textbooks for specific methods will be introduced in the respective lesson.</td>
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Prerequisites / notice
Basic knowledge of optics and interferometry, as taught in introductory physics courses, is advantageous. We encourage the audience to share their specific questions.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Social Competencies
Communication
Cooperation and Teamwork
Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics

151-0544-00L Metal Additive Manufacturing - Mechanical Integrity and Process Simulation
W 4 credits 3G E. Hosseini

Abstract
An introduction to Metal Additive Manufacturing (MAM) (e.g. different techniques, the metallurgy of common alloy-systems, existing challenges) will be given. The focus of the lecture will be on the employment of different simulation approaches to address MAM challenges and to enable exploiting the full advantage of MAM for the manufacture of structures with desired property and functionality.

Objective
The main objectives of this lecture are:
- Acknowledging the possibilities and challenges for MAM (with a particular focus on mechanical integrity aspects),
- Understanding the importance of material science and metallurgical considerations in MAM,
- Appreciating the importance of thermal, fluid, mechanical and microstructural simulations for efficient use of MAM technology,
- Using commercial analysis tools (e.g. ABAQUS) for simulation of the MAM process.

Content
- Introduction to MAM (concept, application examples, pros & cons),
- Powder-bed and powder-blown metal additive manufacturing,
- Thermo-fluid analysis of additive manufacturing,
- Microstructural simulation (basics, analytical, kinetic Monte Carlo, cellular automata, phase-field),
- Mechanical property prediction for MAM,
- Microstructure and mechanical response of MAM material (stainless steel, Ti6Al4V, Inconel 718),
- Design for additive manufacturing
- Artificial intelligence for AM

Exercise sessions use ABAQUS for analysis of MAM process. Detailed video instructions will be provided to enable students to set up their own simulations. Students can install the packages on their own systems.

Lecture notes
Handouts of the presented slides.

Literature
No textbook is available for the course (unfortunately), since it is a dynamic and relatively new topic. In addition to the material presented in the course slides, suggestions/recommendations for additional literature/publications will be given (for each individual topic).

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Social Competencies
Communication
Cooperation and Teamwork
Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics

151-0550-00L Adaptive Materials for Structural Applications
W 4 credits 3G A. Bergamini

Abstract
Adaptive materials offer appealing ways to extend the design space of structures by introducing time-variable properties into them. In this course, the physical working principles of selected adaptive materials are analyzed and simple models for describing their behavior are presented. Some applications are illustrated, also with laboratory experiments where possible.

Objective
The study of adaptive materials covers topics that range from chemistry to theoretical mechanics.

The aim of this course is to convey knowledge about adaptive materials, their properties and the physical mechanisms that govern their function, so as to develop the skills to deal with this interdisciplinary subject.
This course will provide the students with an insight into the properties and physical phenomena which lead to the features of adaptive materials. Starting from chemomechanical (skeletal muscles), the physical behavior of a wide range of adaptive materials, thermo- and photo-mechanical, electro-mechanical, magneto-mechanical and meta-materials will be thoroughly discussed and analyzed. Up-to-date results on their performance and their implementation in mechanical structures will be detailed and studied in laboratory sessions. Analytical tools and energy based considerations will provide the students with effective instruments for understanding adaptive materials and assess their performance when integrated in structures or when arranged in particular fashions.

Basic concepts: Power conjugated variables, dissipative effects, geometry- and materials-based energy conversion


Thermo-mechanical coupling: Shape memory alloys / polymers

Electro-mechanical coupling(1): DEA, EBL, electrorheological fluids

Shape control / morphing: Use, requirements, challenges

Morphing applications of variable stiffness structures: Lab work

Electro-mechanical coupling (2): Piezoelectric, electrostrictive effect

Vibration Reduction: Measurement, passive, semi-active (active) damping methods

Vibration reduction applications of piezoelectric materials: Lab work

Metamaterials: Definition of metamaterials - electromagnetic, acoustical and other metamaterials

Lecture notes (manuscript and handouts) will be provided

This course will provide the students with an insight into the properties and physical phenomena which lead to the features of adaptive materials. Starting from chemomechanical (skeletal muscles), the physical behavior of a wide range of adaptive materials, thermo- and photo-mechanical, electro-mechanical, magneto-mechanical and meta-materials will be thoroughly discussed and analyzed. Up-to-date results on their performance and their implementation in mechanical structures will be detailed and studied in laboratory sessions. Analytical tools and energy based considerations will provide the students with effective instruments for understanding adaptive materials and assess their performance when integrated in structures or when arranged in particular fashions.

Basic concepts: Power conjugated variables, dissipative effects, geometry- and materials-based energy conversion


Thermo-mechanical coupling: Shape memory alloys / polymers

Electro-mechanical coupling(1): DEA, EBL, electrorheological fluids

Shape control / morphing: Use, requirements, challenges

Morphing applications of variable stiffness structures: Lab work

Electro-mechanical coupling (2): Piezoelectric, electrostrictive effect

Vibration Reduction: Measurement, passive, semi-active (active) damping methods

Vibration reduction applications of piezoelectric materials: Lab work

Metamaterials: Definition of metamaterials - electromagnetic, acoustical and other metamaterials

Energy harvesting and sensing: Energy harvesting with EAP and piezoelectric materials, transducers as sensors: Piezo, resistive,...
Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Objective
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

Content
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microrobots

Lecture notes
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

Prerequisites / notice
The lecture will be taught in English.

151-0604-00L
Microrobotics
W  4 credits  3G  B. Nelson

Abstract
Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Objective
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

Content
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microrobots

Lecture notes
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

Prerequisites / notice
The lecture will be taught in English.

151-0620-00L
Embedded MEMS Lab
W  5 credits  3P  C. Hierold, A. Güntner, M. Haluska

Abstract
Practical course: Students are introduced to the process steps required for the fabrication of MEMS (Micro Electro Mechanical System) and carry out the fabrication and testing steps in the clean rooms by themselves. Additionally, they learn the requirements for working in clean rooms. Processing and characterization will be documented and analyzed in a final report.

Objective
Students learn the individual process steps that are required to make a MEMS (Micro Electro Mechanical System). Students carry out the process steps themselves in laboratories and clean rooms. Furthermore, participants become familiar with the special requirements (cleanliness, safety, operation of equipment and handling hazardous chemicals) of working in the clean rooms and laboratories. The entire production, processing, and characterization of the MEMS is documented and evaluated in a final report.

Content
With guidance from a tutor, the individual silicon microsystem process steps that are required for the fabrication of an accelerometer are carried out:
- Photolithography, dry etching, wet etching, sacrificial layer etching, various cleaning procedures
- Packaging and electrical connection of a MEMS device
- Testing and characterization of the MEMS device
- Written documentation and evaluation of the entire production, processing and characterization

Lecture notes
A document containing theory, background and practical course content is distributed at the Introductory lecture day of the course.

Prerequisites / notice
Participating students are required to attend all scheduled lectures and meetings of the course.

Participating students are required to provide proof that they have personal accident insurance prior to the start of the laboratory portion of the course.

For safety and efficiency reasons the number of participating students is limited. We regret to restrict access to this course by the following rules:

Priority 1: master students of the master's program in "Micro and Nanosystems"
Priority 2: master students of the master's program in "Mechanical Engineering" with a specialization in Microsystems and Nanoscale Engineering (MAVT-tutors: Prof. Daraio, Dual, Hierold, Kounoutsakos, Nelson, Norris, Poulikakos, Pratsinis, Stemmer), who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.
Priority 3: master students, who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.
Priority 4: all other students (PhD, bachelor, master) with a background in silicon or microsystems process technology.

If there are more students in one of these priority groups than places available, we will decide by (in following order) best achieved grade from 151-0621-00L Microsystems Technology, registration to this practicum at previous semester, and by drawing lots. Students will be notified at the first lecture of the course (introductory lecture) as to whether they are able to participate.

The course is offered in autumn and spring semester.
**Objective**

Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystem devices by the combination of unit process steps (= process flow).

**Content**

- Introduction to microsystems technology (MST) and micro electro mechanical systems (MEMS)
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.
- Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties.

Application of selected technologies will be demonstrated on case studies.

**Lecture notes**

Handouts (available online)

**Literature**

- S.M. Sze: Semiconductor Devices, Physics and Technology
- W. Menz, J. Mohr, O.Paul: MEMS Technology
- Hong Xin: Introduction to Semiconductor Manufacturing Technology
- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications

**Prerequisites**

Prerequisites: Physics I and II

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**151-0632-00L Vision Algorithms for Mobile Robotics (University of Zurich)**

*No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.*

**UZH Module Code:** DINF2039

**Abstract**

For a robot to be autonomous, it has to perceive and understand the world around it. This course introduces you to the key computer vision algorithms used in mobile robotics, such as feature extraction, structure from motion, dense reconstruction, tracking, image retrieval, event-based vision, and visual-inertial odometry (the algorithms behind Hololens, Oculus Quest, and the NASA Mars rovers).

**Objective**

Learn the fundamental computer vision algorithms used in mobile robotics, in particular: filtering, feature extraction, structure from motion, multiple view geometry, dense reconstruction, tracking, image retrieval, event-based vision, and visual-inertial odometry and Simultaneous Localization And Mapping (SLAM) (the algorithms behind Hololens, Facebook-Oculus Quest, and the NASA Mars rovers).

**Content**

Each lecture will be followed by a lab session where you will learn to implement a building block of a visual odometry algorithm in Matlab. By the end of the course, you will integrate all these building blocks into a working visual odometry algorithm.

**Lecture notes**

Lecture slides will be made available on the course official website: [http://rpg.ifi.uzh.ch/teaching.html](http://rpg.ifi.uzh.ch/teaching.html)

**Literature**


**Prerequisites / notice**

Fundamentals of algebra, geometry, matrix calculus, and Matlab programming.

Note: If you are interested in taking UZH courses, you must register as an incoming mobility student at UZH. For details, see as follows:

UZH course enrollment for ETH student at University of Zurich (UZH) > Mobility within Switzerland – Incoming > Module Mobility: The easiest way to take individual modules/courses to supplement your studies at your home university is with module mobility. This option is not available to students who have dropped out of their home university or have been definitely excluded or banned from the relevant program > Application and Deadlines: Applications are submitted via the UZH application portal ([https://www.uzh.ch/cmsssl/en/studies/application/chmobility.html](https://www.uzh.ch/cmsssl/en/studies/application/chmobility.html))

Step-by-step guidelines on how ETH students can register for this course, are given on the official course website: [https://rpg.ifi.uzh.ch/teaching.html](https://rpg.ifi.uzh.ch/teaching.html)

**ATTENTION:** When you book the course at UZH, you are automatically registered for the exam at UZH and you can unregister until the October deadline. After registering for the course, you as an ETH student need to check out your "UZH email account" to receive the related email from the lecturer.

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**151-0642-00L Seminar on Micro and Nanosystems**

**Abstract**

Scientific presentations from the field of Micro- and Nanosystems

**Objective**

In particular, the seminar addresses students, who are interested in scientific work in the field of Micro- and Nanosystem technologies, or who have started already with it. Respectively, current examples in the research will be discussed.

**Content**

Current themes in the field of Micro- and Nanosystem technologies using the examples of intern and extern research groups, as well as ongoing themes of study-, diplom- and doctoral thesis will be introduced and discussed. The scope of the seminar is broadened by occasional guest speakers.

**Lecture notes**

- Master of MNS, MAVT, ITET, Physics

**151-0655-00L Skills for Creativity and Innovation**

**Abstract**

This lecture aims to enhance the knowledge and competency of students regarding their innovation capability. An overview on prerequisites of and different skills for creativity and innovation in individual & team settings is given. The focus of this lecture is clearly on building competencies - not just acquiring knowledge.

**Objective**

- Reading and applying research papers on individual and team creativity
- Evaluating and developing individual skills for creativity
- Facilitating idea generation and development in teams
- Observing and developing cooperation and communication in innovation teams

**Prerequisites / notice**

- Observing and developing cooperation and communication in innovation teams

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Content

Knowledge about prerequisites of creativity - theoretical models and empirical results:
- Motivation
- Domain knowledge
- Thinking processes

Development of individual skills for creativity:
- Focus on creativity as problem analysis & solving
- Individual skill exercises and reflection

Knowledge about teams - theoretical models and empirical results:
- Team climate, Psychological Safety
- Team development
- Creative problem solving in teams

Facilitating creative team processes:
- The role of the team facilitator
- Cooperation and communication in innovation teams

Development of team-oriented skills for creativity:
- Idea generation and development in teams
- Role of the facilitator
- Team interaction and communication

Lecture notes

Slides, script and other documents will be distributed via moodle.ethz.ch
(access only for students registered to this course)

Literature


As well as material handed out in the lecture

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

Operational Simulation of Production Lines

W 4 credits 2V+1U P. Acél, A. Kunz

Abstract

The students learn the application of the event-based and computer-based simulation for layout and improvement of production facilities by means of practical examples and by using the so-called «Digital Twin» within the context of «Industry 4.0». They learn how virtual and mixed reality tools can be used together with the Digital Twin to plan and support the operation of a production line.

Objective

The students learn the correct use of (Who? When? How?) of the event-driven and computer-based simulation in the illustration of the operating procedures and the production facilities. The simulation is an important basis for creating a digital twin in the context of Industry 4.0.

Operating simulation in the productions, logistic and scheduling will be shown by means of practical examples.

The students should make their first experiences in the use of computer-based simulation.

Further, the lecture gives insights into the methods-time measurement (MTM) for evaluating human work places as basis for the simulation and learn how this is performed using virtual reality.

Content

- Application and application areas of the event-driven simulation
- Simulation in the context of Industry 4.0 (digital twin)
- Exemplary application of a software tool (Technomatrix-Simulation-Software)
- Internal organization and functionality of simulation tools
- Procedure for application: optimizing, experimental design planning, analysis, data preparation
- Controlling philosophies, emergency concepts, production in sequence, line production, rescheduling
- Application on the facilities projecting
- Applications of Virtual and Mixed Reality

The knowledge is enhanced by practice-oriented exercises and an excursion. A guest speaker will present a practical example.

Lecture notes

Will be sent by email before the lecture (pdf).

Literature

A bibliography will be handed out during the lectures.

Prerequisites / notice

Recommended for all Bachelor-Students in the 5th semester and Master-Students in the 7th semester (MAVT, MTEC, PhD students in material sciences) and for all with interest in production (e.g., MTEC, HEST, etc.)
The course provides an introduction into stochastic methods that are applicable for the description, treatment, and modeling of systems that are subject to uncertainties or that respond to parameter changes in a chaotic manner. Corresponding systems may arise in fluid dynamics, structural mechanics, biology, electrical engineering as well as other areas.

By the end of the course you will be familiar with a range of mathematical/statistical tools that enable a quantitative treatment of problems that involve uncertainties.

- Probability theory, single and multiple random variables, mappings of random variables
- Estimation of statistical moments and probability densities based on data
- Stochastic differential equations, Ito calculus, PDF evolution equations
- Monte Carlo integration with importance and stratified sampling
- Markov-chain Monte Carlo sampling
- Control-variate and multi-level Monte Carlo estimation
- Kalman filters (classical and ensemble-based)
- Statistical tests for means and goodness-of-fit

Detailed lecture notes will be provided.

Some textbooks related to the material covered in the course:

The lecture follows the value added process sequence of electric and electronic components. It contains: Development of electric and electronic components, design of electronic circuits on printed circuit boards as well as in hybrid technology, integrated test technology, planning of electric and electronic product as well as their production, planning of production lines, value added process sequence for photovoltaics.

In summary, the course covers fundamental concepts and theories, as well as practical applications in the field of electrical and electronic engineering.
Exciting Leadership in a Thrilling Real Business World

**Prerequisites / notice**
The lecture is partly given by experts from industry. It is supplemented by an excursion to one of the industry partners.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td>Problem-solving</td>
<td>assessed</td>
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<tr>
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<td>Communication</td>
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<td></td>
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<tr>
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<td>Creative Thinking</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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</table>

**Abstract**
What is leadership in a real world? What are the preconditions of personal leadership? What is the differences between Leadership and Management? What is the price to be payed to be a Leader? What are the core competences of a Leader? How to become an inspiring Leader? How to experience exciting leadership in a thrilled real business world.

**Objective**
The objective of this course is to understand the impact of Leadership and to learn based on longterm international leadership experiences very practicale competences and skills needed to be a leader.

**Content**
Definitions and methods what leadership is about based on real industrial examples. Levels of Leadership. Conflicts, challenges and risks of Leaders. Competences of a leader such as: decision making processes, communication, emotional intelligence, change processes and understanding of people behaviours.

**Lecture notes**
Yes, always after lecture via mail.

**Literature**
Not mandatory, but to be recommended: "The Effective Executive" from Peter Drucker, Verlag Vahlen; ISBN 978 3 8006 46715 from 2014.

Colloquium on Manufacturing Technology

**Prerequisites / notice**
- Students must have participated and passed the courses Manufacturing, Production Machines I and Forming Technology III - Forming Processes.
- Further training with specialized lectures and large participation from the industry.

**Abstract**
Future training on selected current topics of the manufacturing technology. Per afternoon a selected topic is presented in several lectures, by the majority by experts from the industry. The students prepare a summary of the lectures given and prepare themselves on the basis of these lectures and own information search.

**Objective**
Continuous further training to current topics of the manufacturing technique. Exchange of experience and knowledge with the industry and other universities.

**Content**
Selected actual topics on manufacturing methods and tools, machine tools, NC-control and drives, components and measuring methods and devices. Topics are changing every year.

**Lecture notes**
- Students must have participated and passed the courses Manufacturing, Production Machines I and Forming Technology III - Forming Processes.
- Further training with specialized lectures and large participation from the industry.

**Literature**
Help for English speaking students on request.

Sustainable Materials

**Abstract**
The lecture addresses the issue of sustainability in manufacturing, focussing on materials. The most used materials, their production and transformation into a product are analysed in terms of energy consumption and emissions. Emphasis is then placed on alternative design strategies which reduce the use of materials and innovative processes which lower energy consumption and emissions.

**Objective**
After this lecture students will be able to:
- Develop a critical thinking of published sustainability data and facts
- Explain where the materials that we use come from, what emissions arise from the different steps of raw material production and product manufacturing
- Determine where significant changes can be brought
- Develop feasible solutions towards a more sustainable use of materials
The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems. The course consists of three parts: First, we will refresh and deepen the student's knowledge in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

## Content
- Introduction: what is sustainability, which industrial sectors are responsible for the most CO2 (and other) emissions
- The "real" numbers: where to find reliable data and how one can play with the figures
- Basics of life cycle analysis
- CO2 and other emissions
- The most used materials
  - The 5 most used materials today, their key properties and what they are used for
  - Evolution of production, consumption and resources
- Production, recyclability and new processing routes for Al and steel
- Use less material by design
- Re-use of materials & prolonging products life
- Production of cement, new developments & alternatives
- Presentation of students' projects

- Crash
- Collapse of structures
- Material behavior (metals and rubber)
- General forming processes

Special attention will be paid to the modeling of the nonlinear material behavior, thermo-mechanical processes and processes with large plastic deformations. The ability to independently create a virtual model and its simulation with associated research activities will be acquired through accompanying exercises. These will include the Matlab programming of important model components such as constitutive equations. The FEM program ABAQUS will be introduced to investigate real engineering problems.

## Objective
The primary objective of this course is to provide an overview of how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing. The course consists of three parts: First, we will refresh and deepen the student's knowledge in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

## Abstract
We will provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing.

## Objective
The primary objective of this course is to provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing. The course consists of three parts: First, we will refresh and deepen the student's knowledge in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

## Content
- Introduction into FEM
- Fundamentals of continuum mechanics to characterize large plastic deformations
- Elasto-plastic material models
- Lagrange and Euler approaches
- FEM implementation of constitutive equations
- Element formulations
- Implicit and explicit FEM methods
- FEM formulations of coupled thermo-mechanical problems
- Modeling of tool contact and the influence of friction
- Solvers and convergence
- Instability problems

Special attention will be paid to the modeling of the nonlinear material behavior, thermo-mechanical processes and processes with large plastic deformations. The ability to independently create a virtual model and its simulation with associated research activities will be acquired through accompanying exercises. These will include the Matlab programming of important model components such as constitutive equations. The FEM program ABAQUS will be introduced to investigate real engineering problems.
### Introduction to Photonics

#### Abstract

This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

#### Objective

Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.

#### Content

<table>
<thead>
<tr>
<th>I- BASICS OF WAVE THEORY</th>
</tr>
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<tbody>
<tr>
<td>1) General concepts</td>
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<tr>
<td>2) Differential wave equation</td>
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<td>3) Wavefront</td>
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<tr>
<td>4) Plane waves and Fourier decomposition of optical fields</td>
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<td>5) Spherical waves and Huygens-Fresnel principle</td>
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<tr>
<th>II- ELECTROMAGNETIC WAVES</th>
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<tbody>
<tr>
<td>1) Maxwell equations</td>
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<td>2) Wave equation for EM waves</td>
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<td>3) Dielectric permittivity</td>
</tr>
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<td>4) Refractive index</td>
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<td>5) Nonlinear optics</td>
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<td>6) Polarisation and polarisation control</td>
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<tr>
<th>III- PROPAGATION OF LIGHT</th>
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<tr>
<td>1) Waves at an interface</td>
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<td>2) The Fresnel coefficients</td>
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<td>3) Total internal reflection</td>
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<td>4) Evanescent waves</td>
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<td>5) Dispersion diagram</td>
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<th>IV- INTERFERENCES</th>
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<tr>
<td>1) General considerations</td>
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<tr>
<td>2) Temporal and spatial coherence</td>
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<tr>
<td>3) The Young double slit experiment</td>
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<td>4) Diffraction gratings</td>
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<td>5) The Michelson interferometer</td>
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<td>6) Multi-wave interference</td>
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<td>7) Antireflecting coating and interference filters</td>
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<td>8) Optical holography</td>
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<tr>
<th>V- LIGHT MANIPULATION</th>
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<tbody>
<tr>
<td>1) Optical waveguides</td>
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<td>2) Photonic crystals</td>
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<td>3) Metamaterials and metasurfaces</td>
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<td>4) Optical cavities</td>
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<tr>
<th>VI- OPTICAL FORCES AND OPTICAL TWEETERS</th>
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<tr>
<td>1) History of optical forces</td>
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<td>2) Theory of optical trapping</td>
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<td>3) Atom cooling</td>
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<td>4) Optomechanics</td>
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<td>5) Applications of optical tweezers</td>
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<tr>
<th>VII- INTRODUCTION TO OPTICAL MICROSCOPY</th>
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<tr>
<td>1) Basic concepts</td>
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<td>2) Direct and Fourier imaging</td>
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<td>3) Image formation</td>
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<td>4) Fluorescence microscopy</td>
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<td>5) Scattering-based microscopy</td>
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<td>6) Digital holography</td>
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<td>7) Computational imaging</td>
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<td>Self-direction and Self-management</td>
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151-0913-00L

Introduction to Photonics

W 4 credits 2V+2U R. Quidant, J. Ortega Arroyo
### Mass Transfer

<table>
<thead>
<tr>
<th>151-0917-00L</th>
<th>Mass Transfer</th>
<th>W</th>
<th>4</th>
<th>M. Tibbitt, V. Mavrantzas, C.-J. Shih</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore, the application of these principles to important engineering problems is demonstrated.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Fick's laws; application and significance of mass transfer; comparison of Fick's laws with Newton's and Fourier's laws; derivation of Fick's 2nd law; diffusion in dilute and concentrated solutions; rotating disk; dispersion; diffusion coefficients, viscosity and heat conduction (Pr and Sc numbers); Brownian motion; Stokes-Einstein equation; mass transfer coefficients (Nu and Sh numbers); mass transfer across interfaces; Analogies for mass-, heat-, and momentum transfer in turbulent flows; film-, penetration-, and surface renewal theories; simultaneous mass, heat and momentum transfer (boundary layers); homogeneous and heterogeneous reversible and irreversible reactions; diffusion-controlled reactions; mass transfer and first order heterogeneous reaction. Applications.</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.</td>
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</table>

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: fostered
  - Media and Digital Technologies: fostered

- **Social Competencies**
  - Communication: fostered
  - Cooperation and Teamwork: fostered
  - Sensitivity to Diversity: fostered

- **Personal Competencies**
  - Adaptability and Flexibility: fostered
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

### Rate-Controlled Separations in Fine Chemistry

<table>
<thead>
<tr>
<th>151-0927-00L</th>
<th>Rate-Controlled Separations in Fine Chemistry</th>
<th>W</th>
<th>6</th>
<th>M. Mazzotti, V. Becattini, N. Casas, F. Kiefer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.</td>
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<tr>
<td><strong>Content</strong></td>
<td>The class covers separation techniques that are central in the purification and downstream processing of chemicals and bio-pharmaceuticals. Examples from both areas illustrate the utility of the methods: 1) Adsorption and chromatography; 2) Membrane processes; 3) Crystallization and precipitation.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>Recommendations for text books will be covered in the class</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Requirements (recommended, not mandatory): Thermal separation Processes I (151-0926-00) and Modelling and mathematical methods in process and chemical engineering (151-0940-00)</td>
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</table>

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: fostered
  - Media and Digital Technologies: fostered

- **Social Competencies**
  - Communication: assessed
  - Cooperation and Teamwork: fostered
  - Leadership and Responsibility: fostered
  - Customer Orientation: fostered
  - Self-presentation and Social Influence: fostered

- **Personal Competencies**
  - Adaptability and Flexibility: fostered
  - Creative Thinking: fostered
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered
Molecular Sensors: From Fundamentals to Health and Environmental Applications

Abstract
Molecular sensors are used in everyday life in health care, environmental monitoring, food safety, space and other fields. Sources of molecular information, its transport and fundamental concepts of molecular sensing will be discussed. In the scope of group projects, the acquired knowledge will be applied and deepened in case studies.

Objective
After the course, the students will:

- know the requirements and merits of molecular sensors for health, environmental and other emerging applications (e.g. space)
- understand transport phenomena of molecular information & surface interactions and know how to quantitatively describe these
- understand fundamental sensing concepts for the detection and quantification of molecular analytes
- know concepts of signal processing
- be capable to apply the learnt knowledge to conceive and engineer sensor concepts and systems
- know how to investigate sensor-related literature and present scientific data

This course consists of a theoretical and a project-based learning block. In the first 10 semester weeks, theoretical knowledge will be provided through lectures and deepened in corresponding exercises. In the last 4 weeks, the students will apply the learned concepts through group projects to investigate case studies. The outcome will be present.

Content
Transport of Molecular Information; Surface Interactions; Sensor Fundamentals; Chemoresistive Sensing; Electrochemical Sensing; Mass-sensitive; Capacitive Sensing; Signal Processing; Medical Requirements for Molecular Sensing

Process Design and Safety

Abstract
The lecture Process Design and Safety deals with the fundamentals of project management, scale-up, dimensioning and safety of chemical process equipment and plants.

Objective
The objective of the lecture is to expound the engineering design approach of important elements in chemical plant design.

Content
Fundamentals in Chemical engineering Design; Project Management, Cost estimate, Materials and Corrosion, Piping and Armatures, Pumps, Reactors and Scale-up, Safety of chemical processes, Patents

Introduction to Aircraft and Car Aerodynamics

Abstract

Objective
To understand the basic relations of the origin of aerodynamic forces (ie lift, drag). To quantify the aerodynamic forces for basic configurations of aircraft and car components. Illustration of the intrinsic problems and results using examples.

Content
Aircraft aerodynamics: atmosphere, aerodynamic forces (ascending force; profile, wings. Resistance, residual resistance, induced resistance); thrust (overview of the propulsion system, aerodynamics of the propellers), introduction to static longitudinal stability.

Process Design and Safety

Lecture notes
The lecture slides will be distributed.

Literature

Prerequisites / notice
A 1-day excursion including a visit of a chemical plant will be part of the lecture.

Introduction to Aircraft and Car Aerodynamics

Lecture notes
Preparation materials & slides are provided prior to each class
The lecture and exercises teach the fundamentals of optimization methods in the context of engineering design. After taking the course, students will be able to express engineering design tasks as formal optimization problems. Students will also be able to select and apply a suitable optimization method given the nature of the optimization model. They will understand the links between optimization and engineering design in order to design more efficient and performance optimized technical products. The exercises are MATLAB based.

Objective

- Critical thinking and reasoned judgements
- Understanding the challenges of engineering projects and design teams
- Development of personal skills to apply and train product development methods
- Knowledge and know-how about applying methods
- Reflection and exchange of experiences about personal coaching situations
- Inspiration and learning from good cases regarding organizational and team management aspects
- Decision-making under uncertainty

Content

The following topics will be covered in the lecture:
- Kick-off & Experience Exchange
- Coaching Role
- Active Listening
- Giving and Receiving Feedback
- Team Building & Psychological Safety
- Building Hypotheses in the coaching process
- conflict resolution and motivation

In addition to the content topics, one-on-one coaching will be provided and classes will reflect on current, practical issues derived from coaching the innovation teams.

Prerequisites / notice

Only for participants (Bachelor Students, Master Students) who are teaching assistants in the innovation project.

Competencies

Subject-specific Competencies
- Concepts and Theories
Method-specific Competencies
- Analytical Competencies
Social Competencies
- Communication
Personal Competencies
- Adaptability and Flexibility

Communication
- Leadership and Responsibility
- Self-presentation and Social Influence

Self-awareness and Self-reflection
- Critical Thinking
- Self-direction and Self-management

Social Competencies
- Conflict resolution and motivation

Method-specific Competencies
- Cooperation and Teamwork
- Decision-making under uncertainty

Personal Competencies
- Reflection and exchange of experiences about personal coaching situations
- Development of personal skills to apply and train product development methods

Only for participants (Bachelor Students, Master Students) who are teaching assistants in the innovation project). In addition to the content topics, one-on-one coaching will be provided and classes will reflect on current, practical issues derived from coaching the innovation teams.

Lecture notes

available on Moodle

Literature

- Aircraft Aerodynamics:
  - Schlichting,H und Truckenbrodt, E: Aerodynamik des Flugzeuge (Ed I und II), Springer Verlag, 1960
  - Hoerner, S.F.: Fluid Dynamic Lift, Hoerner Fluid Dynamics, 1975

- Vehicle Aerodynamics

- Aircraft Aerodynamics

- Aircraft Aerodynamics:

151-3204-00L Coaching Innovation Projects

Objective

- Critical thinking and reasoned judgements
- Understanding the challenges of engineering projects and design teams
- Development of personal skills to apply and train product development methods
- Knowledge and know-how about applying methods
- Reflection and exchange of experiences about personal coaching situations
- Inspiration and learning from good cases regarding organizational and team management aspects
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In addition to the content topics, one-on-one coaching will be provided and classes will reflect on current, practical issues derived from coaching the innovation teams.

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- Critical Thinking
- Self-direction and Self-management

Social Competencies
- Conflict resolution and motivation

Method-specific Competencies
- Cooperation and Teamwork
- Decision-making under uncertainty

Personal Competencies
- Reflection and exchange of experiences about personal coaching situations
- Development of personal skills to apply and train product development methods

Only for participants (Bachelor Students, Master Students) who are teaching assistants in the innovation project). In addition to the content topics, one-on-one coaching will be provided and classes will reflect on current, practical issues derived from coaching the innovation teams.

Lecture notes

available on Moodle

151-3209-00L Engineering Design Optimization

Abstract

The course covers fundamentals of computational optimization methods in the context of engineering design. It develops skills to formally state and model engineering design tasks as optimization problems and select appropriate methods to solve them.

Objective

The lecture and exercises teach the fundamentals of optimization methods in the context of engineering design. After taking the course, students will be able to express engineering design problems as formal optimization problems. Students will also be able to select and apply a suitable optimization method given the nature of the optimization model. They will understand the links between optimization and engineering design in order to design more efficient and performance optimized technical products. The exercises are MATLAB based.

Content

1. Optimization modeling and theory
2. Unconstrained optimization methods
3. Constrained optimization methods - linear and non-linear
4. Direct search methods
5. Stochastic and evolutionary search methods
6. Multi-objective optimization

Lecture notes

available on Moodle

151-3215-00L Design for Additive Manufacturing

Abstract

This course focuses on the design, manufacture and testing of components produced using additive manufacturing (AM) technologies. The course includes a project based on a real-world challenges where students design, fabricate and iteratively optimize functional AM parts using an appropriate AM technology.

Objective

This course provides a basic knowledge of design for additive manufacturing (AM). The course will prepare students to

- Apply basic AM processes (metal and plastic)
- Apply AM design guidelines
- Adopt AM in an industrial environment
- Apply design tools and methods in AM
- Create value from AM
- Work in a project based product development team

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Content In parallel to the lectures, the students design, manufacture and test prototypes in a project at different stages of product development. The course covers the following topics:
- State-of-the-art AM processes for metals and plastics: PBF (also known as SLM, SLS), BJT, MJF, MEX (FDM)
- Design guidelines in AM
- Industrial adoption of AM
- Value creation and business models for AM
- Design tools and methodologies for AM
- Quality management in AM
- Industrial cases of AM applications
- Problem solving and creativity
- Agile development

Lecture notes Script and handouts are available in PDF-format.

Literature

- Christoph Klahn; Mirko Meboldt: Entwicklung und Konstruktion für die Additive Fertigung - Grundlagen und Methoden für den Einsatz in industriellen Endkundenprodukten
  Vogel Business Media, Würzburg
  ISBN: 978-3-8343-3395-7

- Ian Gibson; David Rosen; Brent Stucker: Additive manufacturing technologies - 3D printing, rapid prototyping, and direct digital manufacturing
  Springer, New York
  ISBN: 978-1-4939-2112-6

Prerequisites / notice
This course is for master's students.

Competencies

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<th>Competencies</th>
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151-8101-00L International Engineering: from Hubris to Hope  W 4 credits  3G  E. Tilley

Abstract Since Europe surrendered their colonial assets, engineers from rich countries have returned to the African continent to address the real and perceived ills that they felt technology could solve. And yet, 70 years on, the promise of technology has largely failed to deliver widespread, substantive improvements in the quality of life. Why?

Objective This course is meant for engineers who are interested in pursuing an ethical and relevant career internationally, and who are willing to examine the complex role that well-meaning foreigners have played and continue to play in the disappointing health outcomes that characterize much of the African continent.

After completing the course, participants will be able to
- critique the jargon and terms used by the international community, i.e. “development”, “aid”, “cooperation”, “assistance” “third world” “developing” “global south” “low and middle-income” and justify their own chosen terminology
- recognize the role of racism and white-supremacy in the development of the Aid industry
- understand the political, financial, and cultural reasons why technology and infrastructure have historically failed
- Debate the merits of international engineering in popular culture and media
- Propose improved SDG indicators that address current shortcomings
- Compare the engineering curricula of different countries to identify relative strengths and shortcomings
- Explain the inherent biases of academic publishing and its impact on engineering failure
- Analyse linkages between the rise of philanthropy and strategic priority areas
- Recommend equitable, just funding models to achieve more sustainable outcomes
- Formulate a vision for the international engineer of the future

Content
- Role of international engineering during colonialism
- Transition of international engineering following colonialism
- White saviourism and racism in international engineering
- International engineering in popular culture
- The missing role of Engineering Education
- Biases in academic publishing
- The emerging role in Global Philanthropy
- The paradox of International funding

Literature
### Applied Category Theory for Engineering I

**Note:** The previous course title until HS22 “Applied Compositional Thinking for Engineers II”

**Abstract**
Applied Category Theory is an exciting multidisciplinary field of research which harnesses the mathematical language of category theory for applications across a broad range of disciplines. This course is a gentle introduction focused on applications in engineering and the “compositional approach” to systems analysis, co-design, and computation.

**Objective**
1) Learn basic concepts from algebra and category theory, together with ways to make use of these concepts for engineering applications.
2) Become familiar with case studies of applied category theory, for instance involving dynamical systems, databases, and complex system co-design (e.g. in the context of autonomous vehicles).
3) Be able to recognize compositional structures in concrete scenarios at different levels of abstraction.
4) Understand the “compositional way of thinking” as an approach to systems analysis, co-design, and computation.

**Content**
- Review of basic algebraic structures [sets, relations, (semi)groups, monoids, actions, order theory]
- Gentle introduction to category theory [series and parallel composition, feedback, actions, functors, universal properties]
- Many simple applied examples illustrating concepts along the way. Extended examples from dynamical systems, databases, and systems co-design in engineering.

Homework will consist of 1) basic exercises to check one’s understanding of core concepts, and 2) a choice between either A) coding exercises (in python) to learn how to implement concepts in software or B) further theory exercises to deepen mathematical understanding.

Homework will be graded on a schedule that allows some flexibility, and it will constitute 100% of the grade (no exam).

**Lecture notes**
Slides and a (work-in-progress) textbook for the course will be provided (A. Censi, J. Lorand, G. Zardini, “Applied Compositional Thinking for Engineers”).

**Literature**
- Supplementary references include the following books:
  - Fong, Spivak, “An invitation to applied category theory: Seven sketches in compositionality”
  - Spivak, “Category theory for the sciences”

**Prerequisites / notice**
A knowledge of algebra at the level of a bachelor’s degree in engineering/computer science.

### Structural Reliability and Risk Analysis

**Abstract**
Structural reliability aims at quantifying the probability of failure of systems due to uncertainties in their design, manufacturing and environmental conditions. Risk analysis combines this information with the consequences of failure in view of optimal decision making. The course presents the underlying probabilistic modelling and computational methods for reliability and risk assessment.

**Objective**
The goal of this course is to provide the students with a thorough understanding of the key concepts behind structural reliability and risk analysis. After this course the students will have refreshed their knowledge of probability theory and statistics to model uncertainties in view of engineering applications. They will be able to analyze the reliability of a structure and to use assessment methods for decision making under uncertain conditions. They will be aware of the state-of-the-art computational methods and software in this field.
Content

Engineers are confronted every day to decision making under limited amount of information and uncertain conditions. When designing new structures and systems, the design codes such as SIA or Euro-codes usually provide a framework that guarantees safety and reliability. However the level of safety is not quantified explicitly, which does not allow the analyst to properly choose between design variants and evaluate a total cost in case of failure. In contrast, the framework of risk analysis allows one to incorporate the uncertainty in decision making.

The first part of the course is a reminder on probability theory that is used as a main tool for reliability and risk analysis. Classical concepts such as random variables and vectors, dependence and correlation are recalled. Basic statistical inference methods used for building a probabilistic model from the available data, e.g. the maximum likelihood method, are presented.

The second part is related to structural reliability analysis, i.e. methods that allow one to compute probabilities of failure of a given system with respect to prescribed criteria. The framework of reliability analysis is first set up. Reliability indices are introduced together with the first order-second moment method (FOSM) and the first order reliability method (FORM). Methods based on Monte Carlo simulation are then reviewed and illustrated through various examples. By-products of reliability analysis such as sensitivity measures and partial safety coefficients are derived and their links to structural design codes is shown. The reliability of structural systems is also introduced as well as the methods used to reassess existing structures based on new information.

The third part of the course addresses risk assessment methods. Techniques for the identification of hazard scenarios and their representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. Elements of Bayesian decision making, i.e. pre-, post and pre-post risk assessment methods are presented.

The course also includes a tutorial using the UQLab software dedicated to real world structural reliability analysis.

Lecture notes

Slides of the lectures are available online every week. A printed version of the full set of slides is proposed to the students at the beginning of the semester.

Literature


Prerequisites / notice

Basic course on probability theory and statistics
### Content
- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

### Lecture notes
Available on the course Moodle platform.

### Prerequisites / notice
Sufficient mathematical maturity, in particular in linear algebra, analysis.

### Competencies

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### Biomedical Imaging

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<th>6 credits</th>
<th>S. Kozerke, K. P. Prüssmann</th>
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### Abstract
Introduction to diagnostic medical imaging based on electromagnetic and acoustic fields including X-ray planar and tomographic imaging, radio-tracer based nuclear imaging techniques, magnetic resonance imaging and ultrasound-based procedures.

### Objective
Upon completion of the course students are able to:
- Explain the physical and mathematical foundations of diagnostic medical imaging systems
- Characterize system performance based on signal-to-noise ratio, contrast-to-noise ratio and transfer function
- Design a basic diagnostic imaging system chain including data acquisition and data reconstruction
- Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications

### Content
- Introduction (intro, overview, history)
- Signal theory and processing (foundations, transforms, filtering, signal-to-noise ratio)
- X-rays (production, tissue interaction, contrast, modular transfer function)
- X-rays (resolution, detection, digital subtraction angiography, Radon transform)
- X-rays (filtered back-projection, spiral computed tomography, image quality, dose)
- Nuclear imaging (radioactive tracer, collimation, point spread function, SPECT/PET)
- Nuclear imaging (detection principles, image reconstruction, kinetic modelling)
- Magnetic Resonance (magnetic moment, spin transitions, excitation, relaxation, detection)
- Magnetic Resonance (plane wave encoding, Fourier reconstruction, pulse sequences)
- Ultrasound (mechanical wave generation, propagation in tissue, reflection, transmission)
- Ultrasound (spatial and temporal resolution, phased arrays)
- Ultrasound (Doppler shift, implementations, applications)
- Summary, example exam questions

### Lecture notes
Lecture notes and handouts

### Literature
Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

### Prerequisites / notice
Analysis, Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming

### Competencies

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### Biomedical Engineering

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<th>W</th>
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<th>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</th>
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### Abstract
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the basic vocabulary of biomedical engineering and getting familiar with concepts that govern common medical instruments and the most important organs from an engineering point of view.

### Objective
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs.

In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.
Content

History of BME and the role of biomedical engineers. Ethical issues related to BME.
Biomedical sensors both wearable and also biochemical sensors.
Bioelectronics: Nernst equation, Donnan equilibrium, equivalent circuits of biological membranes and bioelectronic devices.
Bioinformatics: genomic and proteomic tools, databases and basic calculations.
Equations describing basic reactions and enzyme kinetics.
Medical optics: Optical components and systems used in hospitals.
Basic concepts of tissue engineering and organ printing.
Biomaterials and their medical applications.
Function of the heart and the circulatory system.
Transport and exchange of substances in the human body, compartment modeling.
The respiratory system.
Bioimaging.
Orthopedic biomechanics.

Lecture notes

Introduction to Biomedical Engineering
by Enderle, Banchard, and Bronzino

AND

moodle page of the course

Prerequisites /

No specific requirements, BUT
ITET, MAVT, PHYS students will have to learn a lot of new words related to biochemistry, biology and medicine, while
HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.).

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving fostered

Project Management fostered

Social Competencies

Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies

Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

227-0393-10L Bioelectronics and Biosensors W 6 credits 2V+2U J. Vörös, M. F. Yanik

Abstract
The course introduces bioelectricity and the sensing concepts that enable obtaining information about neurons and their networks. The sources of electrical fields and currents in the context of biological systems are discussed. The fundamental concepts and challenges of measuring bioelectronic signals and the basic concepts to record optogenetically modified organisms are introduced.

Objective
During this course the students will:
- learn the basic concepts in bioelectronics including the sources of bioelectronic signals and the methods to measure them
- be able to solve typical problems in bioelectronics
- learn about the remaining challenges in this field

Content
Lecture topics:

1. Introduction
2. Sources of bioelectronic signals
3. Membrane and Transport
4. Action potential and Hodgkin-Huxley
5. Measuring bioelectronic signals
6. Detection and Noise
7. Measuring currents in solutions, nanopore sensing and patch clamp pipettes
8. Measuring potentials in solution and core conductance model
9. Measuring electronic signals with wearable electronics, EGG, EEG
10. In vivo stimulation and recording
11. Functional electric stimulation
12. In vivo electrophysiology
13. Optical recording and control of neurons (optogenetics)
14. Measuring neurons optically, fundamentals of optical microscopy
15. Fluorescent probes and scanning microscopy, optogenetics, in vivo microscopy
16. Measuring biochemical signals

Lecture notes
A detailed script is provided to each lecture including the exercises and their solutions.

Literature
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites /

The course requires an open attitude to the interdisciplinary approach of bioelectronics.
In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning and Convolutional Neural Networks. The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are to evaluate machine types for given specifications and to acquire the ability to perform a rough design of an electrical machine while considering the versatile aspects with respect to magnetic, electrical, mechanical and thermal limitations. Exercises are used to consolidate the presented theoretical concepts.

### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### 227-0447-00L Image Analysis and Computer Vision

**W 6 credits 3V+1U**  
E. Konukoglu, E. Erdil, F. Yu

**Abstract**

**Objective**
- This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

**Content**
- The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.
- The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

**Lecture notes**
- Course material Script, computer demonstrations, exercises and problem solutions

**Prerequisites**
- Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

### 227-0517-10L Fundamentals of Electric Machines

**W 6 credits 4G**  
D. Bortis

**Abstract**
- This course introduces to different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.

**Objective**
- The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are to evaluate machine types for given specifications and to acquire the ability to perform a rough design of an electrical machine while considering the versatile aspects with respect to magnetic, electrical, mechanical and thermal limitations. Exercises are used to consolidate the presented theoretical concepts.

**Content**
- Fundamentals in magnetic circuits and electromechanical energy conversion.
- Force and torque calculation.
- Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine).
- Complex space vector notation, rotating coordinate system (dq-transformation).
- Loss components in electric machines, scaling laws of electromechanical actuators.
- Mechanical and thermal modelling.

**Lecture notes**
- Lecture notes and associated exercises including correct answers

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: fostered

### 227-0523-00L Railway Systems I

**W 6 credits 4G**  
M. Meyer

**Abstract**
- Basic characteristics of railway vehicles and their interfaces with the railway infrastructure:
  - Transportation tasks and vehicle types
  - Running dynamics
  - Mechanical part of rail vehicles
  - Brakes
  - Traction chain and auxiliary supply
  - Railway power supply
  - Signalling systems
  - Standards
  - Availability and safety
  - Traffic control and maintenance
Objective
- Overview of the technical characteristics of railway systems
- Know-how about the design and construction principles of rail vehicles
- Interrelationship between different fields of engineering sciences (mechanics, electro and information technology, transport systems)
- Understanding tasks and opportunities of engineers working in an environment which has strong economical and political boundaries
- Insight into the activities of the railway vehicle industry and railway operators in Switzerland
- Motivation of young engineers to start a career in the railway industry or with railway operators

Content
EST I (Herbstsemester) - Begriffen, Grundlagen, Merkmale

1 Einführung:
1.1 Geschichte und Struktur des Bahnsystems
1.2 Fahrdynamik

2 Vollbahnfahrzeuge:
2.1 Mechanik: Kasten, Drehgestelle, Lauftechnik, Adhäsion
2.2 Bremsen
2.3 Traktionsantriebssysteme
2.4 Hilfsbetriebe und Komfortanlagen
2.5 Steuerung und Regelung

3 Infrastruktur:
3.1 Fahrweg
3.2 Bahnstromversorgung
3.3 Sicherungsanlagen

4 Betrieb:
4.1 Interoperabilität, Normen und Zulassung
4.2 RAMS, LCC
4.3 Anwendungsbeispiele

Voraussichtlich ein oder zwei Gastreferate

Geplante Exkursionen:
Betriebszentrale SBB, Zürich Flughafen
Reparatur und Unterhalt, SBB Zürich Altstetten
Fahrzeugfertigung, Stadler Bussnang

Lecture notes
Abgabe der Unterlagen (gegen eine Schutzgebühr) zu Beginn des Semesters. Rechtzeitig eingeschriebene Teilnehmer können die Unterlagen auf Wunsch und gegen eine Zusatzgebühr auch in Farbe beziehen.

Prerequisites / notice
Dozent: Dr. Markus Meyer, Emkamatik GmbH

Voraussichtlich ein oder zwei Gastvorträge von anderen Referenten.

EST I (Herbstsemester) kann als in sich geschlossene einsemestrige Vorlesung besucht werden. EST II (Frühjahrssemester) dient der weiteren Vertiefung der Fahrzeugtechnik und der Integration in die Bahninfrastruktur.

Competencies

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Critical Thinking

Personal Competencies

252-0535-00L Advanced Machine Learning
W 10 credits 3V+2U+4A C. Cotrini Jimenez

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real-world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
What is data?
Bayesian Learning
Computational learning theory

Supervised learning:
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks

Unsupervised learning:
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation
Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.
This course covers fundamental and advanced concepts of modern computer graphics. Students will learn the fundamentals of digital scene representations, advanced physically-based light transport algorithms for generating photorealistic images from these scene representations, and inverse rendering methods for recovering digital scene representations from captured images.

To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity. Parametric identification methods. On-line and batch approaches.


Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.

Books:

Prerequisites / notice: The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
Objective

Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars of thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding experimental results from the literature.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

Content

- Basics of theory of probability
- Boltzmann’s law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns

Theory and corresponding exercises are merged together during the classes.

I am willingly available Mondays 17.00 o’clock - 18.00 in my office GLC F12.2 for whatever discussion about the lessons and the exercises.

Lecture notes

No lecture notes because the two proposed textbooks are more than exhaustive!

I am using OneNote. All lectures will be broadcast via ZOOM, while corresponding videos of the previous years (lectures and exercises) are available in Moodle!!!

Literature


As further deepening:


Prerequisites / notice

Participants need a good command of

- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Cross-Disciplinary Research and Development in Medicine and Engineering

A maximum of 12 medical degree students and 12 (biomedical) engineering degree students can be admitted, their number should be equal.

IMPORTANT: Note that a special permission from the lecturers is required to register for this course. Contact the head lecturer to that end.
Abstract
Cross-disciplinary collaboration between engineers and medical doctors is indispensable for innovation in health care. This course brings together engineering students from ETH Zurich and medical students from the University of Zurich to experience the rewards and challenges of such interdisciplinary work in a project based learning environment.

Objective
The main goal of this course is to demonstrate the differences in communication between the fields of medicine and engineering. Since such differences become most evident during actual collaborative work, the course is based on a project in physiology, medical or clinical research that combines medicine and engineering.

For the engineering students, the specific aims of the course are to:
- Identify and precisely define a clinical need;
- Acquire a working understanding of the investigated system;
- Identify the engineering challenges in the project and communicate them to the medical students;
- Develop and implement, together with the medical students, solution strategies for the identified challenges;
- Present the solution concept to a cross-disciplinary audience; Preliminary need and solution validation;

Content
After a general introduction to interdisciplinary communication, need identification and product development, the engineering students will team up with medical students to 1) identify a clinically relevant need, 2) develop early-stage solution concepts to it. In the process, they will be supervised both by lecturers from ETH Zurich and the University of Zurich, receiving coaching customized to the project. The project is usually defined by the team itself, but can also be guided by the lecturers. The course will end with each team presenting identified need and solution concept to a cross-disciplinary audience.

Lecture notes
Lecture handouts and relevant material will be provided.

Prerequisites / notice
IMPORTANT: Note that a special permission from the lecturers is required to register for this course. Contact the head lecturer to that end.

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227-0965-00L Micro and Nano-Tomography of Biological Tissues
The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

Objective
Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

Content
Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

Lecture notes
Available online

Literature
Will be indicated during the lecture.

252-0834-00L Information Systems for Engineers
This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).
Objective

Do you want to be able to query your own data productively and efficiently in your future semester projects, bachelor's thesis, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This course teaches you how to do so as well as the dos and don'ts.

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook

Literature

- Lecture material (slides).
- Book: "Database Systems: The Complete Book", H. Garcia-Molina, J.D. Ullman, J. Widom (It is not required to buy the book, as the library has it)

Prerequisites / notice

For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logic
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

Data: 15.06.2024 12:39   Autumn Semester 2024   Page 1797 of 2653
### Computer Vision

**Course Code:** 263-5902-00L  
**Type:** W  
**Credits:** 8  
**Prerequisites:** 3V+1U+3A  
**Instructor:** F. Yu  

**Objective**
- The objectives of this course are:
  1. To introduce the fundamental problems of computer vision.
  2. To introduce the main concepts and techniques used to solve those.
  3. To enable participants to implement solutions for reasonably complex problems.
  4. To enable participants to make sense of the computer vision literature.

**Content**
- Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition.

**Prerequisites / notice**
- It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

**Competencies**

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### Open- and User Innovation

**Course Code:** 351-0555-00L  
**Type:** W  
**Credits:** 3  
**Instructor:** S. Häfliger, S. Spaeth  

**Abstract**
- The course introduces the students to the long-standing tradition of actively involving users of technology and other knowledge-intensive products in the development and production process, and through own cases they develop an entrepreneurial understanding of product development under distributed, user-centered, or open innovation strategies.
The course includes both lectures and exercises alternately. The goal is to understand the opportunity of user innovation for management and develop strategies to harness the value of user-developed ideas and contributions for firms and other organizations.

The students actively participate in discussions during the lectures and contribute presentations of case studies during the exercises. The combination should allow to compare theory with practical cases from various industries.

The course presents and builds upon recent research and challenges the students to devise innovation strategies that take into account the availability of user expertise, free and public knowledge, and the interaction with communities that span beyond one organization.

Performance assessment will be: a written group essay based on the open/user innovation case that participants will research and present during the block seminar (including the slides). Each group will have to hand in a 15-20 page essay, details on the required format and the content will be distributed during the course. Active class participation is required.

This course on user innovation extends courses on knowledge management and innovation as well as marketing. The students are introduced to the long-standing tradition of actively involving users of technology and other knowledge-intensive products in the development and production process, and through own cases they develop an entrepreneurial understanding of product development under distributed, user-centered, or open innovation strategies. Theoretical underpinnings taught in the course include models of innovation, the structuration of technology, and an introduction to entrepreneurship.

Relevant literature for the course includes slides and reading assignments. Papers will be made available through a corresponding Moodle group.

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### Content

The slides of the lectures are made available and updated continuously through Moodle.

**Production and Operations Management (POM)** is at the heart of any business. It is concerned with the business processes that transform input into output and deliver products and services to customers. Factory management is an important part of POM, but it is much more than what takes place inside the production facilities of companies like ABB, Boeing, BMW, LEGO, Nestlé, Roche, TESLA, and Toyota. Did you know that the largest portion of assets and employees in most organizations are engaged in the operations function? Although this course focuses on manufacturing, all types of organizations depend on their operational capabilities. With the ongoing globalization and digitization of manufacturing, POM has won a deserved status for providing a competitive advantage.

This course covers the following topics: Introduction to POM, Manufacturing strategy, Forecasting and capacity, Process design, Layout, Industry 4.0, Information flow, Material flow, Logistics/SCM

Performance management, Performance improvement, Quality management, and Maintenance.

This course is administered via Moodle. The course is designed around five elements:

2. **Video lectures.** Short video lectures presenting basic POM concepts.
3. **Class lectures.** Deep-dives with case examples on select topics.
4. **FactoryVR group assignment.** FactoryVR allows students to visit factories virtually.
5. **Quizzes.** A few quizzes during the semester help students check their progress and prepare for the written exam.

### Literature

Suggested literature is provided in the syllabus.
Communication
Adaptability and Flexibility
The seminar provides state-of-the-art insight to the biomechanical function of bone from molecules, to cells, tissue and up to the organ.

Subject-specific Competencies
assessed

Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management
fostered

Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation
fostered

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management
fostered

What causes economic business cycles? How are limited resources, competition, and cooperation reflected in growth dynamics? To answer such questions, we combine macroeconomic models and methods of nonlinear dynamics. We study the role of bifurcations and control parameters for dynamic stability. Feedback cycles and coupled dynamics are reasons for limited predictability, instability and chaos.

System theory sees the economy as a complex adaptive system. What does this mean for economic modeling? Our approach to economic dynamics combines insights from different disciplines: macroeconomics studying business cycles and growth, system dynamics rooted general system theory and cybernetics, and nonlinear dynamics using applied mathematics.

We start with a comparison of different modeling approaches, to highlight the problems and challenges of system modeling. The subsequent lectures then introduce different one- and two-dimensional nonlinear models with applications in economics, such as models of supply and demand, business cycles, growth and competition. Emphasis is on the formal analysis of these models using methods from applied mathematics and tools for solving coupled differential equations.

Weekly self-study tasks are used to apply the concepts introduced in the lectures. We practice how to solve nonlinear models formally and numerically and how to interpret the results.

Lecture notes
The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.

Prerequisites / notice
Students should be familiar with nonlinear differential equations and should have basic programming skills. All necessary details to solve nonlinear models will be provided in the course. The course will not build on mathematical proofs, optimization, statistics, efficient numerical computation and other specialized skills.

Competencies
Subject-specific Competencies
Concepts and Theories
Analytical Competencies
Decision-making
Problem-solving
fostered

Method-specific Competencies
Communication
fostered

Social Competencies
Cooperation and Teamwork
fostered

Personal Competencies
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
fostered

- apply formal concepts to model economic growth and competition
- identify critical conditions for stability and dynamic transitions
- understand the importance of different modeling approaches
- formalize and solve one- and two-dimensional nonlinear models
- analyze macroeconomic models of business cycles, supply and demand
- apply formal concepts to model economic growth and competition

6 credits

Economic Dynamics and Complexity
W 3 credits 3G F. Schweitzer, L. Verginer

Abstract
What causes economic business cycles? How are limited resources, competition, and cooperation reflected in growth dynamics? To answer such questions, we combine macroeconomic models and methods of nonlinear dynamics. We study the role of bifurcations and control parameters for dynamic stability. Feedback cycles and coupled dynamics are reasons for limited predictability, instability and chaos.

Objective
successful participant of the course is able to:
- formalize and solve one- and two-dimensional nonlinear models
- understand the importance of different modeling approaches
- analyze macroeconomic models of business cycles, supply and demand
- apply formal concepts to model economic growth and competition

Content
System theory sees the economy as a complex adaptive system. What does this mean for economic modeling? Our approach to economic dynamics combines insights from different disciplines: macroeconomics studying business cycles and growth, system dynamics rooted general system theory and cybernetics, and nonlinear dynamics using applied mathematics.

We start with a comparison of different modeling approaches, to highlight the problems and challenges of system modeling. The subsequent lectures then introduce different one- and two-dimensional nonlinear models with applications in economics, such as models of supply and demand, business cycles, growth and competition. Emphasis is on the formal analysis of these models using methods from applied mathematics and tools for solving coupled differential equations.

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Concepts and Theories
Analytical Competencies
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Method-specific Competencies
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fostered

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Personal Competencies
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Integrity and Work Ethics
Self-awareness and Self-reflection
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- apply formal concepts to model economic growth and competition
- identify critical conditions for stability and dynamic transitions
- understand the importance of different modeling approaches
- formalize and solve one- and two-dimensional nonlinear models
- apply formal concepts to model economic growth and competition

6 credits

Multiscale Bone Biomechanics
W 3 credits 3S R. Müller, X.-H. Qin

Abstract
The seminar provides state-of-the-art insight to the biomechanical function of bone from molecules, to cells, tissue and up to the organ. Multiscale imaging and simulation allows linking different levels of hierarchy, where systems biology helps understanding the mechanobiological response of bone to loading and injury in scenarios relevant for personalized health and translational medicine.

Objective
The learning objectives include
1. advanced knowledge of the state-of-the-are in multiscale bone biomechanics;
2. basic understanding of the biological principles governing bone in health, disease and treatment from molecules, to cells, tissue and up to the organ;
3. good understanding of the prevalent biomechanical testing and imaging techniques on the various levels of bone hierarchy;
4. practical implementation of state-of-the-art multiscale simulation techniques;
5. improved programing skills through the use of python;
6. hands on experience in designing solutions for clinical and industrial problems;
7. encouragement of critical thinking and creating an environment for independent and self-directed studying.
Bone is one of the most investigated biological materials due to its primary function of providing skeletal stability. Bone is susceptible to different local stimuli including mechanical forces and has great capabilities in adapting its mechanical properties to the changes in its environment. Nevertheless, aging or hormonal changes can make bone lose its ability to remodel appropriately, with loss of strength and increased fracture risk as a result, leading to devastating diseases such as osteoporosis.

To better understand the biomechanical function of bone, one has to understand the hierarchical organization of this fascinating material down from the molecules, to the cells, tissue, and up to the organ. Multiscale imaging and simulation allow to link these different levels of hierarchy. Incorporating systems biology approaches, not only biomechanical strength of the material can be assessed but also the mechanobiological response of the bone triggered by loading and injury in scenarios relevant for personalized health. Watching cells working together to build and repair bone in a coordinated fashion is a spectacle, which will need dynamic image content and deep discussions in the lecture room to probe the imagination of the individual student interested in the topic. Lastly, state-of-the-art developments in tissue engineering and regeneration, 3D bioprinting and bio-manufacturing and organoid technology will be highlighted towards personalized health.

For the seminar, concepts of video lectures will be used in a flipped classroom setup, where students can study the basic biology, engineering, and mathematical concepts in video tutorials online (TORQUES). All videos and animations will be incorporated in Moodle and PolyBook allowing studying and interactive course participation online. It is anticipated that the students need to prepare 2x45 minutes for the study of the actual lecture material. The course is structured as a seminar in three parts of 45 minutes with video lectures and a flipped classroom setup. In the first part (TORQUES: Tiny, Open-with-Restrictions courses focused on Quality and Effectiveness), students study the basic concepts in short, interactive video lectures on the online learning platform Moodle. Students are able to post questions at the end of each video lecture or the Moodle forum that will be addressed in the second part of the lectures using a flipped classroom concept. For the flipped classroom, the lecturers may prepare additional teaching material to answer the posted questions (Q&A). Following the Q&A, the students will have to form small groups to try to solve such problems and to present their solutions for advanced multiscale investigation of bone ranging from basic science to clinical application. Towards the end of the semester, students will have to present self-selected publications associated with the different topics of the lecture identified through PubMed or the Web of Science.

**Contents**

**Abstract**

This course focuses on the progress in the field of wearable and unobtrusive technologies for sports and health. Topics as monitoring heart health and blood pressure, biofeedback and improvement of motor skills and performance are covered. The focus lies on learning about the principles and design of the new generation of non-invasive technologies in fitness-, athletic and medical applications.

**Objective**

Objective 1: Acquire knowledge about the latest technological advancements in wearable and unobtrusive technologies for sport and health.

Objective 2: Acquire skills to design novel non-invasive technologies for sport and health.

**Content**

The course consists of two modules.

**Module 1: Movement.**

This module provides the scientific background needed to understand the principles that current technologies investigating movement rely on. The latest technological advancements to track parameters of gait and running, improve posture as well as to monitor overall body movement and provide feedback on motion during sport, rehabilitation or at work will be investigated. The focus will be on wearable-related (e.g., textile-based) technologies.

**Module 2: Cardiac.**

This module focuses on the latest technologies for monitoring the cardiac cycle and blood pressure. The module starts by succinctly providing background information on cardiac physiology and then briefly introduces conventional technologies used in daily practice. This module subsequently focuses on the latest technologies and the latest data analysis techniques to monitor the cardiac cycle for assisting individuals in sport activities or monitoring their health conditions.

**Prerequisites / notice**

- Students should be proficient in programming (any language).
- Note: assignments will be in MATLAB. Students are expected to learn MATLAB on their own if not experienced with this programming language.
- Course prerequisites:
  - For Biomedical Engineering Master’s: none
  - For ITET Master’s: none
  - For D-MAVT Master’s: none
  - For D-HEST Master’s and PhD students:
    - If BSc in electrical/mechanical engineering or computer science: none
    - If any other BSc program: 376-0022-00L (Imaging and Computing in Medicine) or 376-1983-00L (Foundations of Data Science)

**376-1176-00L Wearable and Mobile Technologies of the Future - Focus on Sports and Health**

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This course focuses on the progress in the field of wearable and unobtrusive technologies for sports and health. Topics as monitoring heart health and blood pressure, biofeedback and improvement of motor skills and performance are covered. The focus lies on learning about the principles and design of the new generation of non-invasive technologies in fitness-, athletic and medical applications.

**Objective**

Objective 1: Acquire knowledge about the latest technological advancements in wearable and unobtrusive technologies for sport and health.

Objective 2: Acquire skills to design novel non-invasive technologies for sport and health.

**Content**

The course consists of two modules.

**Module 1: Movement.**

This module provides the scientific background needed to understand the principles that current technologies investigating movement rely on. The latest technological advancements to track parameters of gait and running, improve posture as well as to monitor overall body movement and provide feedback on motion during sport, rehabilitation or at work will be investigated. The focus will be on wearable-related (e.g., textile-based) technologies.

**Module 2: Cardiac.**

This module focuses on the latest technologies for monitoring the cardiac cycle and blood pressure. The module starts by succinctly providing background information on cardiac physiology and then briefly introduces conventional technologies used in daily practice. This module subsequently focuses on the latest technologies and the latest data analysis techniques to monitor the cardiac cycle for assisting individuals in sport activities or monitoring their health conditions.

**Prerequisites / notice**

- Students should be proficient in programming (any language).
- Note: assignments will be in MATLAB. Students are expected to learn MATLAB on their own if not experienced with this programming language.
- Course prerequisites:
  - For Biomedical Engineering Master’s: none
  - For ITET Master’s: none
  - For D-MAVT Master’s: none
  - For D-HEST Master’s and PhD students:
    - If BSc in electrical/mechanical engineering or computer science: none
    - If any other BSc program: 376-0022-00L (Imaging and Computing in Medicine) or 376-1983-00L (Foundations of Data Science)

**376-1177-00L Human Factors I**

<table>
<thead>
<tr>
<th>W</th>
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<th>2V</th>
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<tbody>
<tr>
<td>M. Menozzi Jäckli, R. Huang</td>
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</table>

**Abstract**

Strategies of human-system-interaction, individual needs, physical & mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people’s health, well-being, and satisfaction as well as the overall system performance.
Objective
The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications. Students are expected to learn about how to enable an efficient and qualitatively high standing interaction between human and the environment, considering costs, benefits, health, and safety as well. Thus, an ergonomic design and evaluation process of products, tasks, and environments may be promoted in different disciplines. The goal is achieved in addressing a broad variety of topics and embedding the discussion in macroscopic factors such as the behavior of consumers and objectives of economy.

Content
- Physiological, physical, and cognitive factors in sensation, perception, and action
- Body spaces and functional anthropometry, Digital Human Models
- Experimental techniques in assessing human performance, well-being, and comfort
- Usability engineering in system designs, product development, and innovation
- Human information processing and biological cybernetics
- Interaction among consumers, environments, behavior, and tasks

Literature
- Gavriel Salvendy, Handbook of Human Factors and Ergonomics, 4th edition (2012), is available on NEBIS as electronic version and for free to ETH students
- Further textbooks are introduced in the lecture
- Brouches, checklists, key articles etc. are uploaded in ILIAS

376-1219-00L Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions
W 3 credits 2V R. Rieher, O. Lambercy

Abstract
Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

Objective
Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.

Content
Introduction, problem definition, overview
Rehabilitation of visual function
- Anatomy and physiology of the visual sense
- Technical aids (glasses, sensor substitution)
- Retina and cortex implants
- Rehabilitation of hearing function
- Anatomy and physiology of the auditory sense
- Hearing aids
- Cochlea implants
- Rehabilitation and use of kinesthetic and tactile function
- Anatomy and physiology of the kinesthetic and tactile sense
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
- Rehabilitation of vestibular function
- Anatomy and physiology of the vestibular sense
- Rehabilitation strategies and devices (e.g. BrainPort)
- Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter
- Brain stimulation and recording
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces
Literature
Introductory Books:


Selected Journal Articles and Web Links:


VideoTact, ForeThought Development, LLC. http://my.execpc.com/?dwysocki/videotac.html

Target Group:
Students of higher semesters and PhD students of
- D-MAVT, D-ITET, D-INFK, D-HEST
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich

Students of other departments, faculties, courses are also welcome

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

Competencies

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<td>Integrity and Work Ethics</td>
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Abstract

This course focuses on the emerging, interdisciplinary field of physical human-robot interaction, bringing together themes from robotics, real-time control, human factors, haptics, virtual environments, interaction design and other fields to enable the development of human-oriented robotic systems.

Prerequisites / notice

Target Group:
Students of higher semesters and PhD students of
- D-MAVT, D-ITET, D-INFK, D-HEST
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich

Students of other departments, faculties, courses are also welcome

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

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<td>Integrity and Work Ethics</td>
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376-1504-00L Physical Human Robot Interaction (pHRI) W 4 credits 2V+2U O. Lambercy. P. Wolf

Autumn Semester 2024

Page 1803 of 2653
Objective

The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and design safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1) identify critical human factors in physical human-robot interaction and use these to derive design requirements;
2) compare and select mechatronic components that optimally fulfill the defined design requirements;
3) derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;
4) design control hardware and software and implement and test human-interactive control strategies on the physical setup;
5) characterize and optimize such systems using both engineering and psychophysical evaluation metrics;
6) investigate and optimize one aspect of the physical setup and convey and defend the gained insights in a technical presentation.

Content

This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in device design for humans such as transparency and stability analysis, safety hardware and procedures. The course is organized into lecture modules that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical human-robot interaction, laboratory sessions and lab visits.

Students will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. Here the salient features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic paddle (https://relab.ethz.ch/downloads/open-hardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

Lecture notes

Will be distributed on Moodle before the lectures.

Literature


Prerequisites / notice

Notice:
The registration is limited to 26 students
There are 4 credit points for this lecture.
The lecture will be held in English.
The students are expected to have basic control knowledge from previous classes.
http://www.relab.ethz.ch/education/courses/phri.html
Analytical Competencies

This course includes study design, measurement techniques, clinical testing, accessing movement data and analysis as well as modeling.

Social Competencies

Communication

Cooperation and Teamwork

Personal Competencies

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Self-direction and Self-management

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Problem-solving

Project Management

Communication

Cooperation and Teamwork

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Self-direction and Self-management

W. Maniura, M. Rottmar, M. Zenobi-Wong

Clinical and Movement Biomechanics

4 credits

Autumn Semester 2024

Self-awareness and Self-reflection

Integrity and Work Ethics

Critical Thinking

Creativity

Cooperation and Teamwork

Project Management

Communication

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Self-direction and Self-management

E. Wehrle

Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed. A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Handouts are deposited online (moodle).

Lecture notes

Handouts and references therin.

Literature:


(available online via ETH library)

Bone Biology: Basics, Research and Clinics

2 credits

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Problem-solving

Project Management

Communication

Cooperation and Teamwork

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Self-direction and Self-management

E. Wehrle, G. A. Kuhn, to be announced

4 credits

Trauma Biomechanics

4 credits

Announced

K.-U. Schmitt, M. H. Muser

Trauma biomechanics in an interdisciplinary research field investigating the biomechanics of injuries and related subjects such as prevention. The lecture provides an introduction to the basic principles of trauma biomechanics.
Objectives

1. Introduction to the basic principles of trauma biomechanics.

Content

This lecture serves as an introduction to the field of trauma biomechanics. Emphasis is placed on the interdisciplinary nature of impact biomechanics, which uses the combination of fundamental engineering principles and advanced medical technologies to develop injury prevention measures. Topics include: accident statistics and accident reconstruction, biomechanical response of the human to impact loading, injury mechanisms and injury criteria, test methods (including crash tests), computer simulations, aspects of vehicle safety. Real world examples mainly from automobile safety are used to augment lecture material.

Lecture notes

Handouts will be made available.

Literature


Competencies

Method-specific Competencies

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies

- Communication
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies

- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Introduction to Mathematical Optimization

W 5 credits 2V+1U  D. Adjaiehvili

Abstract

Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering.

Objective

The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.

Content

Topics covered in this course include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modeling with mathematical optimization: applications of mathematical programming in engineering.

Literature

Information about relevant literature will be given in the lecture.

Prerequisites / notice

This course is meant for students who did not already attend the course "Mathematical Optimization", which is a more advance lecture covering similar topics. Compared to "Mathematical Optimization", this course has a stronger focus on modeling and applications.

Medical Physics I

W 6 credits 2V+1U  P. Manser

Abstract

Introduction to the fundamentals of medical radiation physics. Functional chain due to radiation exposure from the primary physical effect to the radiobiological and medically manifest secondary effects. Dosimetric concepts of radiation protection in medicine. Mode of action of radiation sources used in medicine and its illustration by means of Monte Carlo simulations.

Objective

The lecture is covering the basic principles of ionizing radiation and its physical and biological effects. The physical interactions of photons as well as of charged particles will be reviewed and their consequences for medical applications will be discussed. The concept of Monte Carlo simulation will be introduced in the exercises and will help the students to understand the characteristics of ionizing radiation in simple and complex situations. Fundamentals in dosimetry will be provided in order to understand the physical and biological effects of ionizing radiation. Deterministic as well as stochastic effects will be discussed and fundamental knowledge about radiation protection will be provided. In the second part of the lecture series, we will cover the generation of ionizing radiation. By this means, the x-ray tube, the linear accelerator, and different radioactive sources in radiology, radiotherapy and nuclear medicine will be addressed. Applications in radiology, nuclear medicine and radiotherapy will be described with a special focus on the physics underlying these applications.

Lecture notes

A script will be provided.

Prerequisites / notice

For students of the MAS in Medical Physics (Specialization A) the performance assessment is offered at the earliest in the second year of the studies.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Cellular Biochemistry (Part I)

W 3 credits 2V  U. Kutay, F. Allain, T. Kleee, I. Zemp

Abstract

Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Content

Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1806 of 2653
Lecture notes: Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials (alicia.smith@bc.biol.ethz.ch).

Literature: Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice: To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

Competencies:
- Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Multidisciplinary Courses:
The students are free to choose individually Master's courses from the Course Catalogue of ETH Zurich, ETH Lausanne and the Universities of Zurich (https://www.uzh.ch/cmsssl/en/studies/application/chmobilityin.html) and St. Gallen.

Course Catalogue of ETH Zurich

Semester Project:

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<td>151-1002-00L</td>
<td>Semester Project Mechanical Engineering</td>
<td>O</td>
<td>8</td>
<td>17A</td>
<td>Supervisors</td>
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</table>

Abstract: The subject of the Semester Project and the choice of the supervisor (ETH-professor) are to be approved in advance by the tutor.

Objective: The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

Industrial Internship:

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<td>Industrial Internship</td>
<td>O</td>
<td>8</td>
<td>external organisers</td>
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Objective: The main objective of the minimum twelve-week internship is to expose Master's students to the industrial work environment. The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

Science in Perspective:

- see Science in Perspective: Language Courses ETH/UZH
- see Science in Perspective: Type A: Enhancement of Reflection Capability
- Recommended Science in Perspective (Type B) for D-MAVT

Master's Thesis:

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<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<td>Master's Thesis Mechanical Engineering</td>
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<td>30</td>
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<td>Supervisors</td>
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Abstract: Students who fulfill the following criteria are allowed to begin with their Master's Thesis:

- a. successful completion of the bachelor program;
- b. fulfilling of any additional requirements necessary to gain admission to the master programme;
- c. successful completion of the semester project and industrial internship;
- d. achievement of 28 ECTS in the category "Core Courses".

Objective: The Master's Thesis must be approved in advance by the tutor and is supervised by a professor of ETH Zurich.

Course Units for Additional Admission Requirements:
The courses below are only available for MSc students with additional admission requirements.

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<tr>
<th>Number</th>
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<td>406-0173-AAL</td>
<td>Linear Algebra I and II</td>
<td>E-</td>
<td>6</td>
<td>13R</td>
<td>N. Hungerbühler</td>
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</tbody>
</table>

Abstract: Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective: Linear algebra is an indispensable tool of engineering mathematics. The course is an introduction to basic methods and fundamental concepts of linear algebra and its applications to engineering sciences. After completion of this course, students are able to recognize linear structures and to apply adequate tools from linear algebra in order to solve corresponding problems from theory and applications. In addition, students have a basic knowledge of the software package Matlab.
Content
Linear maps, kernel and image, coordinates and matrices, coordinate transformations, norm of a matrix, orthogonal matrices, eigenvalues and eigenvectors, algebraic and geometric multiplicity, eigenbasis, diagonalizable matrices, symmetric matrices, orthonormal basis, condition number, linear differential equations, Jordan decomposition, singular value decomposition, examples in MATLAB, applications.

Reading:
Gilbert Strang "Introduction to linear algebra", Wellesley-Cambridge Press: Chapters 1-6, 7.1-7.3, 8.1, 8.2, 8.6

Literature

401-0363-AAL Analysis III
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to partial differential equations. Differential equations which are important in applications are classified and solved. Elliptic, parabolic and hyperbolic differential equations are treated. The following mathematical tools are introduced: Laplace transforms, Fourier series, separation of variables, methods of characteristics.

Objective
Mathematical treatment of problems in science and engineering. To understand the properties of the different types of partial differential equations.

Content
Laplace Transforms:
- Laplace Transform, Inverse Laplace Transform, Linearity, s-Shifting
- Transforms of Derivatives and Integrals, ODEs
- Unit Step Function, t-Shifting
- Short Impulses, Dirac's Delta Function, Partial Fractions
- Convolution, Integral Equations
- Differentiation and Integration of Transforms

Fourier Series, Integrals and Transforms:
- Fourier Series
- Functions of Any Period p=2L
- Even and Odd Functions, Half-Range Expansions
- Forced Oscillations
- Approximation by Trigonometric Polynomials
- Fourier Integral
- Fourier Cosine and Sine Transform

Partial Differential Equations:
- Basic Concepts
- Modeling: Vibrating String, Wave Equation
- Solution by separation of variables; use of Fourier series
- D’Alembert Solution of Wave Equation, Characteristics
- Heat Equation: Solution by Fourier Series
- Heat Equation: Solutions by Fourier Integrals and Transforms
- Modeling Membrane: Two Dimensional Wave Equation
- Laplacian in Polar Coordinates: Circular Membrane, Fourier-Bessel Series
- Solution of PDEs by Laplace Transform

Literature

For reference/complement of the Analysis I/II courses:
Christian Blatter: Ingenieur-Analysis (Download PDF)

Prerequisites / notice
Up-to-date information about this course can be found at:
http://www.math.ethz.ch/education/bachelor/lectures/hs2013/other/analysis3_itet

Competencies

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1808 of 2653
### Mechanical Engineering Master - Key for Type

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<td>Dr</td>
<td>Suitable for doctorate</td>
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<td>O</td>
<td>Compulsory</td>
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### Key for Hours

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<th>P</th>
<th>practical/laboratory course</th>
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<td>A</td>
<td>independent project</td>
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<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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</table>

**ECTS**

- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
### Educational Science

**General course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>871-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2 credits</td>
<td>2V</td>
<td>E. Stern, M. Rau</td>
</tr>
<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in the programs &quot;Teaching Diploma&quot; or &quot;Teaching Certificate&quot;. It is about learning in childhood and adolescence.</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>This course looks into scientific theories and also empirical studies on human learning and relates them to the school.</td>
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<td></td>
<td>Objective</td>
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<td></td>
<td>Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.</td>
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<td></td>
<td>Content</td>
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<td></td>
<td>Thematische Schwerpunkte:</td>
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<td>Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen</td>
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<td>Lecture notes</td>
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<td></td>
<td>Folien werden zur Verfügung gestellt.</td>
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<tr>
<td></td>
<td>Literature</td>
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<tr>
<td></td>
<td>Prerequisites / notice</td>
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<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in the programs &quot;Lehrdiplom&quot; or &quot;Didaktisches Zertifikat&quot;. It is about learning in childhood and adolescence.</td>
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</tbody>
</table>

| 871-0242-06L   | Cognitively Activating Instructions in MINT Subjects ▶️ W | 2 credits | 2S    | R. Schumacher                     |
|                | This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)". |
|                | Abstract                                                |      |        |       |                                   |
|                | This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance. |
|                | Objective                                               |      |        |       |                                   |
|                | - Get to know cognitively activating instructions in MINT subjects |
|                | - Get information about recent literature on learning and instruction |
|                | Prerequisites / notice                                   |      |        |       |                                   |
|                | Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht. |

| 871-0242-07L   | Human Intelligence                                      | W    | 1 credit | 1S    | E. Stern                           |
|                | Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport). |
|                | Abstract                                                |      |        |       |                                   |
|                | The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed. |
|                | Objective                                               |      |        |       |                                   |
|                | - Understanding of research methods used in the empirical human sciences |
|                | - Getting to know intelligence tests                    |
|                | - Understanding findings relevant for education          |

| 871-0240-22L   | Coping with Psychosocial Demands of Teaching (EW4 W DZ)▶️| 2 credits | 3S    | S. Maurer, P. Caprez, I. Sargenti |
|                | The successful participation in EW1 ("Human Learning") and EW2 ("Designing Learning Environments for School") is recommended, but not a mandatory prerequisite. |
|                | Abstract                                                |      |        |       |                                   |
|                | In this class, students will learn concepts and skills for coping with psychosocial demands of teaching |
|                | Objective                                               |      |        |       |                                   |
|                | Students possess theoretical knowledge and practical competences to be able to cope with the psychosocial demands of teaching. |
|                | (1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks). |
|                | (2) They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. illegal or psychological services). |

| 871-0228-00L   | Formation of Knowledge in STEM Fields in Primary and Secondary School ▶️| W    | 2 credits | 1S    | U. Markwalder                     |
|                | Adresses to students enrolled either in Teaching Diploma* (TD) or Teaching Certificate (TC) (excluding Teaching Diploma Sport). |
|                | This course unit can only be enroled after successful participation in the course 871-0240-00L "Human Learning" |

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**Note:**

- **ECTS:** European Credit Transfer System
- **W:** Winter term
- **S:** Summer term
- **TD:** Teaching Diploma
- **TC:** Teaching Certificate
- **O:** Offered
- **W:** Winter term
- **S:** Summer term
- **ECTS:** European Credit Transfer System
- **Hours:** Lecture hours
- **Lecturers:** Names of lecturers

**Data:** 15.06.2024 12:39  Autumn Semester 2024  Page 1810 of 2653
Learning (EW 1)*.

Abstract
Course promotes exchange between student teachers and elementary school teachers in STEM teaching with 3 parts: 1) block seminar (ca. 16 h), 2) collaboration with elementary school teacher in a class (ca. 34 h, with approx. 50% spent in the elementary or middle school class and ca. 50% for preparation), and 3) final report (ca. 10 h). Registration implies participation in all 3 parts.

Objective
Deepening the understanding of knowledge formation and learning processes of primary and secondary students from a cognitive and developmental psychology perspective for students. The assistant ship provides didactic experience and exposure to a different school level (more heterogeneous groups such as for example low-performing to very high-performing Children, language problems etc.).

Content
Students learn more about the potential and challenges of pupils. They get to know the early stages of knowledge as well as the development of pre-concepts of students in their subject area. The seminar with a phase of cooperation consists of three phases: In the block seminar, pre-concepts are discussed in their own subject as well as theoretical inputs from developmental and cognitive psychology. During the cooperation phase, a teaching task defined by the primary and secondary school teachers is actively undertaken in a class.

Finally, a final report is written, which contains a description of the students' level of knowledge. This seminar is only suitable for students who can adapt flexibly to the needs of pupils from lower class levels.

Prerequisites / notice
https://www.minterlink.ch/student

Competencies
- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies
- Social Competencies: Communication
- Personal Competencies: Adaptability and Flexibility

Subject Didactics and Professional Training

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>151-1079-00L</td>
<td>Teaching Internship Including Examination Lessons Mechanical and</td>
<td>W</td>
<td>6</td>
<td>13P</td>
<td>Q. Lohmeyer</td>
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<td></td>
<td>Process Engineering</td>
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<tr>
<td></td>
<td>The teaching internship can just be visited if all other courses of</td>
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<td>TC are completed. Repetition of the teaching internship is excluded</td>
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<td>if the examination lessons are to be repeated.</td>
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<tr>
<td>Abstract</td>
<td>Students apply the insights, abilities and skills they have acquired</td>
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<td>within the context of an educational institution. They observe 10</td>
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<td>lessons and teach 20 lessons independently. Two of them are as</td>
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<td>assessed as Examination Lessons.</td>
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<td>Objective</td>
<td>- Students use their specialist-subject, educational-science and</td>
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<td>subject-didactics training to draw up concepts for teaching.</td>
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<td>- They are able to assess the significance of tuition topics for</td>
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<td>their subject from different angles (including interdisciplinary</td>
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<td>angles) and impart these to their pupils.</td>
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<td>- They learn the skills of the teaching trade.</td>
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<td>- They practise finding the balance between instruction and</td>
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<td>openness so that pupils can and, indeed, must make their own</td>
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<td></td>
<td>cognitive contribution.</td>
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<td>- They learn to assess pupils' work.</td>
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<td></td>
<td>- Together with the teacher in charge of their teacher training,</td>
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<td></td>
<td>the students constantly evaluate their own performance.</td>
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<tr>
<td>Content</td>
<td>Die Studierenden sammeln Erfahrungen in der Unterrichtsführung, der</td>
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<tr>
<td></td>
<td>Auseinandersetzung mit Lernenden, der Klassenbetreuung und der</td>
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<tr>
<td>Lecture notes</td>
<td>Dokument: schriftliche Vorbereitung für Prüfungslektionen.</td>
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<tr>
<td>Literature</td>
<td>Wird von der Praktikumslehrperson bestimmt.</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Alle anderen Lehrveranstaltungen des DZ (inkl. der Mentorierten Arbeit) sind erfolgreich abgeschlossen.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1072-00L</td>
<td>Mentored Thesis in Didactics of Mechanical and Process Engineering</td>
<td>O</td>
<td>2</td>
<td>4A</td>
<td>Q. Lohmeyer</td>
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<tr>
<td>Abstract</td>
<td>The purpose of the mentored thesis is to bring together the findings</td>
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<td>of didactics and to expand them by incorporating specific teaching</td>
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<td></td>
<td>techniques and teaching methods. The thesis can be thematically</td>
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<td></td>
<td>aligned with the subsequent teaching internship.</td>
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<tr>
<td>Objective</td>
<td>The students learn to link theoretical topics from the didactic</td>
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<td>education with practice-relevant aspects and to articulate the result</td>
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<td>in written form by means of a suitable task.</td>
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<tr>
<td>Content</td>
<td>The choice of the topic and the definition of the contents takes</td>
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<td>place in agreement between the students and the mentor. The topic</td>
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<td>must be chosen in such a way that the learning objective described</td>
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<td>above can be achieved.</td>
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<tr>
<td>Lecture notes</td>
<td>A short guideline is available.</td>
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<tr>
<td>Literature</td>
<td>The use of suitable literature is part of the assignment.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisite: Both didactics courses completed.</td>
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<td></td>
<td>The work should be completed before the start of the internship.</td>
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<table>
<thead>
<tr>
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<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0857-00L</td>
<td>Subject Didactics I for D-MAVT and D-ITET</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>Q. Lohmeyer, R. Büchi</td>
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<tr>
<td>Abstract</td>
<td>Didactics I focuses on teaching techniques as building blocks of</td>
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<tr>
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<td>typical lessons. This is done on the basis of the findings of</td>
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<td></td>
<td>teaching and learning research and their implementation in practice.</td>
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<td>The aim is the planning and implementation of effective teaching</td>
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<td>sequences as well as their evaluation and reflection.</td>
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</tbody>
</table>
Objective
- The students can plan, conduct and critically reflect single lessons.
- They orient themselves towards the academic goals and take into account existing knowledge, the professional environment and the ambitions of the students.
- They can apply the basic teaching principles meaningfully in their subject and suitably structure the learning phases.
- They can reduce and present complex technical content such that it is in a form suitable for the students to learn.
- They have considered examples of the common conceptual errors encountered by students.

Content
- Planning a teaching unit
- Opening a lecture
- Direct Instruction
- Embedded exercises
- Learning objectives
- Practicing teaching
- Excursion Fachhochschule

Lecture notes
- Lecture materials are provided via Moodle.

Prerequisites / notice
- Prerequisite: Educational science course already completed or at the same time.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Media and Digital Technologies
- Project Management

Social Competencies
- Communication
- Customer Orientation
- Leadership and Responsibility

Personal Competencies
- Critical Thinking
- Self-awareness and Self-reflection

Mechanical and Process Engineering TC - Key for Type

<table>
<thead>
<tr>
<th>Key for Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</table>

Key for Hours

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

ECTS
- European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Materials Science Bachelor

 Bachelor Studies (Programme Regulations 2020)

 Basis Courses Part 1

 First Year Examinations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>401-0261-00L</td>
<td>Analysis I</td>
<td>O</td>
<td>8</td>
<td>5V+3U</td>
<td>A. Steiger</td>
</tr>
<tr>
<td>Objective</td>
<td>Functions: Differential and integral calculus for functions of one variable; power series. The mathematical methods are applied in a large number of examples from mechanics, physics and other areas which are basic to engineering.</td>
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<tr>
<td>Lecture notes</td>
<td>U. Stammbach: Analysis I/II</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Exercises and online quizzes are an important aspect of this course. Attempts at solving these problems will be honored with a bonus on the final grade. See &quot;Performance assessment&quot; for more information.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
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<td></td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>401-0171-00L</td>
<td>Linear Algebra I</td>
<td>O</td>
<td>3</td>
<td>2V+1U</td>
<td>N. Hungerbühler</td>
</tr>
<tr>
<td>Abstract</td>
<td>Linear algebra is an indispensable tool of engineering mathematics. The course offers an introduction into the theory with many applications. The new notions are practised in the accompanying exercise classes. The course will be continued as Linear algebra II.</td>
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<tr>
<td>Objective</td>
<td>Upon completion of this course, students will be able to recognize linear structures, and to solve corresponding problems in theory and in practice.</td>
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<tr>
<td>Content</td>
<td>Systems of linear equations, Gaussian elimination, solution space, matrices, LR decomposition, Determinants, structure of linear spaces, normed vector spaces, inner products, method of least squares, QR decomposition, introduction to MATLAB, applications</td>
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<tr>
<td>* K. Meyberg / P. Vachenauer, Höhere Mathematik 1, Springer 2003</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Active participation in the exercises is part of this course. It is expected, that students submit 3/4 of all exercises for control.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<tr>
<td></td>
<td>Concepts and Theories</td>
<td>fostered</td>
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<td></td>
<td>Techniques and Technologies</td>
<td>fostered</td>
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<td></td>
<td>Method-specific Competencies</td>
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<td></td>
<td>Analytical Competencies</td>
<td>fostered</td>
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<td></td>
<td>Problem-solving</td>
<td>fostered</td>
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<td></td>
<td>Personal Competencies</td>
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<td></td>
<td>Creative Thinking</td>
<td>fostered</td>
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<td></td>
<td>Critical Thinking</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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<tr>
<td>327-0112-00L</td>
<td>Chemistry I</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>M. Niederberger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to the basics, terms and concepts of general chemistry, their application to questions in material science and their connection to laboratory experiments and projects.</td>
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<tr>
<td>Objective</td>
<td>1) Students can describe the different atomic structures of metals, polymers and ceramics and derive basic material-technical properties.</td>
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<td>2) Students are familiar with the concept of mole and molar mass and can perform stoichiometric calculations.</td>
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<td>3) Students are able to formulate the law of mass action and, with the help of the equilibrium constant, make statements about the position of equilibrium. They understand how a chemical equilibrium reacts to changes in concentration, pressure and temperature and how to apply Le Châtelier's principle.</td>
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<td>4) Students can define oxidation and reduction, determine oxidation numbers, assign reducing and oxidizing agents and calculate redox potentials. They can transfer the basics of redox chemistry to material science processes and applications such as corrosion or batteries.</td>
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<td>5) They can explain the meaning of acids and bases using material science examples.</td>
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<tr>
<td>Content</td>
<td>We start the lecture with the question what chemistry has to do with material science. After that, we devote ourselves to the classification and separation of substances. In the next chapter we discuss the atomic structure and the periodic table. After the introduction to stoichiometry, the field of chemistry that deals with the amounts of substances added and formed in chemical reactions, we will cover the concept of chemical equilibrium, where we will learn about the law of mass action, equilibrium constants, solubility product, and also acid-base equilibria. In the final block of the lecture, materials science will once again be in the focus when we discuss redox reactions, electrochemistry and corrosion as well as the influence of chemical bonding on material properties.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture slides with references to further literature and additional exercises are available on Moodle.</td>
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<tr>
<td>Literature</td>
<td>German</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<td></td>
<td>Concepts and Theories</td>
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<td></td>
<td>Techniques and Technologies</td>
<td>fostered</td>
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<td>Method-specific Competencies</td>
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<td>Analytical Competencies</td>
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<td>Problem-solving</td>
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<td>Personal Competencies</td>
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<td></td>
<td>Critical Thinking</td>
<td>fostered</td>
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<tr>
<td>402-0050-00L</td>
<td>Physics I</td>
<td>O</td>
<td>4</td>
<td>2V+2U</td>
<td>D. Rupp</td>
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<tr>
<td>Abstract</td>
<td>The lecture covers the basics of classical mechanics.</td>
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<tr>
<td>Objective</td>
<td>The aim of this lecture is to become familiar with the central concepts of classical mechanics, to test and consolidate basic concepts and physical intuition, and to be able to describe and solve problems with applications from everyday life and technology with the tools learned.</td>
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<tr>
<td>Content</td>
<td>- Inertia, equations of motion, Newton's laws, forces and system boundaries</td>
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<td>- Energy, impulse, rocket launch</td>
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<td>- Central forces, celestial mechanics</td>
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<td>- Tidal/apparent forces, resting and accelerated reference systems</td>
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<td></td>
<td>- Rotational motion</td>
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<td></td>
<td>- Basic properties of deformable bodies</td>
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<td></td>
<td>- Vibrations and resonance phenomena, waves</td>
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<tr>
<td>Lecture notes</td>
<td>A skript to the lecture is provided online.</td>
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</tbody>
</table>
Abstract
The basic physical concepts for the description of materials are taught, partly in self-study, and applied in exercises. Basic atomistic and macroscopic concepts (e.g. phase diagrams, phase transformations, response functions) are introduced through examples. Selected topics are deepened in classroom lectures.

Objective
Students are able to
- name the basic concepts of materials science. (remember, 1)
- describe simple relations between atomic structure and macroscopic properties. (understand, 2)
- calculate basic material-specific quantities. (apply, 3)
- read and interpret phase diagrams, material characteristic (e.g. stress-strain) diagrams and Ashby plots (analyse, 4)

Content
Atomic structure
Crystalline structure and defects
Thermodynamics, phase diagrams and phase transformations
Diffusion
Mechanical and thermal properties of materials

Literature
Main textbook:
William D. Callister, Jr., David G. Rethwisch
Materials Science and Engineering - An Introduction

Alternatives:
Milton Ohring
Engineering Materials Science

James F. Shackelford
Introduction to Materials Science for Engineers

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies fostered
Decision-making assessed
Problem-solving assessed
Social Competencies
Cooperation and Teamwork fostered
Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

Additional First Year Basic Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>327-0111-00L</td>
<td>Projects and Lab Courses I</td>
<td>O</td>
<td>7</td>
<td>7P</td>
<td>M. B. Willeke, L. De Pietro, M. R. Dusselier, S. Morgenthaler Kobas, T.-B. Schweizer</td>
</tr>
</tbody>
</table>

Abstract
Practical introduction to the basics of the scientific method, materials science, physics and chemistry in the form of laboratory experiments and projects, some of which are closely related to the lectures in the first year. Important chemical and physical methods are tested, project work is practiced and the basics of working safely in the laboratory are learned.

Objective
The students
- keep a laboratory journal independently, completely and appropriately.
- can evaluate and display measurement data in a targeted manner.
- are able to write laboratory reports appropriately.
- know the communicative and rhetorical factors that are decisive for the success of an oral presentation.
- create effective presentation documents.
- know the general safety rules and disposal concepts for working in laboratories and apply them practically.
- proceed correctly in case of accidents and evacuations.
- learn practically how to fight a fire (fire protection course of the ETH).
- apply the basic knowledge in analytics, chemistry, physics and materials science acquired in the base year in a practical way.
- practice carrying out small experiments or small projects independently under supervision.

Content
In the area of scientific work: Keeping lab journals, data analysis, writing reports, presentation techniques, Test preparation and introduction to safe working and behaviour in the lab.
Lab experiments: Experiments from the fields of synthetic and analytical chemistry and experiments from the fields of physics and materials science, e.g.: Mechanical/thermal properties (e.g. modulus of elasticity, fracture mechanics), thermodynamics, colloid chemistry, "particle tracking" with DLS and microscopy, surface technology, "wood, stone and metal" processing, and electrochemistry. Some practical experiments are organized as short projects (two afternoons), e.g. "Building a microscope from a webcam", etc.
In the projects: Two "reverse engineering" projects with everyday objects: Analysis of construction and materials, functioning in the overall context, life cycle of materials, alternative materials, etc.

Lecture notes
Instructions and further information on the individual experiments and projects (objectives, theory, experimental procedure, notes on evaluation) are available on the following website ( -> Moodle dieser Veranstaltung).

Prerequisites / notice
Special students and auditors need a special permission from the lecturers
### 327-0114-00L Programming I

**O 2 credits 2G L. De Pietro**

**Abstract**
This course provides an introduction to the general computer and programming concepts, which are necessary to perform numerical calculations, representations and simulations in materials science.

**Objective**
- Students independently develop programs to accomplish numerical calculations, representations and simulations.
- They analyse and understand the functionality of existing programs and can supplement or adapt them according to their requirements.
- They recognize basic computer science concepts and apply algorithmic thinking, i.e. they have the ability to solve problems systematically using developed algorithms.

**Content**
The course contains a first introduction to Python and Matlab. It contains:
- Basic programming concepts of structural programming like
  - Variables
  - Lists
  - Loops
  - Branches
  - Control structures
- Input and output
- Modular structure of programs with functions
- Flowcharts
- Numerical accuracy
- Data evaluation and presentation
  - Regression
  - Interpolation
  - Curves fit
- Complexity Theory
- Sorting and searching
- Dynamic programming
- Recursion
- Graph Algorithms

**Lecture notes**
Moodle, Code Expert, ...

**Literature**
https://wiki.python.org/moin/BeginnersGuide

### Second Year Basic Courses

#### Examination Blocks

##### Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-0363-10L</td>
<td>Analysis III</td>
<td>O</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>A. Iozzi</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to partial differential equations. Differential equations which are important in applications are classified and solved. Elliptic, parabolic and hyperbolic differential equations are treated. The following mathematical tools are introduced: Laplace transforms, Fourier series, separation of variables, methods of characteristics.

**Objective**
Mathematical treatment of problems in science and engineering. To understand the properties of the different types of partial differential equations.

**Content**
Laplace Transforms:
- Laplace Transform, Inverse Laplace Transform, Linearity, s-Shifting
- Transforms of Derivatives and Integrals, ODEs
- Unit Step Function, t-Shifting
- Short Impulses, Dirac's Delta Function, Partial Fractions
- Convolution, Integral Equations
- Differentiation and Integration of Transforms

Fourier Series, Integrals and Transforms:
- Fourier Series
- Functions of Any Period p=2L
- Even and Odd Functions, Half-Range Expansions
- Forced Oscillations
- Approximation by Trigonometric Polynomials
- Fourier Integral
- Fourier Cosine and Sine Transform

Partial Differential Equations:
- Basic Concepts
- Modeling: Vibrating String, Wave Equation
- Solution by separation of variables; use of Fourier series
- D'Alembert Solution of Wave Equation, Characteristics
- Heat Equation: Solution by Fourier Series
- Heat Equation: Solutions by Fourier Integrals and Transforms
- Modeling Membrane: Two Dimensional Wave Equation
- Laplacian in Polar Coordinates: Circular Membrane, Fourier-Bessel Series
- Solution of PDEs by Laplace Transform
Lecture notes by Prof. Dr. Alessandra Iozzi:
https://polybox.ethz.ch/index.php/s/D3K0TayQXvfpCAA

Literature


For reference/complement of the Analysis I/II courses:

Christian Blatter: Ingenieur-Analysis
https://people.math.ethz.ch/~blatter/dlp.html

Prerequisites / notice

For students in the bachelor's degree programme in mechanical engineering:
Precondition for this course unit are passed first year examination blocks A and B.

327-0316-00L Quantum Mechanics and Solid State Physics I O 3 credits 2V+1U S. Stepanow

Abstract
Analysis and motivation for the necessity of a theory beyond classical mechanics to describe materials properties. The principles, terminology and concepts of quantum mechanics will be introduced and mathematically represented on the basis of simple problems.

Objective
Give reasons for the necessity of quantum mechanical description of matter and explain experimental observations leading to this description.
Clarification of the term quantum object.
Formulate and solve the Schrödinger equation for simple problems.
Application of the operator formalism for the calculation of observables and the interpretation of physical processes. Interpretation of the wavefunction.
Explain the solution of the hydrogen atom. Derivation of the approach to the solution in the application of symmetries and angular momentum operators.
Give reasons for the electron spin and calculate magnetic moments.

Content
Crisis of classical physics
Planck's law of radiation (cavity radiation), photoelectric effect (Einstein's light quantum hypothesis), Bohr quantisation of the atom, De Broglie hypothesis
Wave-particle dualism - wave mechanics, matter waves, double-slit experiment, comparison of classical mechanics and quantum mechanics
Introduction of the wave function, de-Broglie relation, probability
Postulates of quantum mechanics
Introduction of the Schrödinger equation, normalisation of the wave function, stationary Schrödinger equation, location and momentum space, location representation of the momentum operator
Wave packets (Gaussian bell curve), decay of wave packets, indeterminacy principle
Wave mechanics with forces
Piecewise constant potentials, particles in the potential well, potential step, probability current density, potential wall, tunnel effect, potential well
Formalism of quantum mechanics
Hilbert space, scalar product, vectors (basis), states, normalizability, completeness, eigenfunctions, rotations, operators - general definitions and properties, Expectation values, spectrum (discrete, continuous), matrix representation, Ehrenfest theorem, measurement process and collapse of the wave function
Central potential
Eigenvalue problem in spherical coordinates, limiting cases, particles in a 3D pot, symmetries, rotation and angular momentum, angular momentum operator and spherical surface functions
Hydrogen atom
Coulomb potential, radial wave function, orbitals, atomic structure

Lecture notes

in German, provided in the Moodle course together with the exercise sheets and corresponding solutions.

Literature


Prerequisites / notice

A. Messiah, Quantenmechanik I und II, de Gruyter, 1990/91.

Physics I and II.
Analysis I and II.
Linear Algebra I and II.
Foundations of Probability theory from Programming II.
Fourier-Transformation from Analysis III is used, but is not a basic requirement.
Adaptability and Flexibility

Statistical Thermodynamics

Concepts and Theories
Techniques and Technologies

Analytical Competencies
Decision-making
Problem-solving

Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Lecture slides with references to further literature will be available on Moodle.

Materials Characterization I

Introduction to the main spectroscopic methods and their applications to gain compositional and structural information.

Objective
The aim of the course is to enable the students to select and apply the optimal analytical/spectroscopic methods for the identification of organic, inorganic and polymeric materials.

Content
Particular emphasis is given to qualitative and quantitative analysis of material composition at the atomic/molecular level by mass spectrometry, atomic absorption, vibrational and UV-vis spectroscopy, thermal analysis, nuclear magnetic resonance. The course will include lectures as well as hands-on practical sessions.

Materials Synthesis I - Polymers

The course teaches the basics and terminology of polymer synthesis. To synthesize various polymeric materials, different polymerization techniques are required. This course will introduce representative polymerization methodologies and will discuss how they operate in order to yield materials with enhanced polymeric characteristics.

Objective
1) The students will be able to recognize different polymer types and associate them with their chemical structure and properties (i.e. rubber elasticity, glass transition temperature, etc.)
2) The students will become familiar with various synthetic methods to produce polymers of different architectures and topologies
3) The students will be exposed to different characterization methods (e.g. size exclusion chromatography, mass-spectrometry, nuclear magnetic resonance) that are necessary to confirm the successful synthesis and structure of a polymer
4) The students will understand the mechanism of selected polymerization methodologies
5) The students will be introduced to state-of-the-art polymer synthesis and recent literature examples will be critically discussed

Content
Conventional chain growth polymerization, living chain growth polymerization, step growth polymerization, polymeric architectures, molecular weight determination methods, polymer properties, polymerization mechanisms, polymer characterization methods

Literature

Statistical Thermodynamics

Foundations and applications of equilibrium thermodynamics and statistical mechanics, supplemented by an elementary theory of transport phenomena.

Objective
The course provides a solid working knowledge in thermodynamics (as the appropriate language for treating a variety of problems in materials science) and in statistical mechanics (as a systematic tool to find thermodynamic potentials for specific problems)

Literature
R. Piazza, Statistical Physics, Springer International Publishing Switzerland 2017

Crystallography - Introduction to lattices and symmetries

The properties of crystals, which make up a large part of solid materials, are closely related to the symmetry of their internal structure. The objective of the crystallography lecture is to provide concepts and mathematical fundamentals of symmetry theory, structure-property relationships, and the basic principles of structure determination. Simple crystal structures will be discussed.

Objective
Students are able to:
- mathematically represent the geometry of a crystal lattice and derive and understand its symmetry.
- apply concepts of group theory to classify crystal lattices based on their symmetry.
- analyse simple crystal structures in terms of their symmetry.
- develop a basic understanding of the relationships between crystal structure, symmetry and physical properties of solids.
- understand the concept of X-ray diffraction as an elementary experimental technique for determining crystal structures.
- apply the methods and concepts presented in the lecture and communicate the results in written and oral form.

Content
Symmetry and crystal lattices: symmetry operations and lattices in two and three dimensions, point groups, space groups.

Crystal structures: symmetry and typical simple crystal structures.
Structure/property relationships: Neumann's principle; examples: piezoelectricity, ferroelectricity.

Literature
A script for the lecture up to 2014 is available. The slides for the current lecture will be made available before the start of each lecture.

Analytical Competencies
Concepts and Theories
- assessed
Techniques and Technologies
- assessed
Method-specific Competencies
Analytical Competencies
- assessed
Decision-making
- fostered
Problem-solving
- fostered
Social Competencies
Communication
- fostered
Personal Competencies
Creative Thinking
- fostered

Projects and Applications

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>327-0314-00L</td>
<td>Computational Thinking Lab I</td>
<td>O</td>
<td>2</td>
<td>1G+1A</td>
<td>M. Kröger</td>
</tr>
<tr>
<td>Abstract</td>
<td>You are going to address, in groups, problems that are arising or may arise in the context of remaining courses of your studies, that cannot be solved analytically or manually within reasonable amounts of time, but solved computationally with the help of a programming language and computers. Knowledge of a computing language is required.</td>
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<tr>
<td>Objective</td>
<td>- Getting used to the idea that solving problems using a programming language is a dynamic process, where one can learn from errors</td>
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<tr>
<td>Content</td>
<td>- Thinking in modules that perform a task and can be tested separately. Modules are then combined to interact lateron.</td>
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<td>- Organizing the distribution of work across a small group of students and ask questions, as soon as they arise.</td>
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<td>- Using existing resources if helpful to implement your ideas</td>
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<td>- Getting confronted with computational tasks as they may occur during scientific work</td>
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<td></td>
<td>- Develop ideas to solve well-defined problems using computational methods</td>
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<td>- Make use of collaborative tools (vscode, github) to edit, store and execute python code in groups</td>
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<td>- Create accompanying descriptions and resulting graphs (at github, using mark-down language)</td>
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<td>- Make use of internet resources or vscode to find answers to questions that arise (python command and their syntax, existing libraries, if helpful)</td>
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<td>- Short oral presentation of algorithms, results, possible improvements at the end of the semester</td>
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<tr>
<td>Lecture notes</td>
<td>There is no script for this course. Each project has its own project description at github. Information available at <a href="https://polyphys.mat.ethz.ch/education/courses/CTL-I.html">https://polyphys.mat.ethz.ch/education/courses/CTL-I.html</a> and alternatively, at <a href="https://ctl.polyphys.mat.ethz.ch/">https://ctl.polyphys.mat.ethz.ch/</a></td>
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<tr>
<td>Prerequisites</td>
<td>Basic knowledge of a programming language, ideally python</td>
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<tr>
<td>notice</td>
<td>github account</td>
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<td>Local installation of python and Visual Studio code (vscode) until the 2nd week of the semester. Detailed information available at <a href="https://ctl.polyphys.mat.ethz.ch/">https://ctl.polyphys.mat.ethz.ch/</a></td>
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<td>327-0311-00L</td>
<td>Projects and Lab Courses III</td>
<td>O</td>
<td>8</td>
<td>8P</td>
<td>M. B. Willeke, L. De Pietro, T.-B. Schweizer</td>
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<tr>
<td>Abstract</td>
<td>A project lasting one semester, with special requirements regarding choice of materials, properties, etc., concluding project presentation event.</td>
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<tr>
<td>Objective</td>
<td>Experiments to teach experimental competence using selected examples from polymer chemistry, analytics and physics (e.g. for the storage or conversion of energy), partly based on courses.</td>
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<td>Content</td>
<td>Learn how to organize, manage, and execute a semester-long project.</td>
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<td>To impart basic knowledge and experimental competence using selected examples from chemistry and physics.</td>
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<td>Semester-long project, project assignment is determined at the beginning of each semester.</td>
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<td>Chemistry III: Synthesis of PMMA via Transesterification; PET recycling or manufacture of poly(methylmethacrylat) via radical polymerization of methylmethacrylat; 3D-printing.</td>
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<td>Physics I, five experiments out of: reflection spectroscopy, experiments on the field of polyers, e.g. viscoelasticity of the polymer melt (or an equivalent exp.), 2 physics experiments (out of 4) at the EMPA: e.g. X-ray flourescence analysis, impedance measurements of batteries, &quot;power to gas&quot; or texture measurement, building a Lithium ionic battery; and further physic experiments.</td>
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<tr>
<td>Lecture notes</td>
<td>Notes with information for each experiment (aim of the experiment, theory, experimental procedure, data analysis) will be made available via moodle (link in mystudies).</td>
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Competencies

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management

Social Competencies

Communication
Cooperation and Teamwork
Self-presentation and Social Influence
Negotiation

Personal Competencies

Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics

Third Year Basic Courses

Individual courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tr>
<td>327-0512-00L</td>
<td>Electronic, Optical and Magnetic Properties of Materials</td>
<td>O</td>
<td>7 credits</td>
<td>5V+2U</td>
<td>P. Gambardella</td>
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</tbody>
</table>

Abstract
This course provides physical foundations to understand the response of different classes of materials to electromagnetic fields, focusing on their electrical, optical, and magnetic properties, and on the basic functioning of devices that exploit such properties. The lectures build on classical and quantum mechanical concepts to provide microscopic understanding and modelling.

Objective
Student should be able to:
- Apply fundamental concepts in solid state physics to describe and explain the behavior of different types of materials, including the ability to make semi-quantitative assertions about relevant physical quantities.
- Analyze and evaluate different models and approaches to describe specific material properties, and appreciate the pertinence of these models to real-world applications, including the ability to make numerical estimates of the relevant parameters.
- Explain the working principles of a range of devices that take advantage of the physical properties of materials, including electronic, photonic, and magnetic devices.
- Develop an appreciation for the role of solid state physics in modern society and technology, and understand the importance of continued research and development in this field for future technological advancements.

Content
Understanding the electronic properties of solids is at the heart of modern society and technology. The aim of this course is to provide fundamental physical concepts that allow one to relate the electronic structure of different types of materials to their electrical, optical, and magnetic behavior as well as the functioning of basic electronic, photonic, and magnetic devices. Beyond fundamental curiosity, such level of understanding is required in order to develop and appropriately describe new classes of materials for future technology applications. The course is divided in six parts.

PART I: The electronic structure of metals, semiconductors, and insulators
Revision of classical concepts: electric fields and currents, Ohm’s and Drude’s model of electrical conductivity, Hall effect, thermoelectric effects.
Revision of quantum mechanical concepts: Electron bands, Fermi statistics, Fermi energy and Fermi surface, density of states in k-space and as a function of energy.

PART II: Semiconductors: concepts and devices

PART III: Dielectric properties of insulators

PART IV: Interaction of electromagnetic waves with matter
The electromagnetic (EM) spectrum. Electromagnetic waves in vacuum; Energy, momentum, and angular momentum of EM waves; Sources of EM radiation; EM waves in matter. The refractive index. Transmission, Reflection, and Refraction from a microscopic point of view. Optical anisotropy, Optical activity, Dichroism. Optical properties of crystalline insulators and semiconductors, glasses, and metals.

PART V: Photonic devices
Photodiodes, photovoltaic cells, light emitting devices (LEDs), Laser diodes, displays, optical fibers.

PART VI: Magnetism

Lecture notes
in English, available for download at http://www.intermag.mat.ethz.ch/education.html
This course provides the fundamentals for understanding the mechanical properties of different classes of materials. The role played by the Analytical Competencies fosters and assessed Mechanical Properties.

**Objective**

The students are able to:
- Apply the interplay of structure and properties in the selection and development of materials.
- Understand plasticity, crack growth, high temperature properties, corrosion, diffusion, environmental influences, grain growth, fatigue, fracture mechanics across material classes.
- to adjust mechanical properties in a targeted manner.
- to select and develop the optimal materials for specific application areas by understanding the temperature-dependent material properties.
- take measures to increase the service life of materials.
- understand concepts of material development and apply them to new materials.

**Content**

This lecture has the irreversible mechanical deformation of materials as its core topic. Independent of the material classes, the following phenomena are explained in detail and rigorously derived: Crystal plasticity at low temperatures (dislocation theory, hardening mechanisms, twinning, brittle-ductile transitions), plasticity in disordered structures (shear bands and strain localisation), Fracture mechanics (Griffith criterion, Weibull statistics, crack tip plasticity, J-integral, R-curve), fatigue (Wöhler curves and Paris law), environmental influences, high temperature plasticity (creep and deformation mechanism diagrams). All phenomena are illustrated by actual case studies using concrete materials and material systems. These include aluminium alloys, steels, high temperature alloys, advanced ceramics, structural polymers and composites. The lecture is supported by exercises and practical experiments and uses material databases.

**Competencies**

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<tr>
<th>Subject-specific Competencies</th>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
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<td></td>
<td>Self-direction and Self-management</td>
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</table>

**Literature**


C. Kittel, Introduction to Solid State Physics (Wiley, 2005), also printed in German. General text that covers many arguments from the point of view of condensed matter physics.


D. A. Neamen, Semiconductor Physics and Devices (McGraw-Hill, 2012). General treatment of semiconductor physics and devices, including both basic and more advanced topics.


Introduction to optics and light waves: E. Hecht, Optics (Lehrmanns);

Optoeletronic devices: D. A. Neamen (see above); Simon Sze, Physics of Semiconductor Devices (Wiley)


Physik I and II, Materialphysik I and II. The lecture will be given in English. The script will be available in English.

**Prerequisites / notice**

The lecture has the irreversible mechanical deformation of materials as its core topic. Independent of the material classes, the following phenomena are explained in detail and rigorously derived: Crystal plasticity at low temperatures (dislocation theory, hardening mechanisms, twinning, brittle-ductile transitions), plasticity in disordered structures (shear bands and strain localisation), Fracture mechanics (Griffith criterion, Weibull statistics, crack tip plasticity, J-integral, R-curve), fatigue (Wöhler curves and Paris law), environmental influences, high temperature plasticity (creep and deformation mechanism diagrams). All phenomena are illustrated by actual case studies using concrete materials and material systems. These include aluminium alloys, steels, high temperature alloys, advanced ceramics, structural polymers and composites. The lecture is supported by exercises and practical experiments and uses material databases.

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**327-0513-00L**

**Thermal and Transport Properties**

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**Objective**

Students will learn how to create models describing transport processes. They will solve the resulting equations both analytically and numerically. They will apply these results to design materials processes and understand real-life experiments. A key takeaway will be the ability to construct simple order-of-magnitude estimates and scaling relationships that can be applied to efficient data analysis and design.

**Lecture notes**

A script in English will be provided on the Moodle course website.
### Computational Thinking Lab II

**Number:** 327-0514-00L  
**Title:** Computational Thinking Lab II  
**Type:** O  
**ECTS:** 3 credits  
**Hours:** 1G+2A  
**Lecturers:** M. Kröger

**Abstract:** You are going to address, in groups, problems that are arising or may arise in the context of remaining courses of your studies, that cannot be solved analytically or manually within reasonable amounts of time, but solved computationally with the help of a programming language and computers. Knowledge of a computing language is required.

**Objective:**
- Getting used to the idea that solving problems using a programming language is a dynamic process, where one can learn from errors.
- Thinking in modules that perform a task and can be tested separately. Modules are then combined to interact lateron.
- Organizing the distribution of work across a small group of students and ask questions, as soon as they arise.
- Using existing resources if helpful to implement your ideas.
- Getting confronted with computational tasks as they may occur during scientific work.

**Content:**
- Create transparent (re-usable, using functions) and ideally efficient algorithms using python.
- Make use of collaborative tools (vscode, github) to edit, store and execute python code in groups.
- Create accompanying descriptions and resulting graphs (at github, using markdown language).
- Make use of internet resources or vscode to find answers to questions that arise (python command and their syntax, existing libraries, if helpful).
- Short oral presentation of algorithms, results, possible improvements at the end of the semester.

**Lecture notes:** Information available at [https://polyphys.mat.ethz.ch/education/courses/CTL-II.html](https://polyphys.mat.ethz.ch/education/courses/CTL-II.html) or alternatively, at [https://ctl.polyphys.mat.ethz.ch](https://ctl.polyphys.mat.ethz.ch)

**Literature:**

**Prerequisites / notice:**
- Basic knowledge of a programming language, ideally python.
- github account.
- Local installation of python and Visual Studio code (vscode) until the 2nd week of the semester. Detailed information available at [https://ctl.polyphys.mat.ethz.ch](https://ctl.polyphys.mat.ethz.ch)

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### Capstone Project

**Number:** 327-0511-00L  
**Title:** Capstone Project  
**Type:** O  
**ECTS:** 6 credits  
**Hours:** 6P  
**Lecturers:** M. B. Willeke, J. F. Löffler

**Abstract:** Acquisition of independent scientific-technical skills; project management; organization and undertaking of experiments; interpretation, scientifically and technically correct project presentation in oral and written form.

**Objective:** Acquisition of independent scientific/technical skills; project management; organization and conducting of experiments; interpretation and scientifically/technically correct presentation of projects in oral and written form.

**Content:** Supervision by D-MATL research Groups.

**Prerequisites / notice:**
- Groups of students (2 or 3 per group) each work on a research project throughout the semester.
- Prerequisite: Successful participation in the “Projekte & Praktika I - IV” (courses within the material science bachelor study at ETH) or comparable practical lab courses.
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**Compensatory Courses**

*Only possible after consultation with the Director of Studies.*

**Bachelor's Thesis**

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<td>O</td>
<td>12 credits</td>
<td>23D</td>
<td>Supervisors</td>
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</table>

Abstract

Independent scientific project in a D-MATL research group. A written report will be prepared on the scientific studies carried out, as well as on the evaluation and discussion of the results.

Objective

To develop the capability of independently analyzing and addressing scientific problems.

**Bachelor Studies (Programme Regulations 2017)**

**Industrial Internship or Project**

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**Abstract**

12 weeks of industrial internship which is completed with a written report.

Objective

The main objective of the 12-week internship is to expose bachelor's students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.

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<tr>
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**Abstract**

Project in a research group at ETH or at an University of 12 weeks. The project is completed with a written report.

Objective

The main objective of the 12-week research project is to expose bachelor's students to the professional research environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.

**Bachelor’s Thesis**

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<td>O</td>
<td>10 credits</td>
<td>17D</td>
<td>Professors</td>
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</table>

**Abstract**

Independent scientific project in a D-MATL research group. A written report will be prepared on the scientific studies carried out, as well as on the evaluation and discussion of the results.

**Objective**

To develop the capability of independently analyzing and addressing scientific problems.

**Content**

Independent work on a scientific research project. The project will be carried out either for two days per week during the 6th semester or in a block within the first 6 weeks after the 6th semester.

**Prerequisites / notice**

The entire project, including preparation of the report, needs to take place within the allotted time.

**Science in Perspective**

*see Science in Perspective: Type A: Enhancement of Reflection Capability*

**Recommended Science in Perspective (Type B) for D-MATL**

**Language Courses**

*see Science in Perspective: Language Courses ETH/UZH*

### Materials Science Bachelor - Key for Type

<p>| O | Compulsory |
| E- | Recommended, not eligible for credits |
| W+ | Eligible for credits and recommended |
| Z | Courses outside the curriculum |
| W | Eligible for credits |
| Dr | Suitable for doctorate |</p>
<table>
<thead>
<tr>
<th>Key for Hours</th>
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</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

**ECTS**  
European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Materials Science Master

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>327-0505-00L</td>
<td>Surfaces and Interfaces I: Fundamentals, Analytics and Applications</td>
<td>W Dr</td>
<td>6</td>
<td>3G</td>
<td>L. Isa, M. P. Heuberger</td>
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Abstract
This course teaches the basics of surface and interface science and technology, including surface modifications and forces. It covers various analytical techniques to study surface and interface properties, and explores phenomena of applied relevance like friction, lubrication, phoresis, and wetting where surfaces play a crucial role.

Objective
Students are able to
- describe the physical and chemical properties of surfaces and interfaces.
- analyze and compare analytical tools for surfaces.
- choose and combine appropriate surface-analytical approaches for solving problems connected to applications.
- understand and explain the importance of surfaces and interfaces in a broad range of phenomena and applications.

Content
- Introduction to surfaces and interfaces
- Structure of surfaces over different length scales: from macroscopic roughness to atomic structure
- Surface modifications
- Adsorption and adsorption models
- Surface forces
- Basic physical concepts
- Thermodynamics of surfaces and interfaces
- Measurement of intermolecular and surface forces
- Dynamics and history effects
- Surface analytics: X-ray Photoelectron Spectroscopy (XPS) – principles and modern developments
- Surface analytics: Secondary Ion Mass Spectroscopy (SIMS) and IR Spectroscopy – Principles and examples
- Atomic Force Microscopy (AFM): Principles and modes of operation
- Tribology: Adhesion, Friction and Lubrication
- Contact mechanics
  - Micro and macroscale friction
  - Boundary lubrication
  - Wetting
  - Contact angles
  - Phoretic phenomena
  - Electric double layer and electrophoresis
  - Electro-osmosis
  - Other types of phoresis
  - Case studies

Lecture notes

Literature

Prerequisites / notice
Chemistry:
General undergraduate chemistry including basic chemical kinetics and thermodynamics

Physics:
General undergraduate physics including basic theory of interatomic and intermolecular forces, atomic and crystalline structure of materials and their mechanical and electronic properties

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Problem-solving assessed

Personal Competencies
- Creative Thinking assessed
- Critical Thinking assessed

327-0703-00L Electron Microscopy in Material Science W 4 credits 2V+2U S. Gerstl, R. Erni, F. Gramm, A. Käch, F. Krumeich, K. Kunze

Abstract
A comprehensive understanding of the interaction of electrons and ions with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

Objective
A comprehensive understanding of the interaction of electrons and ions with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

Content
This course provides a general introduction into electron- and ion- microscopy of organic and inorganic materials. In the first part, the basics of transmission- and scanning electron microscopy are presented. The second part includes the most important aspects of specimen preparation, imaging and image processing. In the third part, focused ion-beam and atom probe microscopes are presented. Throughout the semester, various applications in materials science, solid state physics, structural biology, structural geology, and structural chemistry will be reported.

Lecture notes
will be distributed in English

Literature
- Erni: Aberration-corrected imaging in transmission electron microscopy, Imperial College Press (2010, and 2nd ed. 2015)
In this course, we discuss engineering aspects of soft materials. First, we cover different classes of soft matter systems, e.g. suspensions, gels, emulsion and foams, and introduce scaling principles to design their structural, mechanical and functional properties. Second, we cover essential characterisation techniques to interrogate the structure-property relations in soft materials.

The learning goals of the course are to introduce the students to soft matter and its technological applications, to see how the structure property relations depend on fundamental formulation properties and processing steps. Students should also be able to select a measurement technique to evaluate the properties.

By the end of this course, students will be able to explain how natural selection optimizes biological materials at the molecular and microstructural levels and how this optimization process has resulted in the emergence of biological design principles that fulfill essential functions for species’ survival.

Students will gain the ability to analyze and integrate bio-inspired adaptive functions into synthetic material systems, as well as interpret the correlation between function, microstructure, and performance of biological and bio-inspired materials. Through engaging activities, students will also develop strategies to create bio-inspired solutions for typical engineering problems and predict the performance of bio-inspired materials.

This course is divided into two main blocks. The first block focuses on the primary molecular adaptations of living organisms, while the second block covers the fundamental microstructural design principles present in biological materials.

**Block I: Molecular Adaptations of Living Organisms and Creation of Adaptive Bio-inspired Materials**
- Temporal regulation in biological and bio-inspired molecular systems;
- Autonomous molecular structures and out-of-equilibrium systems;
- Molecular motion and work generation mechanisms in biological and bio-inspired systems;
- Sensing, adaptation, and communication in biological and bio-inspired material systems;

**Block II: Principles of Microstructural Design in Biological Materials and Their SYNthetically Engineered Counterparts**
- Fundamentals of engineering in biological and bio-inspired materials;
- Replicating biological design principles in synthetic materials (structural, optical, surface properties, etc.);
- Bio-inspired design and systems (mechanical actuation and bio-inspiration in the built environment).

### Literature

The aim is an overview of the different ordering phenomena that occur in materials: magnetic, electrical, mechanical, structural. Special emphasis is placed on a comprehensive definition of the term "ferroic". Novel forms of order, such as multiferroicity, are of particular interest. Their exploration and the material functionalities derived from these are a central theme in our Department.

Ferromagnetism is known to humankind for 2500 years, but there are many other forms of spontaneously ordered states in nature that wait to be explored. One of these is ferroelectricity, the spontaneous electric order of a materials, which rapidly gains importance in science and technology. It is the aim of this course to learn what actually defines a state as ferroic, what forms of ordering are known or newly proposed, and what kind of materials and functionalities are related to ferroic materials. We also explore the transition from order to disorder, which is fluent and offers materials properties that are not found in the fully ordered or disordered state.

It is an equally important goal that attendees learn to work critically and creatively with the "unfinished knowledge" of a "hot" research field that is in continuous and rapid development. Realizing that scientific results are not eternally true, but need to be constantly challenged and revised if necessary is very important in becoming a researcher working at the forefront of science. It is important that attendees of the lecture form their own view of this field rather than following the filtered and biased view presented in a script.

It is equally important that attendees of the lecture learn to work critically and creatively with the "unfinished knowledge" of a "hot" research field that is in continuous and rapid development. Realizing that scientific results are not eternally true, but need to be constantly challenged and revised if necessary is very important in becoming a researcher working at the forefront of science. It is important that attendees of the lecture form their own view of this field rather than following the filtered and biased view presented in a script.

We will give an introduction to thin films deposition techniques and applications with a focus on the growth of multifunctional oxide thin films. Oxide films with a thickness of just a few atoms can now be grown with a precision matching that of semiconductors. This opens up a whole world of functional device concepts and fascinating phenomena that would not occur in the expanded bulk crystal.
### Objective
In this course students will obtain an overarching view on thin film deposition techniques with a focus on epitaxial deposition processes. The main learning objectives are:

- Identification of most relevant deposition technique for a given application.
- Understanding of growth mechanism and growth modes.
- Understanding strategies for engineering the functionalities of the films using the deposition process.
- Selection of the most appropriate characterization technique.
- Understanding device concepts and fundamental limits in the technology relevant ultra-thin limit.
- Assessing the relevance of scientific literature dealing with complex oxide thin films.

### Content
A lab visit visit will be organized and students will participate to the design of thin films with atomic precision.

General description of the leading deposition routes including physical and chemical vapor deposition techniques (PVD and CVD) as well as so called "wet techniques" (e.g. spin coating and spray pyrolysis).

Growth modes and processes.

Part of the course discusses vacuum technologies.

Fundamental characterization techniques for application-relevant thin films as well as state of the art approaches for in situ and ex-situ determination of the structural, chemical and ferroic (ferromagnetic and ferroelectric) properties of films: (XRD for thin films, RHEED, EDX, scanning probe microscopy techniques, laser-optical characterization and many more)

Epitaxy for the advanced design and characterization of high quality thin films for energy efficient oxide electronics.

Types of ferroic order, multiferroics, multifunctional oxide materials, epitaxial strain related effects, oxide thin film based devices and examples.

Regular discussions on preselected scientific literature and mini-seminars will be organized.

### Competencies

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### Lecture notes
Learning material will be made available through Moodle and through the ETH JupyterHub.

### Prerequisites / notice
Students are assumed to possess a basic background knowledge in quantum mechanics, solid-state and statistical physics as well as classical electromagnetism.

Students will have the opportunity to self-assess their understanding through quizzes and interactive tutorials, mostly inspired by topics of current research in nanoscale magnetism.
**Competencies**

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Analytical Competencies
Media and Digital Technologies
Problem-solving

Personal Competencies

Creative Thinking
Critical Thinking
Self-direction and Self-management

**Elective Courses**

The students are free to choose individually from the entire course offer of ETH Zürich on the Master level. Please consult the study administration in case of questions.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<tr>
<td>327-0702-00L</td>
<td>EM-Practical Course in Materials Science</td>
<td>W</td>
<td>2</td>
<td>4P</td>
<td>K. Kunze, S. Gerstl, F. Gramm, F. Krumeich, J. Reuteler</td>
</tr>
</tbody>
</table>

Abstract

Practical work on TEM, SEM, FIB and APT treatment of typical problems
data analysis, writing of a report

Objective

Application of basic electron microscopic techniques to materials science problems

Literature

see lecture Electron Microscopy (327-0703-00L)

Prerequisites / notice

Attendance of lecture Electron Microscopy (327-0703-00L) is recommended.
Maximum number of participants 15, work in groups of 3 people.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>327-1101-00L</td>
<td>Biomineralization</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>K.-H. Ernst</td>
</tr>
</tbody>
</table>

Abstract

The course addresses undergraduate and graduate students interested in getting introduced into the basic concepts of biomineralization.

Objective

The course aims to introduce the basic concepts of biomineralization and the underlying principles, such as supersaturation, nucleation and growth of minerals, the interaction of biomolecules with mineral surfaces, and cell biology of inorganic materials creation. An important part of this class is the independent study and the presentation of original literature from the field.

Content

Biomineralization is a multidisciplinary field. Topics dealing with biology, molecular and cellular biology, solid state physics, mineralogy, crystallography, organic and physical chemistry, biochemistry, dentistry, oceanography, geology, etc. are addressed. The course covers definition and general concepts of biomineralization (BM)/ types of biominerals and their function / crystal nucleation and growth / biological induction of BM / control of crystal morphology, habit, shape and orientation by organisms / strategies of compartmentalization / the interface between biomolecules (peptides, polysaccharides) and the mineral phase / modern experimental methods for studying BM phenomena / inter-, intra, extra- and epicellular BM / organic templates and matrices for BM / structure of bone, teeth (vertebrates and invertebrates) and mollusk shells / calcification / silification in diatoms, radiolaria and plants / calcium and iron storage / impact of BM on lithosphere and atmosphere/ evolution / taxonomy of organisms.

1. Introduction and overview
2. Biominerals and their functions
3. Chemical control of biomineralization
4. Control of morphology: Organic templates and additives
5. Modern methods of investigation of BM
6. BM in matrices: bone and nacre
7. Vertebrate teeth
8. Invertebrate teeth
9. BM within vesicles: calcite of coccoliths
10. Silica
11. Iron storage and mineralization

Literature

3) P. M. Dove, J. J. DeYoreo, S. Weiner (Eds.) Biomineralization, Reviews in Mineralogy & Geochemistry Vol. 54, 2003

Prerequisites / notice

No special requirements are needed for attending. Basic knowledge in chemistry and cell biology is expected.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
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<tr>
<td>327-2103-00L</td>
<td>Composites and Hybrids: From Design to Application</td>
<td>W</td>
<td>5</td>
<td>3V+1U</td>
<td>F. J. Clemens, B. Weisse, A. Winstößer</td>
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</table>

Abstract

Composites/hybrids are heterogeneous materials consisting of two or more bonded components, and it is possible to tailor material properties for certain applications. Typically, The components retain their structure and properties, but the properties of the composite are a combination of the properties of its components.

Objective

In this course you will get an inside to lightweight material with high strength, materials that are resistive against abrasion, ceramics with damage tolerance behavior, composites with bioactive, bioreabsorbable, piezoresistive and –electric properties. Enables materials scientists to design composite/hybrid materials for different applications. The course will comprise a balance of lectures, exercises and laboratory classes.
Content

Introduction and basic concepts on biomedical composites and smart composites/hybrids with sensing and actuation properties; production and properties of composites reinforced with particles, whiskers, short or long fibers; selection criteria, case studies and applications, future perspectives.

1. Structural composites (polymer-, metal- and ceramic matrix composites)
   1.1. Introduction and historical background
   1.2. Components: Matrix and reinforcement materials
   1.3. Types of composites and mechanisms of reinforcement
   1.4. Production processes
   1.5. Physical and chemical properties
   1.6. Applications

2. Biomedical Composites
   2.1. Introduction and historical background
   2.2. Components: metals&alloys, natural/synthetic polymers, bioceramics
   2.3. Types of biocomposites
   2.4. Production processes
   2.5. Properties
   2.6. Applications

3. Functional Composites (Sensors and Actuators)
   3.1. Introduction and historical background
   3.2. Components: Matrix and functional filler material
   3.3. Types of composites
   3.4. Production processes
   3.5. Properties
   3.6. Applications

Lecture notes

We will work with handouts

Literature


Biomedical composites, J. Paulo Davin (Ed.), De Gruyter (2014)


Bioresorbable polymers for biomedical applications – from fundamentals to translational medicine, G. Perale, J. Hilborn (Eds), Woodhead Publishing (2017)


Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Microscopy Training SEM I - Introduction to SEM

The number of participants is limited. In case of overbooking, the course will be repeated once. All registrations will be recorded on the waiting list.

For PhD students, postdocs and others, a fee will be charged (https://scopem.ethz.ch/education/MTP.html).

All applicants must additionally register on this form: https://docs.google.com/forms/d/1Xw8L_2yXTE9qXxW9Ccb6njKmVqdVlxSJEa--9CwDXkd0/edit

The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

Abstract

This introductory course on Scanning Electron Microscopy (SEM) emphasizes hands-on learning. Using ScopeM SEMs, students have the opportunity to study their own samples (or samples provided) and solve practical problems by applying knowledge acquired during the lectures. At the end of the course, students will be able to apply SEM for their (future) research projects.

Objective

- Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize microscope performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.
During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications. This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

**Lectures:**
- Introduction on Electron Microscopy and instrumentation
- electron sources, electron lenses and probe formation
- beam/specimen interaction, image formation, image contrast and imaging modes.
- sample preparation techniques for EM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

**Practicals:**
- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast (and image processing)
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Practice on real-world samples and report results

**Literature**
- P. Zeng
- The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

**Practicals:**
1. align and operate a TEM
2. acquire data using different operation modes of a TEM instrument, i.e. Bright-field and Dark-field imaging
3. record electron diffraction patterns and index diffraction patterns
4. interpret TEM data
5. sample preparation techniques

**Learning how to**
- Hand-on training for students: sample loading, instrument alignment and data acquisition.
- Sample preparation for different types of materials
- Practical work with TEMs
- Demonstration of advanced Transmission Electron Microscopy techniques

**Lecture notes**
Lecture notes will be distributed.

**Prerequisites / notice**
No mandatory prerequisites.

**Content**
- basics of electron optics and the TEM instrument set-up
- TEM imaging modes and image contrast
- STEM operation mode
- Sample preparation techniques for hard and soft materials

**Practicals:**
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping
- Sample preparation techniques for hard and soft materials
- Practice on image formation, image contrast (and image processing)

**Literature**

**Prerequisites / notice**
No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.

**Content**
- Introduction to TEM
- The number of participants is limited. In case of overbooking, the course will be repeated once. All registrations will be recorded on the waiting list.

**Abstract**
The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

**Objective**
Understanding of
1. the set-up and individual components of a TEM
2. the basics of electron optics and image formation
3. the basics of electron beam – sample interactions
4. the contrast mechanism
5. various sample preparation techniques

**Content**
- basics of electron optics and the TEM instrument set-up
- TEM imaging modes and image contrast
- STEM operation mode
- Sample preparation techniques for hard and soft materials

**Practicals:**
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping
- Sample preparation techniques for hard and soft materials
- Practice on real-world samples and report results

**Literature**

**Prerequisites / notice**
No mandatory prerequisites.
The main goal of this hands-on course is to provide students with a detailed understanding of physical processes that enable the EDS technique and data evaluation algorithms. This advanced course provides analytical EM techniques to students with prior EM experience (TEM or SEM). At the end of the course, students will understand the physical processes that enable the EDS technique and data evaluation algorithms and apply the technique for composition quantification, understanding of data acquisition and evaluation routines including practical understanding of different data acquisition set-ups, optimization of acquisition parameters for most reliable quantification of the results, and the knowledge of the available and most reliable quantification algorithms and their handling. The effect of the specimen geometry on the data and experimental solutions for minimization of the artefacts.

Content
This advanced course provides new skills to students with previous TEM experience. At the end of the course, students will know how to obtain HR(STEM) images, how to analyse, process and simulate them.

Topics:
1. Introduction to HRTEM and HRSTEM
2. Considerations on (S)TEM instrumentation for high resolution imaging
3. Lectures on aberrations, aberration correction and aberration corrected images
4. HRTEM and HRSTEM simulation
5. Data analysis, phase restoration and lattice-strain analysis

Literature
- Detailed course manual

Prerequisites / notice
The students should fulfill one or more of these prerequisites:
- Prior attendance to the ScopeM TEM basic course
- Prior attendance to ETH EM lectures (327-7030-00L Electron Microscopy in Material Science)
- Prior TEM experience

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<tr>
<td>327-2129-00L</td>
<td>Nanoncharacterization using Analytical Electron Microscopy</td>
<td>Lecture</td>
<td>1 credit</td>
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<tr>
<td>327-2136-00L</td>
<td>Chemical Analysis and Spectroscopy for Energy</td>
<td>Lecture</td>
<td>2 credits</td>
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</table>

Abstract
This advanced course on High Resolution Transmission Electron Microscopy (HRTEM) provides lectures focused on HRTEM and HRSTEM imaging principles, related data analysis and simulation and phase restoration methods.

Objective
- Learning how HRTEM and HRSTEM images are obtained.
- Learning about the aberrations affecting the resolution in TEM and STEM and the different methods to correct them.
- Learning about TEM and STEM images simulation software.
- Performing TEM and STEM image analysis (processing of TEM images and phase restoration after focal series acquisitions).

Content
This course provides an introduction to the chemical analysis and operando spectroscopy related to current scientific questions in energy research.

Objective
- Hand-on experience of data acquisition and evaluation routines including practical understanding of different data acquisition set-ups, optimization of acquisition parameters for most reliable quantification of the results, and the knowledge of the available and most reliable quantification algorithms and their handling.
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- Hand-on experience of data acquisition and evaluation routines including practical understanding of different data acquisition set-up
Content

Future as well as existing energy supply relies on the precise determination of the amount of the energy carrier either produced or spent. The devices used for this purpose range from simple amperemeter and its scientific pendant impendence spectrometer for electricity, and the chemical analysis of fuels and their combustion products. With the advent of renewable energy and its chemical or electro-chemical storage, there is increasing demand for advanced analysis tools as well as operando spectroscopy. The objective of the course is to introduce the physical basics of most commonly used methods, i.e., separation techniques (GC, MS), spectroscopic methods (impedance spectroscopy, UV-Vis, IR, Raman spectroscopy), and scattering techniques (X-ray/photoelectron spectroscopy, neutron scattering) with focus on operando techniques. The methods are discussed within the framework of current scientific questions in renewable energy research such as the analysis of reaction mechanisms in thermo- and electro-catalysis and the in-situ characterization of new energy materials with particular focus on surface phenomena and gas-solid interactions.

The course will build on the Bachelor's degree courses Analytical Chemistry and Materials Characterization Methods.

327-2137-00L Scattering Techniques for Material Characterization

Objective

Students are able to do:
- systematically characterise the microstructure and phases of a given material with X-rays and electrons
- select the right tool (source, instrument, measurement strategy) and design a workflow for solving a microstructure or phase analysis problem
- comprehensively store experimentally collected data in a repository following modern data management rules such that data can be evaluated by students not involved in the experiment
- qualitatively and quantitatively evaluate and present experimental data and results collected by others

Abstract

The lecture presents the currently most efficient experimental techniques for microstructure material characterization: X-ray diffraction (XRD) and transmission electron microscopy (TEM). The theoretical basics, instrumentation, complementarity and exclusivity of both techniques will be taught. The course will provide practical elements and examples of current research projects at D-MATL.

Literature


327-2140-00L Focused Ion Beam and Applications

Objective

Overview of FIB theory, instrumentation, FIB hardware operation and applications. Set-up, align and operate a FIB-SEM successfully and safely. Accomplish operational tasks (milling and deposition) and optimize microscope parameters. Perform cross-sections: preparation and analysis Understanding of workflow for sample preparation (TEM lamella, APT needles, XCT pillars...) using FIB-SEM. Applying FIB-SEM for materials characterization.

Abstract

The course on Focused Ion Beam (FIB) provides theoretical and hands-on learning, applying what is learned in lectures to hands-on sessions.

Registration form:

https://docs.google.com/forms/d/1QXveZo6nTdGdH4xZyPFkLoDd2jwKYGQzYNzDGO89/edit
This course provides FIB techniques to students with previous SEM experience. At the end of the course, students will be able to set-up a FIB-SEM session and characterize cross-sections. Students will also understand how to prepare TEM & APT samples and design a FIB experiment to solve research problems.

**Introduction to FIB theory and instrumentation.**
**Discussion of FIB operation and applications.**
**Lecture and demonstration on FIB automation.**
**Practicals on FIB-SEM set-up and alignment.**
**Practicals on cross-section and site-specific sample characterization.**
**Practicals on sample preparation (TEM lamella/APT needles).**

**Registration form:**
https://docs.google.com/forms/d/e/1QdrFnFjQ4rc0gB5erO-mjeJDT59FdmRy7QFFh0hIZia/edit

**Prerequisites / notice**
The students should fulfill one or more of these prerequisites:
- Prior attendance to the ScopeM Microscopy Training SEM I: Introduction to SEM (327-2125-00L)
- Prior TEM experience

**Content**
Modern polymer synthesis (based on recent development of new organic reactions) is discussed to enable students to develop synthesis schemes for certain target structures. Both chain (ionic, coordination, ROMP, radical, catalyst-transfer) and step-growth polymerizations (transition metal catalysis) including how to achieve living polymerization or improve selectivity will be discussed.

**Objective**

**Abstract**

**Literature**

**Prerequisites / notice**
The students should fulfill one or more of these prerequisites:
- Prior attendance to the ScopeM Microscopy Training SEM I
- Prior TEM experience

**Content**
Polymerization is a series of continuous organic transformation and connects small molecules. The course will give an overview of the following important polymerization procedures:
- Modern Step-growth polymerization
- Living Anionic polymerization
- Group transfer polymerization (GTP)
- Controlled cationic polymerization
- Controlled radical polymerization
- Coordination polymerization: Ziegler-Natta and Metallocene catalysts
- Olefin metathesis polymerization: ROMP, ADMET and cyclopolymerization
- Synthesis of conjugated polymers based on transition metal catalysis
- Complex macromolecules including brush and dendronized polymers

**Objective**

**Abstract**

**Literature**

**Prerequisites / notice**
Strong basic knowledge of Organic Chemistry. Any course on Introductory Polymer Chemistry such as "Advanced Building Blocks for Soft Materials" or "Introduction to Macromolecular Chemistry" or equivalent (bachelor level is also sufficient). Please discuss with the lecturer if one is not certain about the prerequisites.
Communication

3G

assessed

Fabrication and Characterisation of Magnetic Films

327-2146-00L

Raw Materials: From Earth to Consumer (and back) W 3 credits 2V W. J. Malfait

Abstract

Each year, we extract and process a staggering amount of resources from the Earth and biosphere to cover our needs and appetite for housing, energy, transport, nutrition, technology and consumer goods. In this course, we investigate the material cycles primarily from a technical and scientific perspective (geoscience & biosphere, process engineering, material science).

Objective

At the end of the course, the students should have a qualitative and quantitative understanding of where most of the materials around them come from, how they were processed, how they got to where they are used, and what happens to them after use. The students should be able to:

- Answer the question where the world’s raw materials come from within the earth and biosphere.
- For the most important elements, describe where the major deposits are located and in which geological setting.
- Explain how these resources are mined and how the commodities are extracted from the ore.
- Estimate how much material we consume globally in terms of volume and value.
- Analyse whether there are alternatives to digging things up from the ground and plan (or decide) with recycling and sustainability in mind.
- Independently research a specific raw material and compile a summary of its cycle and value chain.

Content

The earth from a materials’ perspective

Coal, oil and gas – not just energy, but a materials resource
Phosphor and nitrogen – how we feed 8 billion people
Biological resources
Sand, gravel and limestone – how we build infrastructure
Copper keeps the light on
Iron versus Aluminum
Noble metals – small volume, big business
Rare earth elements – when demand and supply do not match
Lithium gold rush
Radioactivity
Student presentations on selected topics
Raw materials – how geopolitics, industry, and activists shape policy
Gemstones & curiosities

Lecture notes

Lecture notes & presentations will be provided in electronic format.

Prerequisites / notice

Students signing up should have a strong interest in both the natural and man-made world around them.

327-2148-00L

Fabrication and Characterisation of Magnetic Films ■ W 2 credits 3G A. Hrabec, L. Heyderman, V. Scagnoli

Abstract

This block course takes place at the campus of the Paul Scherrer Institute on the premises of Laboratory for Mesoscopic Systems. The course consists of brief introductory lectures to the fabrication and characterization of thin magnetic films, which will be followed by hands-on sessions.

Objective

The goal of this course is to provide the participants with a full overview of the fabrication and characterization of magnetic films and magnetic devices. The specific objectives are as follows:

1. Participants will gain a comprehensive understanding and a hands-on experience of the processes involved in fabricating magnetic materials and devices.
2. Participants will be able to explain the application areas of magnetic films and devices, including their role in fundamental research, data storage, and computation technologies.
3. Participants will develop skills in evaluating and present the suitability of different fabrication techniques for specific applications of magnetic materials.
4. Participants will be able to assess and present the potential impact of advancements in magnetic materials and devices on future technological developments in areas such as data storage and computation.

Content

The course takes place at the campus of the Paul Scherrer Institute in the Laboratory for Mesoscopic Systems. The morning consists of introductory lectures on the use of specific fabrication and characterization techniques, which are listed below. In the afternoon, the participants will carry out hands-on experiments, where they will have a chance to step through the multifaceted chain of magnetic film development. At the end of the week, the students will be required to give a presentation about the fabrication techniques presented in the course and of the results they obtained with their experiments in relation to future applications.

Lecture notes

Slides from the lectures will be available prior to the lectures.

Literature

- Jens Als-Nielsen and Des McMorrow, Elements of Modern X-ray Physics, Wiley
- https://www.youtube.com/watch?v=SDR2kkdO8&ab_channel=QuantumDesignUSA
The course on Advances in Building Materials provides an introductory overview of the needs and future of materials science in the building sector. The course lays the grounds in the specialization Materials and Mechanics and complements the second introductory course of the specialization on Numerical Mechanics of Materials. The course also addresses master students in Materials Science and other study programs interested in deepening their understanding of application-relevant properties of engineering materials and sustainability related challenges. The following topics are covered:

1. Material selection
2. Materials and sustainability
3. Materials and sustainability
4. Recyclability
5. Material science of wood durability
6. Material science of concrete durability
7. Foams in construction and thermal insulation
8. Sealants and adhesives in construction
9. Coatings
10. Flame retardants
11. Future of wood – 1
12. Future of wood – 2
13. Future of concrete – 1
14. Future of concrete – 2

Lecture notes
Copies of the slides will be made available for download before each lecture.

Literature
The Science of Soft Robots

Prerequisites / notice
Basic knowledge in material properties, circuits, and polymers covered at the bachelor level required. (courses: Physics 2, Mechanics, Material Synthesis)

101-0617-01L Advances in Building Materials

Abstract
The course on Advances in Building Materials provides an introductory overview of the needs and future of materials science in the building sector. Focus topics concern sustainability, durability, thermal insulation, coatings, sealants, adhesives, flame retardancy and the future perspective and developments of concrete and wood with regard to smart material development and ecological concerns.

Objective
In this course, the students will gain a broad overview of the use of materials in the building sector, with a particular focus on concrete and wood. Current limitations and in particular sustainability related challenges will be detailed with the objective of laying the grounds to discuss future developments anticipated in this field.

Content
This course for civil engineers lays the grounds in the specialization Materials and Mechanics and complements the second introductory course of the specialization on Numerical Mechanics of Materials. The course also addresses master students in Materials Science and other study programs interested in deepening their understanding of application-relevant properties of engineering materials and sustainability related challenges. The following topics are covered:

1. Material selection
2. Materials and sustainability
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5. Material science of wood durability
6. Material science of concrete durability
7. Foams in construction and thermal insulation
8. Sealants and adhesives in construction
9. Coatings
10. Flame retardants
11. Future of wood – 1
12. Future of wood – 2
13. Future of concrete – 1
14. Future of concrete – 2

Lecture notes
Handouts will be provided for each lecture.
Based on the lecture 'Werkstoffe' students receive deep concrete technology training. Comprehensive knowledge of the most important properties of conventional concrete and the current areas of research in concrete technology will be presented. The course covers various topics, including:

- concrete components
- concrete properties
- concrete mix design
- production, transport, casting
- demoulding, curing and additional protective measures
- durability
- standards
- chemical admixtures
- alternative binders
- specialty concretes such as: self compacting concrete, fiber reinforced concrete, fast setting concrete
- the role of sustainability in concrete technology
- new research in digital fabrication with concrete

Lecture notes
Slides provided for download.

Competencies

### Subject-specific Competencies

<table>
<thead>
<tr>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
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### Method-specific Competencies

<table>
<thead>
<tr>
<th>Problem-solving</th>
<th>assessed</th>
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### Social Competencies

<table>
<thead>
<tr>
<th>Communication</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
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### Personal Competencies

<table>
<thead>
<tr>
<th>Adaptability and Flexibility</th>
<th>fostered</th>
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<tbody>
<tr>
<td>Creative Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>assessed</td>
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</tbody>
</table>

151-0353-00L Mechanics of Composite Materials  
W 4 credits  2V+1U  G. Pappas

**Abstract**

The course treats aspects related to elastic behavior of unidirectional and multidirectional laminates, micromechanics, failure and damage analysis, analysis and design of composite structures. The focus is on laminated fiber-reinforced polymer composites.

**Objective**

The objective is to introduce the basic concept of composite materials and provide a thorough understanding of the mechanical response of such materials and structures particularly made from fiber reinforced polymer composites, including elastic behavior, failure, fracture and damage analysis as well as structural design aspects. The ultimate goal is to provide the necessary skills to address the design and analysis of modern lightweight composite structures.

**Content**

The course is addressing following topics:

- Introduction
- Elastic anisotropy
- Micromechanics & Homogenization
- Classical Laminate Theory (CLT)
- Strength, failure and damage analysis
- Thin ply composite shells & effects of material non-linearity
- Analysis and design of composite structures

Lecture notes
Script, handouts, exercises and additional material are available in PDF-format on the moodle page of the lecture.

Literature
The lecture material is covered by a script/lecture notes compiled by CMASLab and further literature is referenced therein.

Competencies

### Subject-specific Competencies

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### Method-specific Competencies

<table>
<thead>
<tr>
<th>Analytical Competencies</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>fostered</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
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<td>Project Management</td>
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### Social Competencies

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<td>Customer Orientation</td>
<td>fostered</td>
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<tr>
<td>Leadership and Responsibility</td>
<td>fostered</td>
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<tr>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
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<tr>
<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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<td>Critical Thinking</td>
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<tr>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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<tr>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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151-0544-00L Metal Additive Manufacturing - Mechanical Integrity and Process Simulation  
W 4 credits  3G  E. Hosseini

**Note:** The previous course title until HS22 "Metal Additive Manufacturing - Mechanical Integrity and Numerical Analysis”

**Abstract**

An introduction to Metal Additive Manufacturing (MAM) (e.g. different techniques, the metallurgy of common alloy-systems, existing challenges) will be given. The focus of the lecture will be on the employment of different simulation approaches to address MAM challenges and to enable exploiting the full advantage of MAM for the manufacture of structures with desired property and functionality.

**Objective**

The main objectives of this lecture are:

- Acknowledging the possibilities and challenges for MAM (with a particular focus on mechanical integrity aspects),
- Understanding the importance of material science and metallurgical considerations in MAM,
- Appreciating the importance of thermal, fluid, mechanical and microstructural simulations for efficient use of MAM technology,
- Using commercial analysis tools (e.g. ABAQUS) for simulation of the MAM process.

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Adaptive materials offer appealing ways to extend the design space of structures by introducing time-variable properties into them. In this course, the physical working principles of selected adaptive materials are analyzed and simple models for describing their behavior are presented. Some applications are illustrated, also with laboratory experiments where possible.

Basic concepts: Power conjugated variables, dissipative effects, geometry- and materials-based energy conversion


Thermo-mechanical coupling: Shape memory alloys / polymers

Electromechanical coupling(1): DEA, EBL, electrorheological fluids

Shape control / morphing: Use, requirements, challenges

Morphing applications of variable stiffness structures: Lab work

Electromechanical coupling (2): Piezoelectric, electrostrictive effect

Vibration Reduction: Measurement, passive, semi-active (active) damping methods

Vibration reduction applications of piezoelectric materials: Lab work

Metamaterials: Definition of metamaterials - electromagnetic, acoustical and other metamaterials

Energy harvesting and sensing: Energy harvesting with EAP and piezoelectric materials, transducers as sensors: Piezo, resistive,...
### Lecture notes
Lecture slides (PDF files in English) will be available on Moodle and lecture recordings will be available on the ETH video portal.

### Prerequisites / notice
Prerequisites: Basic knowledge of semiconductors.

### Competencies
<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
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<tbody>
<tr>
<td>Charge Transport in Energy Conversion and Storage Devices</td>
<td>W</td>
<td>6 credits</td>
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</table>

### Abstract
The students will be introduced to the fundamental concepts of charge transport in solar cells, batteries, and electrolyzers. Emphasizing analogies between semiconductor physics and electrochemistry, this course is designed to provide a unified modern perspective of energy conversion and storage concepts for students in electrical engineering, materials science, physics, and chemistry.

### Objective
By the end of this course, the students will (1) understand the fundamentals of electronic and ionic charge transport, (2) understand the operational principles of solar cells, batteries, and electrolyzers, and (3) understand fundamental limits for each device type. In addition, the students will learn how to simulate these devices during guided exercise sessions and develop an intuitive understanding on how to interpret the most important device characteristics.

### Literature
- R. Huggins, Advanced Batteries, DOI:10.1007/9780387764245

### Prerequisites / notice
Be motivated to change the world to renewable energies!

This course is taught simultaneously at ETH Zurich and EPFL. All lectures will be recorded by zoom and made available to the students. Lectures will be streamed live from ETH Zurich with four lectures taught onsite at EPFL Lausanne.

A visit to Empa’s Energy Conversion and Storage Labs will be organized during the semester. Possibility to interact and meet your classmates from EPFL via online lecture platform and during two special lectures with guest lecturers from industry (one guest lecture by ABB at ETH Zurich, one guest lecture by Northvolt at EPFL). Travel expenses for students will be covered.

Elements of calculus will be reviewed during the lectures, where necessary, but we leave the hard work of solving coupled differential charge transport equations to the computer and focus on developing a strong intuition. Prior knowledge in semiconductor physics or electrochemistry is an advantage, but not a prerequisite.

Students are required to bring a windows-compatible computer with a common data analysis software to the exercises. Apps for simulating devices under different operating conditions will be made available to the students.

### Competencies
<table>
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<tr>
<th>Subject-specific Competencies</th>
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<tbody>
<tr>
<td>Emerging Memory Technologies</td>
<td>W</td>
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</table>

This course focuses on the current state and prospects of memory technologies, emerging beyond the silicon transistor era. We explore resistive PCM and RRAM, magnetic MRAM and ferroelectric FRAM memories, covering physics, device aspects and the latest research in the field. Through interactive lectures and laboratory sessions, students gain up-to-date knowledge and compare emerging memory techs.

In this course, students will learn about the leading contenders for post-silicon storage-class and main memory technologies. Decades of research have yielded several efficient memory device working principles, including phase-change of the structure (PCM), materials conversion (OxRAM), ion diffusion (CBRAM), magnetic properties (STT-MRAM, MTJ), and ferroelectricity (FRAM, FeFET). Currently, these memory technologies are transitioning from research to industry, and are predicted to have at least niche applications in the ever-growing hardware market. Some technologies, such as PCM, may even eventually surpass silicon-based flash memory, providing better performance and unique features.

Students will have the opportunity to compare emerging memory technologies with state-of-the-art SSD Flash, DRAM, and SRAM, as well as evaluate their potential. Through critical thinking discussions, students will acquire important skills for assessing the strengths and limitations of these emerging technologies.

The course is organized as a series of lectures, focusing on selected memory technologies. This class also includes practical laboratory sessions for the PCM research topics. Students will spend 2 hours per week in the class or laboratory and additional 2-3 hours per week to prepare for the exam.

Lecture notes will be made available on the website.

### Competencies
<table>
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<tr>
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<tbody>
<tr>
<td>Frontiers in Nanotechnology</td>
<td>W</td>
<td>4 credits</td>
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</table>

Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.

Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within manmade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the-art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.
Lecture notes

All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Lecturer(s)</th>
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</thead>
<tbody>
<tr>
<td>376-1714-00L</td>
<td>Biocompatible Materials</td>
<td>W 4 credits 3V</td>
<td>K. Maniura, M. Rottmar, M. Zenobi-Wong</td>
</tr>
<tr>
<td>402-0317-00L</td>
<td>Semiconductor Materials: Fundamentals and Fabrication</td>
<td>W 6 credits 2V+1U</td>
<td>S. Schön, W. Wegscheider</td>
</tr>
<tr>
<td>402-0468-15L</td>
<td>Nanomaterials for Photonic Devices</td>
<td>W 6 credits 2V+1U</td>
<td>R. Grange, E. Baill, R. Chapman, V. Falcone, A. Morandi</td>
</tr>
</tbody>
</table>

**Abstract**

**Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues).** The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

**Objective**

The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

**Content**

Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated.

Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Lecture notes**

Handouts are deposited online (moodle).

**Literature**


Handouts and references therein.

**402-0317-00L Semiconductor Materials: Fundamentals and Fabrication**

**Abstract**

This course gives an introduction into the fundamentals of semiconductor materials. The main focus is on state-of-the-art fabrication and characterization methods. The course will be continued in the spring term with a focus on applications.

**Objective**

Basic knowledge of semiconductor physics and technology. Application of this knowledge for state-of-the-art semiconductor device processing

**Content**

1. Fundamentals of Solid State Physics
   1.1 Semiconductor materials
   1.2 Band structures
   1.3 Carrier statistics in intrinsic and doped semiconductors
   1.4 p-n junctions
   1.5 Low-dimensional structures
2. Bulk Material growth of Semiconductors
   2.1 Czochalski method
   2.2 Floating zone method
   2.3 High pressure synthesis
   2.4 Molecular Beam Epitaxy (MBE)
   3. Fundamentals of Epitaxy
   3.1 Epitaxy and RAS
   3.2 Molecular Beam Epitaxy (MBE)
   3.3 Metal-Organic Chemical Vapor Deposition (MOCVD)
   3.4 Liquid Phase Epitaxy (LPE)
   3.5 In situ characterization
   4. Pressure and temperature
   4.1 Reflectometry
   4.2 Reflector technology
   4.3 Ellipsometry and RAS
   4.4 LEED, AES, XPS
   4.5 STM, AFM
   5. The invention of the transistor - Christmas lecture

**Lecture notes**

https://moodle-app2.let.ETH.ch/course/view.php?id=20749

**Prerequisites / notice**

The "compulsory performance element" of this lecture is a short presentation of a research paper complementing the lecture topics.

Several topics and corresponding papers will be offered on the moodle page of this lecture.

**Competencies**

Subject-specific Competencies
- Concepts and Theories
  - fostered
- Techniques and Technologies
  - fostered

Method-specific Competencies
- Analytical Competencies
  - fostered
- Communication
  - fostered
- Self-presentation and Social Influence
  - fostered

**402-0468-15L Nanomaterials for Photonic Devices**

**Abstract**

The lecture describes various nanomaterials (semiconductor, metal, dielectric, carbon-based...) for photonic applications (optoelectronics, plasmonics, photonic integrated circuits, ordered and disordered structures...). It starts with concepts of light-matter interactions, fabrication and characterization, the description of the properties and the state-of-the-art applications and devices.

**Objective**

The students will acquire theoretical and experimental knowledge about the different types of nanomaterials (semiconductors, metals, dielectric, carbon-based, ...), and their uses as building blocks for advanced applications in photonics (optoelectronics, plasmonics, photonic crystal, ...). Together with the exercises, the students will learn (1) to read, summarize and discuss scientific articles related to the lecture, (2) to estimate order of magnitudes with calculations using the theory seen during the lecture, (3) to prepare a short oral presentation and report about one topic related to the lecture, and (4) to imagine an original photonic device.
Semiconductor Nanostructures

Abstract
The course covers the foundations of semiconductor nanostructures, e.g., materials, band structures, bandgap engineering and doping, field-effect transistors. The physics of the quantum Hall effect and of common nanostructures based on two-dimensional electron gases will be discussed, i.e., quantum point contacts, Aharonov-Bohm rings and quantum dots.

Objective
At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:
1. The integer quantum Hall effect
2. Conductance quantization in quantum point contacts
3. the Aharonov-Bohm effect
4. Coulomb blockade in quantum dots

Content
1. Introduction and overview
2. Semiconductor crystals: Fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k.p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

Lecture notes

Literature
In addition to the lecture notes, the following supplementary books can be recommended:

Prerequisites / notice
The lecture is suitable for all physics students, students of Quantum Engineering, and students of Micro- and Nanosystems beyond the bachelor of science degree. Basic knowledge of solid state physics is a prerequisite. Very ambitious students in the third year of Physics may be able to follow. The lecture can be chosen as part of the PhD-program. The course is taught in English.
### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Media and Digital Technologies: assessed
- Problem-solving: fostered

**Social Competencies**
- Communication: fostered
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: fostered

**Personal Competencies**
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-direction and Self-management: fostered

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**402-0809-00L Introduction to Computational Physics**

<table>
<thead>
<tr>
<th>Objective</th>
<th>Abstract</th>
<th>Content</th>
<th>Literature /</th>
<th>Prerequisites /</th>
<th>Competencies</th>
<th>Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.</td>
<td>Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.</td>
<td>Lecture notes and slides are available online and will be distributed if desired.</td>
<td>Lecture and exercise lessons in english, exams in German or in English</td>
<td>Subject-specific Competencies: Concepts and Theories</td>
<td>Method-specific Competencies: Analytical Competencies</td>
</tr>
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</table>

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**529-0615-01L Biochemical and Polymer Reaction Engineering**

<table>
<thead>
<tr>
<th>Objective</th>
<th>Abstract</th>
<th>Content</th>
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</thead>
<tbody>
<tr>
<td>The aim of the course is to learn how to design polymerization reactors and bioreactors to produce polymers and proteins with the specific product qualities that are required by different applications in chemical, pharmaceutical and food industry. This activity includes the post-treatment of polymer latexes, the downstream processing of proteins and the analysis of their colloidal behavior.</td>
<td>Polymerization reactions and processes. Homogeneous and heterogeneous (emulsion) kinetics of free radical polymerization. Post treatment of polymer colloids. Bioprocesses for the production of molecules and therapeutic proteins. Kinetics and design of aggregation processes of macromolecules and proteins.</td>
<td>We will cover the fundamental processes and the operation units involved in the production of polymeric materials and proteins. In particular, the following topics are discussed: Overview on the different polymerization processes, Kinetics of free-radical polymerization and use of population balance models. Production of polymers with controlled characteristics in terms of molecular weight distribution. Kinetics and control of emulsion polymerization. Surfactants and colloidal stability. Aggregation kinetics and aggregate structure in conditions of diffusion and reaction limited aggregation. Modeling and design of colloid aggregation processes. Physico-chemical characterization of proteins and description of enzymatic reactions. Operation units in bioprocessing: upstream, reactor design and downstream. Industrial production of therapeutic proteins. Characterization and engineering of protein aggregation. Protein aggregation in biology and in biotechnology as functional materials.</td>
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</table>

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**529-0659-00L Electrochemistry: Fundamentals, Cells & Applications**

<table>
<thead>
<tr>
<th>Objective</th>
<th>Abstract</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>The course establishes the fundamentals to understand and describe electrochemical reactions and phenomena related to these. The students are familiarized with key concepts and approaches in electrochemistry and selected aspects of materials science and engineering and how they are put to use in selected applications.</td>
<td>Introduction to electrochemistry from a physical chemistry point of view, focusing on thermodynamics &amp; kinetics of electrochemical reactions, and engineering aspects of electrochemical cells. The topics are of generic nature yet also discussed in the context of specific applications in industrial electrochemistry, energy storage and conversion, electroanalytical techniques, sensors and corrosion.</td>
<td>The course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.</td>
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</tbody>
</table>

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**Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1841 of 2653**
This Master level course delves into the emerging field of biomolecular condensates - membrane-less organelles in cells. Using Adaptability and Flexibility

Concepts and Theories
Techniques and Technologies

Chapter I - Redox reactions, Faraday's laws;

Chapter II - Equilibrium electrochemistry:
cells, galvanic and electrolytic cells, thermodynamic state functions, theoretical cell voltage, half-cell / electrode potential, hydrogen electrode, the electrochemical series, Nernst equation;

Chapter III - Electrodes & interfaces:
 electrochemical potential, phase potentials, work function, Fermi level, the electrified interface, the electrochemical double layer, reference electrodes and laboratory cells;

Chapter IV - Electrolytes:
 conductivity, aqueous electrolytes, transference effects, liquid junctions, polymer electrolytes, ion-exchange membranes, Donnan exclusion, solid state ion conductors;

Chapter V - Dynamic electrochemistry:
 overpotentials, description of charge-transfer reaction, Butler-Volmer and Tafel equation, exchange current density, mass transport limitations;

Chapter VI - Industrial electrochemistry:
 electrochemical engineering, process and reactor types, current density distribution, porous electrodes, chlor-alkali and HCl electrolysis, oxygen depolarized cathode;

Chapter VII - Energy storage & conversion:
 important primary and secondary battery chemistries, fuel cells, polymer electrolyte fuel cells, low temperature H2 and O2 electrochemistry, electrocatalysis, triple-phase boundary, solid oxide fuel cell, conversion efficiency;

Chapter VIII - Electroanalytical methods & sensors:
 potentiometry, amperometry, cyclic and stripping voltammetry, rotating disc electrode studies, electrochemical sensors;

Chapter IX - Corrosion:
corrosion reactions, Pourbaix diagram, corrosion potential, passivation, corrosion protection

Lecture notes
- lecture notes, lecture slides, exercise & solutions (PDF files)

Prerequisites / notice
Students should be familiar with the fundamentals of physical chemistry.

Competencies

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving

Social Competencies
Communication
Cooperation and Teamwork
Self-presentation and Social Influence

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Cellular Matters: Properties, Functions and Applications of Biomolecular Condensates

W 4 credits 2S


551-0357-00L

Abstract
This Master level course delves into the emerging field of biomolecular condensates - membrane-less organelles in cells. Using interdisciplinary concepts from biology, chemistry, biophysics, and soft matter, we will explore the biological properties of these condensates, their functions in health and disease, and their potential as new biomimetic materials for various applications.

Objective
In the last decade, a novel type of cell compartments called biomolecular condensates have been discovered. This discovery is radically changing our understanding of the cell, its organization, and dynamics. The emerging picture is that the cytoplasm and nucleoplasm are highly complex fluids that can (meta)stably segregate into membrane-less compartments, similar to emulsions.

This interdisciplinary course encompasses milestone works and cutting-edge research questions in the young field of biomolecular condensates, including their properties, functions, and applications. The course begins with a lecture series that introduces the topic of condensates to an interdisciplinary audience and provides a theoretical foundation for understanding current research questions in the field. The lectures provide a base for student presentations of recent publications in the field, and for research seminars given by course lecturers, who are all active researchers with diverse expertise. Through this exciting interdisciplinary understanding of biomolecular condensates, bridging biology, chemistry, biophysics, and soft matter.

Students will not only learn how to critically read and evaluate scientific literature but will also gain valuable experience in giving scientific presentations to an interdisciplinary audience. Each presentation will require an introduction, critical analysis of the results, and a discussion of their significance, allowing student to substantiate their statements with a critical mindset that considers the pros and cons of chosen approaches and methods, as well as any limitations or possible follow-up experiments. This process will enable student to ask relevant querions and actively participate in class discussions, further enhancing their scientific skills.

In preparing the presentations, the students will have the unique opportunity to interact closely with each other and with the lecturers, who are all internationally well-established experts, and receive guidance in selectin a topic for the final presentaton and supporting literature.
Content
The topic of biomolecular condensates goes beyond the boundaries of traditional disciplines and requires a multi-disciplinary approach that leverages and cross-fertilizes biology, physical chemistry, biophysics, and soft matter. This course will explore the properties, functions and potential applications of biomolecular condensates, including their role in neurodegenerative diseases such as Alzheimer's and Parkinson's, as well as their use as smart biomimetic materials.

This course is divided into two parts. The fist part will introduce the basic concepts essential to the study of biomolecular condensates and phase separation. Topics include: fundamental units and scales in soft matter, phase transitions in biology, biopolymers and molecular self-assembly, introduction to active matter. This will establish a foundation for the second part, which will explore milestone works and current research in the field of biomolecular condensates. Each lecture of this second part will consist of:
1) a short literature seminar, where student groups will present and discuss a milestone paper assigned in advance and
2) a research seminar, where one of the course lecturers will present their own state-of-the-art research in the field, building upon the milestone literature.
At the beginning of the course, student groups will be formed and assigned to the milestone papers. To facilitate this, students must confirm their registration by the beginning of the 3rd week of semester.

Lecture notes
Lecture slides and some scripts will be provided.

Literature
No compulsory textbooks. Literature will be provided during the course.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
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<td>assessed</td>
<td>assessed</td>
<td>fostered</td>
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<tr>
<td>Techniques and Technologies</td>
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<tr>
<td>Analytical Competencies</td>
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<td>Decision-making</td>
<td>fostere</td>
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<tr>
<td>Media and Digital Technologies</td>
<td>fostered</td>
<td>Problem-solving</td>
<td>fostered</td>
<td>fostered</td>
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<tr>
<td>Project Management</td>
<td>fostered</td>
<td>Communication</td>
<td>assessed</td>
<td>fostered</td>
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<tr>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
<td>Leadership and Responsibility</td>
<td>assessed</td>
<td>fostered</td>
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<tr>
<td>Customer Orientation</td>
<td>fostered</td>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
<td>assessed</td>
<td>fostered</td>
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<tr>
<td>Negotiation</td>
<td>assessed</td>
<td>Integity and Work Ethics</td>
<td>assessed</td>
<td>fostered</td>
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<tr>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<tr>
<td>Creative Thinking</td>
<td>assessed</td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
<td>fostered</td>
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<tr>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
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752-2314-00L  

Physics of Food Colloids  
W 3 credits 2V  P. A. Fischer, R. Mezzenga, M. Radioni

Abstract
In Physics of Food Colloids the principles of colloid science will applied to the aggregation of food materials based on proteins, polysaccharides, and emulsifiers. Mixtures of such raw material determine the appearance and performance of our daily food. In a number of examples, colloidal laws are linked to food science and the manufacturing and processing of food.

Objective
The aggregation of food material determines the appearance and performance of complex food system as well as nutritional aspects. The underlying colloidal laws reflect the structure of the individual raw material (length scale, time scale, and interacting forces). Once these concepts are appreciated the aggregation of most food systems falls into recognizable patterns that can be used to modify and structure exiting food or to design new products. The application and use of these concepts are discussed in light of common food production.

Content
Lectures include interfacial tension (4h), protein aggregation in bulk and interfaces (4h), Pickering emulsions (2h), gels (2h), aggregation of complex mixtures (4h), and the use of light scattering in investigation complex food structures (8h). Most chapters include some hand-ons examples of the gain knowledge to common food products.

Lecture notes
Notes will be handed out during the lectures.

Literature
Provided in the lecture notes.

Research Project (only for Programme Regulations 2023)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>327-1210-10L</td>
<td>Research Project</td>
<td>O</td>
<td>12</td>
<td>23A</td>
<td>Professors</td>
</tr>
</tbody>
</table>

Abstract
Independent scientific practice of 8 weeks which is completed with a written report.

Objective
Projects, with themes from the chosen scientific fields of interest, are intended to familiarise candidates with scientific procedures and operational methodologies through supervised participation in current research work.

Industrial Internship (only for Programme Regulations 2023)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>327-2001-00L</td>
<td>Industrial Internship</td>
<td>O</td>
<td>12</td>
<td></td>
<td>external organisers</td>
</tr>
</tbody>
</table>

Abstract
12 weeks of industrial internship which is completed with a written report.

Objective
The main objective of the 12-week internship is to expose students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.
### Projects (only for Programme Regulations 2012)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>327-1210-00L</td>
<td>Project I</td>
<td>O</td>
<td>12 credits</td>
<td>23A</td>
<td>Professors</td>
</tr>
<tr>
<td></td>
<td>Only for Materials Science MSc, Programme Regulations 2012</td>
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<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Independent scientific practice of 8 weeks which is completed with a written report.</td>
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<tr>
<td>Objective</td>
<td>Projects, with themes from the chosen scientific fields of interest, are intended to familiarise candidates with scientific procedures and operational methodologies through supervised participation in current research work.</td>
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<tr>
<td>327-1211-00L</td>
<td>Project II</td>
<td>O</td>
<td>12 credits</td>
<td>23A</td>
<td>Professors</td>
</tr>
<tr>
<td></td>
<td>Only for Materials Science MSc, Programme Regulations 2012</td>
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</tr>
<tr>
<td>Abstract</td>
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<tr>
<td>Objective</td>
<td>Projects, with themes from the chosen scientific fields of interest, are intended to familiarise candidates with scientific procedures and operational methodologies through supervised participation in current research work.</td>
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</table>

### Master's Thesis

<table>
<thead>
<tr>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>327-9000-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Supervisors</td>
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<tr>
<td></td>
<td>Only students who fulfill the following criteria are allowed to begin with their master thesis: a. successful completion of the bachelor programme; b. fulfilling of any additional requirements necessary to gain admission to the master programme.</td>
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<tr>
<td>Abstract</td>
<td>Independent scientific work of current topics in the field of materials science. Duration 6 months. The work is documented in a written form.</td>
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<tr>
<td>Objective</td>
<td>Master thesis is a six month fulltime project and will encourage the students to work independently and in a structured and scientific way. It is guided by a professor of the Department of Materials.</td>
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</tbody>
</table>

### Science in Perspective

- see Science in Perspective: Language Courses ETH/UZH
- see Science in Perspective: Type A: Enhancement of Reflection Capability
- Recommended Science in Perspective (Type B) for D-MATL

### Materials Science Master - Key for Type

<table>
<thead>
<tr>
<th>W+</th>
<th>Eligible for credits and recommended</th>
<th>Z</th>
<th>Courses outside the curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
<td>O</td>
<td>Compulsory</td>
</tr>
</tbody>
</table>

### Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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</tbody>
</table>

### ECTS

- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
### Mathematics (General Courses)

#### Generally Accessible Seminars and Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-5000-00L</td>
<td>Zurich Colloquium in Mathematics</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>A. Bandeira, S. Mishra, R. Pandharipande, University lecturers</td>
</tr>
<tr>
<td>401-5960-00L</td>
<td>Colloquium on Mathematics, Computer Science, and Education Subject didactics for mathematics and computer science teachers.</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>N. Hungerbühler, M. Akveld, D. Grawehr Morath, D. Komm, P. Spindler</td>
</tr>
</tbody>
</table>

**Abstract**

Didactics colloquium

#### Actuary SAA Education at ETH Zurich

Further pieces of information are available at Prof. M. Wüthrich's secretariat, HG F 42.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-3925-00L</td>
<td>Non-Life Insurance: Mathematics and Statistics Does not take place this semester.</td>
<td>W</td>
<td>8</td>
<td>4V+1U</td>
<td>M. V. Wüthrich</td>
</tr>
</tbody>
</table>

**Abstract**

The lecture aims at providing a basis in non-life insurance mathematics which forms a core subject of actuarial science. It discusses collective risk modeling, individual claim size modeling, approximations for compound distributions, ruin theory, premium calculation principles, tariffication with generalized linear models and neural networks, credibility theory, claims reserving and solvency.

**Objective**

The student is familiar with the basics in non-life insurance mathematics and statistics. This includes the basic mathematical models for insurance liability modeling, pricing concepts, stochastic claims reserving models and ruin and solvency considerations.

**Content**

- Collective Risk Modeling
- Claim Counts Models
- Individual Claim Size Modeling
- Censoring and Truncation
- Approximations for Compound Distributions
- Ruin Theory in Discrete Time
- Premium Calculation Principles
- Tarification
- Generalized Linear Models and Neural Networks
- Bayesian Models and Credibility Theory
- Claims Reserving
- Solvency Considerations

**Lecture notes**

M.V. Wüthrich, Non-Life Insurance: Mathematics & Statistics
http://ssrn.com/abstract=2319328

**Literature**

M.V. Wüthrich, M. Merz. Statistical Foundations of Actuarial Learning and its Applications

**Prerequisites / notice**

The exams ONLY take place during the official ETH examination period (no semester end exams), and only in person exams (i.e. no remote exams).

This course will be held in English and counts towards the diploma of “Aktuar SAV”. For the latter, see details under www.actuaries.ch.

**Prerequisites:** knowledge of probability theory, statistics and applied stochastic processes.

**Competencies**

Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies

- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-3922-00L</td>
<td>Life Insurance Mathematics</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>M. Koller</td>
</tr>
</tbody>
</table>

**Abstract**

The classical life insurance model is presented together with the important insurance types (insurance on one and two lives, term and endowment insurance and disability). Besides that the most important terms such as mathematical reserves are introduced and calculated. The profit and loss account and the balance sheet of a life insurance company is explained and illustrated.

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<thead>
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<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>401-3929-00L</td>
<td>Financial Risk Management in Social and Pension Insurance</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>P. Blum</td>
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</table>

**Abstract**

Investment returns are an important source of funding for social and pension insurance, and financial risk is an important threat to stability. We study short-term and long-term financial risk and its interplay with other risk factors, and we develop methods for the measurement and management of financial risk and return in an asset/liability context with the goal of assuring sustainable funding.
Objective

Understand the basic asset-liability framework: essential principles and properties of social and pension insurance; cash flow matching, duration matching, valuation portfolio and loose coupling; the notion of financial risk; long-term vs. short-term risk; coherent measures of risk.

Understand the conditions for sustainable funding: derivation of required returns; interplay between return levels, contribution levels and other parameters; influence of guaranteed benefits.

Understand the notion of risk-taking capability: capital process as a random walk; measures of long-term risk and relation to capital; short-term solvency vs. long-term stability; effect of embedded options and guarantees; interplay between required return and risk-taking capability.

Be able to study empirical properties of financial assets: the Normal hypothesis and the deviations from it; statistical tools for investigating relevant risk and return properties of financial assets; time aggregation properties; be able to conduct analysis of real data for the most important asset classes.

Understand and be able to carry out portfolio construction: the concept of diversification; limitations to diversification; correlation breakdown; incorporation of constraints; sensitivities and shortcomings of optimized portfolios.

Understand and interpret the asset-liability interplay: the optimized portfolio in the asset-liability framework; short-term risk vs. long-term risk; the influence of constraints; feasible and non-feasible solutions; practical considerations.

Understand and be able to address essential problems in asset / liability management, e.g. optimal risk / return positioning, optimal discount rate, target value for funding ratio or turnaround issues.

Content

For pension insurance and other forms of social insurance, investment returns are an important source of funding. In order to earn these returns, substantial financial risks must be taken, and these risks represent an important threat to financial stability, in the long term and in the short term.

Risk and return of financial assets cannot be separated from one another and, hence, asset management and risk management cannot be separated either. Managing financial risk in social and pension insurance is, therefore, the task of reconciling the contradictory dimensions of

1. Required return for a sustainable funding of the institution,
2. Risk-taking capability of the institution,
3. Returns available from financial assets in the market,
4. Risks incurred by investing in these assets.

This task must be accomplished under a number of constraints. Financial risk management in social insurance also means reconciling the long time horizon of the promised insurance benefits with the short time horizon of financial markets and financial risk.

It is not the goal of this lecture to provide the students with any cookbook recipes that can readily be applied without further reflection. The goal is rather to enable the students to develop their own understanding of the problems and possible solutions associated with the management of financial risks in social and pension insurance.

To this end, a rigorous intellectual framework will be developed and a powerful set of mathematical tools from the fields of actuarial mathematics and quantitative risk management will be applied. When analyzing the properties of financial assets, an empirical viewpoint will be taken using statistical tools and considering real-world data.

Solid base knowledge of probability and statistics is indispensable. Specialized concepts from financial and insurance mathematics as well as quantitative risk management will be introduced in the lecture as needed, but some prior knowledge in some of these areas would be an advantage.

This course counts towards the diploma of "Aktuar SAV".

The exams ONLY take place during the official ETH examination period.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Subject-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td>3. Returns available from financial assets in the market</td>
<td>Decision-making</td>
<td>fostered</td>
</tr>
<tr>
<td>4. Risks incurred by investing in these assets</td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
</tr>
<tr>
<td>Customer Orientation</td>
<td>fostered</td>
<td></td>
</tr>
<tr>
<td>Leadership and Responsibility</td>
<td>fostered</td>
<td></td>
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<tr>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Creative Thinking</td>
<td>fostered</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
</tr>
</tbody>
</table>

401-3927-00L Mathematical Modelling in Life Insurance

W 4 credits 2V T. J. Peter

Abstract

In life insurance, it is essential to have adequate mortality rates, be it for reserving or pricing purposes. The course provides the classical tools necessary to create mortality tables from scratch as well as modern machine learning approaches to forecast mortality rates. It also covers the basics of survival analysis.

Objective

The course's objective is to provide the students with the understanding and the tools to create mortality tables on their own. Additionally, students should learn the basics of survival analysis.
Following main topics are covered:
- Determining raw mortality rates
- Smoothing techniques
- Trends in mortality rates
- Integration of safety margins
- Stochastic mortality model due to Lee and Carter
- Neural network extension of the Lee-Carter model
- Machine learning for mortality forecasts
- Survival analysis

Lectures notes and slides will be provided

The course counts towards the diploma of "Aktuar SAV".

Basic knowledge in probability theory is assumed. Some knowledge in financial mathematics is useful.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.

Lecture notes
See information on course homepage

Literature

This book can also be used for the course '363-0503-00L Principles of Microeconomics' (Filippini).
Competencies | Subject-specific Competencies | Concepts and Theories | assessed
| Method-specific Competencies | Techniques and Technologies | fostered
| | Analytical Competencies | assessed
| | Decision-making | fostered
| | Media and Digital Technologies | fostered
| | Problem-solving | assessed
| | Project Management | fostered
| Social Competencies | Communication | fostered
| | Cooperation and Teamwork | fostered
| | Customer Orientation | fostered
| | Leadership and Responsibility | fostered
| | Self-presentation and Social Influence | assessed
| | Sensitivity to Diversity | fostered
| | Negotiation | fostered
| Personal Competencies | Adaptability and Flexibility | fostered
| | Creative Thinking | fostered
| | Critical Thinking | assessed
| | Integrity and Work Ethics | fostered
| | Self-awareness and Self-reflection | fostered
| | Self-direction and Self-management | fostered

401-3931-00L | Responsible Machine Learning with Insurance Applications | W | 4 credits | 2G | M. Mayer, C. Lorentzen-Geiser

Abstract
This lecture covers important aspects of applying supervised machine learning models in a responsible way, based on sound statistical theory. The focus is on model interpretability, calibration (bias) assessment, and proper model comparison. The methods are illustrated with actuarial datasets.

Objective
The student is familiar with the main tools of model interpretability, calibration assessment, and model comparison and knows how to apply supervised machine learning in a responsible way.

Content
- Overview of supervised machine learning (statistical learning theory, GLMs, tree based methods, and neural nets; cross-validation)
- Model interpretability methods (partial dependence plots, measures of variable importance, and SHAP)
- Bias/calibration assessment with identification functions
- Model comparison with consistent scoring functions
- Working with dependent observations and further topics

Prerequisites / notice
This course will be held in English and counts towards the diploma of "Aktuar SAV". For the latter, see details under www.actuaries.ch.

Prerequisites: Good knowledge in statistics/probability theory, statistical modelling and Python (or R) programming are assumed.

Competencies

| Subject-specific Competencies | Concepts and Theories | assessed
| Techniques and Technologies | fostered
| Method-specific Competencies | Analytical Competencies | assessed

363-1017-00L | Risk and Insurance Economics | W | 3 credits | 2G | H. Schernberg

Abstract
The course covers the economics of risk and insurance, in particular the following topics will be discussed:
2) individual decision making under risk
3) models of insurance demand, risk sharing, insurance supply
4) information issues in insurance markets
5) advanced topics in microeconomics and behavioral economics
5) the macroeconomic role of insurers and insurance regulation

Objective
The course introduces students to basic microeconomic models of risk attitudes and highlight the role insurance can – or cannot – play for individuals facing risks.

Content
In the first part of this lecture, we discuss a normative decision concept, Expected Utility theory, and compare it with empirically observed behaviour.

Students then learn about the rationale for individuals to purchase insurance, and for companies to offer it. We derive the optimal level of insurance demand and discuss how it depends on our model's underlying assumptions.

We then discuss the consequences of information asymmetries in insurance markets and the consequences for insurance supply.

Finally, we discuss refinements in decision theory that help account for observed behaviours that don't fit with the basic models of microeconomic theory. For example, we'll explore how behavioural economics can be leveraged by the insurance industry.

Main literature:
- Handbook of the Economics of Risk and Uncertainty, Volume1;

Further readings:

Competencies

| Subject-specific Competencies | Concepts and Theories | assessed
| Method-specific Competencies | Analytical Competencies | assessed
| Problem-solving | assessed
| Personal Competencies | Critical Thinking | assessed
| Self-direction and Self-management | fostered
### Mathematics (General Courses) - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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### Key for Hours

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<tr>
<td>V</td>
<td>lecture</td>
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<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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### ECTS

- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
# First Year Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>401-1261-07L</td>
<td>Analysis I: One Variable</td>
<td>O</td>
<td>10 credits</td>
<td>6V+3U</td>
<td>L. Kobel-Keller</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to the differential and integral calculus in one real variable: fundamentals of mathematical thinking, numbers, sequences, basic point set topology, continuity, differentiable functions, ordinary differential equations, Riemann integration.

**Objective**
The ability to work with the basics of calculus in a mathematically rigorous way.

**Literature**
- J. Amann, J. Escher: Analysis I
  https://link.springer.com/book/10.1007/978-3-7643-7756-4
- J. Appell: Analysis in Beispielen und Gegenbeispielen
- R. Courant: Vorlesungen über Differential- und Integralrechnung
- O. Forster: Analysis 1
- H. Heuser: Lehrbuch der Analysis
- K. Königsberger: Analysis 1
  https://link.springer.com/book/10.1007/978-3-642-18490-1
- W. Walter: Analysis 1
  https://link.springer.com/book/10.1007/978-3-540-35078-0
- V. Zorich: Mathematical Analysis I (englisch)
- A. Beutelspacher: "Das ist o.B.d.A. trivial"
- H. Schichl, R. Steinbauer: Einführung in das mathematische Arbeiten

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<td>402-1701-00L</td>
<td>Physics I</td>
<td>O</td>
<td>7 credits</td>
<td>4V+2U</td>
<td>K. Ensslin</td>
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</table>

**Abstract**
This course gives a first introduction to Physics with an emphasis on classical mechanics.

**Objective**
Acquire knowledge of the basic principles regarding the physics of classical mechanics. Skills in solving physics problems.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>252-0847-00L</td>
<td>Computer Science</td>
<td>O</td>
<td>5 credits</td>
<td>2V+2U</td>
<td>M. Fischer, F. Friedrich Wicker</td>
</tr>
</tbody>
</table>

**Abstract**
The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.

**Objective**
Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens "behind the scenes" when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.

**Content**
The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.

**Lecture notes**
Lecture slides and all other material will be made available for download on the course web page.

**Literature**
- Bjarne Stroustrup: Einführung in die Programmierung mit C++, Pearson Studium, 2010
- Andrew Koenig and Barbara E. Moo: Accelerated C++, Addison-Wesley, 2000

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Techniques and Theories</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Media and Digital Technologies</th>
<th>Problem-solving</th>
<th>Communication</th>
<th>Cooperation and Teamwork</th>
<th>Creative Thinking</th>
<th>Critical Thinking</th>
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Bachelor Studies (Programme Regulations 2021)

Compulsory Courses

Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>401-2303-00L</td>
<td>Complex Analysis</td>
<td>O</td>
<td>6</td>
<td>3V+2U</td>
<td>Ö. Imamoglu</td>
</tr>
<tr>
<td>Abstract</td>
<td>Complex functions of one variable, Cauchy-Riemann equations, Cauchy theorem and integral formula, singularities, residue theorem, index of closed curves, analytic continuation, special functions, conformal mappings, Riemann mapping theorem.</td>
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<tr>
<td>Objective</td>
<td>Working knowledge of functions of one complex variable; in particular applications of the residue theorem.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-2003-00L</td>
<td>Algebra I</td>
<td>O</td>
<td>7</td>
<td>3V+2U</td>
<td>L. Halbeisen</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction and development of some basic algebraic structures - groups, rings, fields. Introduction to basic notions and results of group, ring and field theory.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Group Theory: basic notions and examples of groups, subgroups, factor groups, homomorphisms, group actions, Sylow theorems, applications Ring Theory: basic notions and examples of rings, ring homomorphisms, ideals Field Theory: basic notions and examples of fields and field extensions, applications</td>
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<td></td>
</tr>
<tr>
<td>Content</td>
<td>Concepts and Theories</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies Method-specific Competencies Personal Competencies</td>
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<tr>
<td>Competencies</td>
<td>Concepts and Theories Analytical Competencies Creative Thinking</td>
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<td>assessed assessed fostered</td>
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<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-2653-21L</td>
<td>Numerical Analysis I</td>
<td>O</td>
<td>7</td>
<td>3V+2U</td>
<td>C. Schwab</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course will give an introduction to mathematical analysis of numerical methods, aimed at mathematics majors. It covers numerical linear algebra, quadrature, interpolation and approximation methods as well as their error analysis and implementation. Knowledge of the fundamental numerical methods, their mathematical foundation as well as 'numerical literacy': application of numerical methods for the solution of application problems, mathematical foundations of numerical methods, and basic mathematical methods of the analysis of stability, consistency and convergence of numerical methods, MATLAB implementation. Rounding errors, direct solution of linear systems of equations, iterative solution of systems of nonlinear equations, interpolation and approximation (polynomial as well as trigonometric), least squares problems, extrapolation, numerical quadrature, elementary optimization methods, fast Fourier transformation.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Knowledge of the fundamental numerical methods, their mathematical foundation as well as 'numerical literacy': application of numerical methods for the solution of application problems, mathematical foundations of numerical methods, and basic mathematical methods of the analysis of stability, consistency and convergence of numerical methods, MATLAB implementation.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Lecture Notes and reading list will be available. Lecture Notes (german or english) will be made available to registered students of ETH BSc MATH.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Quarteroni, Sacco and Saleri, Numerische Mathematik 1 + 2, Springer Verlag 2002 (in German).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Literature</td>
<td>There is an English version of this text, containing both German volumes, from the same publisher. If you feel more comfortable with English, you can follow this text as well. Content and Indexing are identical in the German and the English text.</td>
<td></td>
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</tr>
</tbody>
</table>
Admission Requirements:
Completed courses and passed written exams
Linear Algebra I, Analysis I in ETH BSc MATH
Linear Algebra II, Analysis II in ETH BSc MATH
Weekly homework assignments involving MATLAB programming
are an integral part of the course.
Turn-in of solutions will be graded.

## Competencies

### Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

### Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

### Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

### Problem-solving
- Assessed

### Project Management
- Fostered

## Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-2283-00L</td>
<td>Analysis III (Measure Theory)</td>
<td>O</td>
<td>6</td>
<td>3V+2U</td>
<td>F. Da Lio</td>
</tr>
</tbody>
</table>

Abstract
Measure and integration theory, including: Caratheodory's theorem, Lebesgue measure, Radon measure, Hausdorff measure, convergence theorems, L^p spaces, Radon-Nikodym theorem, product measure and Fubini's theorem

Objective
Basics of abstract measure and integration theory

Content
- Measure Spaces (Lebesgue Measure, Hausdorff Measure, Radon Measure)
- Measurable Functions: definition and properties
- Integration: definition, properties, theorems of convergence, Lebesgue L^p spaces
- Product Measures and Multiple Integrals. Fubini and Tonelli Theorems, Convolutions
- Differentiation of measures (if time permits)

Lecture notes
Die Vorlesung folgt dem Skript von der Dozentin
(https://people.math.ethz.ch/~fdalio/Measuremainfile.pdf)

Literature
1. Lecture notes by Professor Michael Struwe (http://www.math.ethz.ch/~struwe/Skripten/AnalysisIII-SS2007-18-4-08.pdf)
2. L. Evans and R.F. Gariepy "Measure theory and fine properties of functions"
3. Walter Rudin "Real and complex analysis"
4. R. Bartle The elements of Integration and Lebesgue Measure

Prerequisites / notice
Analysis 1 & 2 und basic notions of topology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-2883-00L</td>
<td>Physics III</td>
<td>W</td>
<td>7</td>
<td>4V+2U</td>
<td>S. Johnson</td>
</tr>
</tbody>
</table>

Abstract
Introductory course on quantum and atomic physics including optics and statistical physics.

Objective
A basic introduction to quantum and atomic physics, including basics of optics and equilibrium statistical physics. The course will focus on the relation of these topics to experimental methods and observations.

Content
- Einführung in die Quantenphysik: Planck'sche Strahlung (Wärmestrahlung), Photonen, Photoelektrischer Effekt, Thomson und Rutherford Streuung, Compton Streuung, Bohrsche Atommodell, de-Broglie Materiewellen.
- Optik-Wellenoptik: Linsen, Abbildungssysteme, Brechung und Fermatsches Prinzip, Beugung, Interferenz, Fabry-Perot, Interferometer, Spektrometer.
- Quantenmechanik: Dualismus Teilchen-Welle, Wellenfunktionen, Operatoren, Schrödinger-Gleichung, Potentialstufe und Potentialkasten, harmonischer Oszillator
Im Rahmen der Veranstaltung werden die Folien in elektronischer Form zur Verfügung gestellt. Ergänzendes Buch wird als Pflichtlektüre empfohlen. Es wird kein Skript in der Vorlesung verteilt.

Wir werden die Quantenmechanik anhand der Schrödinger-Gleichung mit den klassischen elektro-magnetischen Wellen vergleichen. Zu den klassischen Wellen werden Ergänzungsunterlagen verteilt.

402-2203-01L Classical Mechanics
- **Objective**: A conceptual introduction to theoretical physics: Newtonian mechanics, central force problem, oscillations, Lagrangian mechanics, symmetries and conservation laws, Hamiltonian mechanics, canonical transformations, Hamilton-Jacobi equation, spinning top, relativistic space-time structure.
- **Competencies**:
  - Subject-specific Competencies: Concepts and Theories
  - Method-specific Competencies: Analytical Competencies
- **Competencies**:
  - Subject-specific Competencies: Sensitivity to scale
  - Method-specific Competencies: Analytical Competencies
- **Literature**:

Further reading:

More exercises and examples in:
6. A. Asteroth, Ch. Baier: Theoretische Informatik

**Method-specific Competencies**
- Design of algorithms for hard problems
- Complexity theory and NP-completeness
- Turing machines and computability
- Finite automata, regular and context-free grammars
- Complexity theory and NP-completeness
- Design of algorithms for hard problems

252-0057-00L Theoretical Computer Science
- **Objective**: Learning the basic concepts of computer science along their historical development
- **Content**: This lecture gives an introduction to theoretical computer science, presenting the basic concepts and methods of computer science in its historical context. We present computer science as an interdisciplinary science which, on the one hand, investigates the border between the possible and the impossible and the quantitative laws of information processing, and, on the other hand, designs, analyzes, verifies, and implements computer systems.

The main topics of the lecture are:
- Alphabets, words, languages, measuring the information content of words, representation of algorithmic tasks
- Finite automata, regular and context-free grammars
- Turing machines and computability
- Complexity theory and NP-completeness
- Design of algorithms for hard problems

**Lecture notes**
The lecture is covered in detail by the textbook "Theoretical Computer Science".

**Literature**

Further reading:

More exercises and examples in:
6. A. Asteroth, Ch. Baier: Theoretische Informatik

**Prerequisites / notice**
During the semester, two non-obligatory test exams will be offered.

227-0045-00L Signals and Systems I
- **Content**: Introduction to mathematical signal processing and system theory.

**Lecture notes**
Lecture notes, problem set with solutions.

**Bachelor Studies (Programme Regulations 2016)**

**Minor Courses**

**402-0351-00L Astronomy**
- **Objective**: An overview of important topics in modern astronomy: planets, sun, stars, milky way, galaxies, and cosmology
- **Content**: Planeten, Sonne, Sterne, Milchstrasse, Galaxien und Kosmologie.

**ECTS**
2 credits

**Type**
W

**Number of Credits**
2

**Lecturers**
A. M. Glauer
Lecture notes
Kopien der Präsentationen werden zur Verfügung gestellt.

Literature
Der Neue Kosmos. A. Unsöld, B. Baschek, Springer

Oder sonstige Grundlehrbücher zur Astronomie.

(Core Courses (ONLY for Programme Regulations 2016))

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0057-00L</td>
<td>Theoretical Computer Science</td>
<td>W</td>
<td>7</td>
<td>4V+2U</td>
<td>D. Komm, H.-J. Böckenhauer, J. Hromkovic</td>
</tr>
</tbody>
</table>

Abstract
Concepts to cope with: a) what can be accomplished in a fully automated fashion (algorithmically solvable) b) How to measure the inherent difficulty of tasks (problems) c) What is randomness and how can it be useful? d) What is nondeterminism and what role does it play in CS? e) How to represent infinite objects by finite automata and grammars?

Objective
Learning the basic concepts of computer science along their historical development

Content
This lecture gives an introduction to theoretical computer science, presenting the basic concepts and methods of computer science in its historical context. We present computer science as an interdisciplinary science which, on the one hand, investigates the border between the possible and the impossible and the quantitative laws of information processing, and, on the other hand, designs, analyzes, verifies, and implements computer systems.

The main topics of the lecture are:
- alphabets, words, languages, measuring the information content of words, representation of algorithmic tasks
- finite automata, regular and context-free grammars
- Turing machines and computability
- complexity theory and NP-completeness
- design of algorithms for hard problems

Lecture notes
The lecture is covered in detail by the textbook "Theoretical Computer Science".

Literature
Basic literature:

Further reading:
5. I. Wegener; Theoretische Informatik. Teubner.

More exercises and examples in:
6. A. Asteroth, Ch. Baier: Theoretische Informatik

Prerequisites /
During the semester, two non-obligatory test exams will be offered.

(Core Courses: Pure Mathematics)

(Core Courses: Pure Mathematics)

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
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<tbody>
<tr>
<td>401-3531-00L</td>
<td>Differential Geometry I</td>
<td>W</td>
<td>9</td>
<td>4V+1U</td>
<td>U. Lang</td>
</tr>
</tbody>
</table>

Abstract
Introduction to differential manifolds and differential geometry.

Introduce the language, tools, and basic results of differentiable manifolds, tensors, Riemannian geometry, and related geometric structures. Relate geometric intuition to formulas involving curvature, derivatives and tensors.

Objective
Learn to compute, describe, prove, and solve problems in the language of differential geometry.

Content
Submanifolds of \( \mathbb{R}^n \), immersions, submersions, and embeddings. Sard's Theorem, abstract differentiable manifolds, charts, vector fields and flows, vector bundles, tensor fields, covariant derivatives, parallel transport, Riemannian metrics, geodesics, Riemann curvature tensor. Complete manifolds, Hopf-Rinow theorem. Many examples including curves, surfaces, hyperbolic space, \( S^3 \), the unit quaternions, the Gauss-Bonnet theorem, etc.

Literature
John M. Lee: Introduction to Smooth Manifolds
John M. Lee: Introduction to Riemannian Manifolds

This following books were inherited from before. The only one I know is DoCarmo.
- Manfredo P. do Carmo: Differential Geometry of Curves and Surfaces
- S. Montiel, A. Ros: Curves and Surfaces
- S. Kobayashi: Differential Geometry of Curves and Surfaces
- Wolfgang Kühnel: Differentialgeometrie. Kurven-Flächen-Mannigfaltigkeiten
- Dennis Barden & Charles Thomas: An Introduction to Differential Manifolds
Core Courses: Pure Mathematics (Mathematics Master)

401-3461-00L  Functional Analysis I
At most one of the three course units (Bachelor Core Courses)
401-3461-00L Functional Analysis I
401-3531-00L Differential Geometry I
401-3601-00L Probability Theory
can be recognised for the Master's degree in Mathematics
or Applied Mathematics. In this case, you cannot change
the category assignment by yourself in myStudies but
must take contact with the Study Administration Office
(www.math.ethz.ch/studiensekretariat) after having
received the credits.

W 9 credits 4V+1U M. Burger

Abstract
Baire category; Banach and Hilbert spaces, bounded linear operators; basic principles: Uniform boundedness, open mapping/closed graph
theorem, Hahn-Banach; convexity; dual spaces; weak and weak* topologies; Banach-Alaoglu; reflexive spaces; compact operators and

Objective
Acquire a good degree of fluency with the fundamental concepts and tools belonging to the realm of linear Functional Analysis, with special
emphasis on the geometric structure of Banach and Hilbert spaces, and on the basic properties of linear maps.

Literature
Recommended references include the following:
Elias M. Stein and Rami Shakarchi: "Functional analysis" (volume 4 of Princeton Lectures in Analysis). Princeton University Press,

Prerequisites / notice
Solid background on the content of all Mathematics courses of the first two years of the undergraduate curriculum at ETH. Most importantly:

Competencies
Subject-specific Competencies Concepts and Theories assessed
Method-specific Competencies Analytical Competencies assessed
Social Competencies Sensitivity to Diversity assessed
Personal Competencies Creative Thinking assessed
Analytical Competencies assessed
Problem-solving assessed
Critical Thinking assessed

401-3001-61L  Algebraic Topology I
Abstract
This is an introductory course in algebraic topology, which is the study of algebraic invariants of topological spaces. Topics covered
include:
singular homology, cell complexes and cellular homology, the Eilenberg-Steenrod axioms.

W 7 credits 4G P. Biran

Literature
Book can be downloaded for free at:
http://www.math.cornell.edu/~hatcher/AT/ATpage.html
See also:
http://www.math.cornell.edu/~hatcher/#anchor1772800
3) E. Spanier, "Algebraic topology", Springer-Verlag
You should know the basics of point-set topology.
Useful to have (though not absolutely necessary) basic knowledge of the fundamental group and covering spaces (at the level covered in
the course "topology").
Some knowledge of differential geometry and differential topology is useful but not strictly necessary.
Some (elementary) group theory and algebra will also be needed.

Prerequisites / notice

Competencies
Subject-specific Competencies Concepts and Theories assessed
Method-specific Competencies Analytical Competencies assessed
Personal Competencies Creative Thinking assessed

401-3132-00L  Commutative Algebra
Abstract
This course provides an introduction to commutative algebra. It serves in particular as a foundation for modern algebraic geometry.

W 9 credits 4V+1U C. Urech

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1855 of 2653
Objective
The topics presented in the course will include:
* Basics facts about rings, ideals, and modules
* Constructions of rings: quotients, polynomial rings, localization
* The prime spectrum of a ring
* Chain conditions, Noetherian/Artinian rings and modules
* The tensor product of modules over commutative rings
* SOME homological algebra
* Integral extensions, going up, going down
* Finitely generated algebras over fields, including the Noether Normalization Theorem and the Nullstellensatz
* Discrete valuation rings and some applications
* Dimension theory

Literature
Primary Reference:
"Introduction to Commutative Algebra" by M. F. Atiyah and I. G. Macdonald (Addison-Wesley Publ., 1969)

Secondary References:

Prerequisites / notice
Prerequisites: Algebra I/II (or a similar introduction to the basic concepts of ring theory, including field theory).

Competencies
Subject-specific Competencies

Techniques and Technologies
assessed

Concepts and Theories
assessed

Abstract
This course will give an introduction to various aspects of number theory, both algebraic and analytic.

Objective
The course will present some representative results in important directions of number theory. Students who attend the lecture will acquire a solid background in all aspects of modern number theory, both towards algebraic and analytic directions. They will also learn how to use software such as Pari/GP for experiments in number theory.

Content
The course will present some representative results in the following directions, each of which belongs to an important area of number theory:

1. congruences, including the law of Quadratic Reciprocity
2. diophantine approximation (Dirichlet’s Theorem, continued fractions)
3. sums of two and four squares
4. elementary algebraic number theory
5. examples of Diophantine equations
6. the Prime Number Theorem
7. Dirichlet characters and primes in arithmetic progressions
8. Arithmetic functions and their statistical properties

The lecture will emphasize the connections between the topics and their links to current research. Moreover, computer experiments using Pari/GP and other software will be part of the lecture.

Lecture notes
The lecturer’s notes will be scanned and available.

Literature
J-P. Serre, "A course in arithmetic"
Ireland and Rosen, "A classical introduction to modern number theory"
Hardy and Wright, "An introduction to the theory of numbers"

Prerequisites / notice
Integration theory

Competencies
Subject-specific Competencies

Techniques and Technologies
assessed

Concepts and Theories
assessed

Method-specific Competencies

Problem-solving
fostered

Personal Competencies

Creative Thinking
fostered

Core Courses: Applied Mathematics and Further Appl.-Oriented Fields

<table>
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<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>401-3651-00L</td>
<td>Numerical Methods for Elliptic and Parabolic Partial Differential Equations</td>
<td>W</td>
<td>9</td>
<td>4V+1U</td>
<td>J. Nick</td>
</tr>
</tbody>
</table>

Abstract
This course gives a comprehensive introduction into the numerical treatment of linear and nonlinear elliptic boundary value problems, related eigenvalue problems and linear, parabolic evolution problems. Emphasis is on theory and the foundations of numerical methods. Practical exercises include MATLAB implementations of finite element methods.

Objective
Participants of the course should become familiar with
* concepts underlying the discretization of elliptic and parabolic boundary value problems
* analytical techniques for investigating the convergence of numerical methods for the approximate solution of boundary value problems
* methods for the efficient solution of discrete boundary value problems
* implementational aspects of the finite element method
The course will address the mathematical analysis of numerical solution methods for linear and nonlinear elliptic and parabolic partial differential equations. Functional analytic and algebraic (De Rham complex) tools will be provided. Primal, mixed and nonstandard (discontinuous Galerkin, Virtual, Trefftz) discretizations will be analyzed. Particular attention will be placed on developing mathematical foundations (Regularity, Approximation theory) for a-priori convergence rate analysis. A-posteriori error analysis and mathematical proofs of adaptivity and optimality will be covered. Implementations for model problems in MATLAB and Python will illustrate the theory.

A selection of the following topics will be covered:

- Elliptic boundary value problems
- Galerkin discretization of linear variational problems
- The primal finite element method
- Mixed finite element methods
- Discontinuous Galerkin Methods
- Boundary element methods
- Spectral methods
- Adaptive finite element schemes
- Singularly perturbed problems
- Sparse grids
- Galerkin discretization of elliptic eigenproblems
- Non-linear elliptic boundary value problems
- Discretization of parabolic initial boundary value problems

**Content**

The course will address the mathematical analysis of numerical solution methods for linear and nonlinear elliptic and parabolic partial differential equations. Functional analytic and algebraic (De Rham complex) tools will be provided. Primal, mixed and nonstandard (discontinuous Galerkin, Virtual, Trefftz) discretizations will be analyzed. Particular attention will be placed on developing mathematical foundations (Regularity, Approximation theory) for a-priori convergence rate analysis. A-posteriori error analysis and mathematical proofs of adaptivity and optimality will be covered. Implementations for model problems in MATLAB and Python will illustrate the theory.

A selection of the following topics will be covered:

- Elliptic boundary value problems
- Galerkin discretization of linear variational problems
- The primal finite element method
- Mixed finite element methods
- Discontinuous Galerkin Methods
- Boundary element methods
- Spectral methods
- Adaptive finite element schemes
- Singularly perturbed problems
- Sparse grids
- Galerkin discretization of elliptic eigenproblems
- Non-linear elliptic boundary value problems
- Discretization of parabolic initial boundary value problems

**Literature**


Additional Literature:


(Also available in German.)


**Abstract**

Basics of probability theory and the theory of stochastic processes in discrete time

**Objective**

This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- Measure theory formalism and probability theory,
- Dynkin's lemma and independence, convergence of series of independent random variables, law of large numbers,
- conditional expectation, martingale convergence theorems, uniform integrability, optional stopping theorem for martingales,
- the Bienaymé-Galton-Watson process and its R-number, convergence in distribution and the central limit theorem.

**Content**

This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- Measure theory formalism and probability theory,
- Dynkin's lemma and independence, convergence of series of independent random variables, law of large numbers,
- conditional expectation, martingale convergence theorems, uniform integrability, optional stopping theorem for martingales,
- the Bienaymé-Galton-Watson process and its R-number, convergence in distribution and the central limit theorem.

**Lecture notes**

will be available in electronic form.

**Literature**


H. Bauer, Probability Theory, de Gruyter 1996

J. Jacod and P. Protter, Probability essentials, Springer 2004

A. Klenke, Wahrscheinlichkeitstheorie, Springer 2006

D. Williams, Probability with martingales, Cambridge University Press 1991

**Prerequisites / notice**

- Measure Theory
- Basic notions in probability theory (probability space, conditional probability, Borel Cantelli, Dynkin Lemma, random variables, expectation, variance, law of large numbers).
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Content
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Literature

Prerequisites / notice
Solid background in linear algebra.

401-3621-00L Fundamentals of Mathematical Statistics

Abstract
In this course we study the basics of theoretical statistics. The course includes methods for designing estimators, confidence intervals and tests, and various ways to evaluate the accuracy of estimators, confidence intervals and tests. We consider optimality criteria such as admissibility and minimaxity, as well as Bayesian criteria. We will also present the asymptotic point of view.

Objective
The aim of this course is to gain insight into the main statistical ideas and concepts. The course considers classical low-dimensional models, with pointers towards today's highly complex models.

401-3901-00L Linear & Combinatorial Optimization

Abstract
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

Objective
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Literature
Abstract


Applications: simple potentials in wave mechanics, scattering and resonance, harmonic oscillator, hydrogen atom, and perturbation theory.

Objective

Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems.

Content

The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradox and Bell's inequality); Perturbation theory.

Lecture notes

Auf Moodle

Literature

G. Baym, Lectures on Quantum Mechanics
E. Merzbacher, Quantum Mechanics
L.I. Schiff, Quantum Mechanics
R. Feynman and A.R. Hibbs, Quantum Mechanics and Path Integrals
J.J. Sakurai: Modern Quantum Mechanics
A. Messiah: Quantum Mechanics I
S. Weinberg: Lectures on Quantum Mechanics

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies fostered

Method-specific Competencies

Analytical Competencies assessed

Decision-making fostered

Media and Digital Technologies fostered

Problem-solving assessed

Project Management fostered

Social Competencies

Communication fostered

Cooperation and Teamwork fostered

Customer Orientation fostered

Leadership and Responsibility fostered

Self-presentation and Social Influence fostered

Sensitivity to Diversity fostered

Negotiation fostered

Personal Competencies

Adaptability and Flexibility fostered

Creative Thinking assessed

Critical Thinking fostered

Integrity and Work Ethics fostered

Self-awareness and Self-reflection fostered

Self-direction and Self-management fostered

Electives

Selection: Algebra, Number Thy, Topology, Discrete Mathematics, Logic

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>401-3059-00L</td>
<td>Combinatorics II</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>N. Hungerbühler</td>
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<tr>
<td></td>
<td>Does not take place this semester.</td>
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</tbody>
</table>

Abstract

The course Combinatorics I and II is an introduction into the field of enumerative combinatorics.

Objective

Upon completion of the course, students are able to classify combinatorial problems and to apply adequate techniques to solve them.

Content

Contents of the lectures Combinatorics I and II: congruence transformation of the plane, symmetry groups of geometric figures, Euler's function, Cayley graphs, formal power series, permutation groups, cycles, Bunsides' lemma, cycle index, Polya's theorems, applications to graph theory and isomers.

Selection: Geometry

<table>
<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>401-3057-00L</td>
<td>Finite Geometries II</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>N. Hungerbühler</td>
</tr>
</tbody>
</table>

Abstract

Finite geometries I, II: Finite geometries combine aspects of geometry, discrete mathematics and the algebra of finite fields. In particular, we will construct models of axioms of incidence and investigate closing theorems. Applications include test design in statistics, block design, and the construction of orthogonal Latin squares.

Objective

Finite geometries I, II: Students will be able to construct and analyse models of finite geometries. They are familiar with closing theorems of the axioms of incidence and are able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design.

Content

Finite geometries I, II: finite fields, rings of polynomials, finite affine planes, axioms of incidence, Euler's thirty-six officers problem, design of statistical tests, orthogonal Latin squares, transformation of finite planes, closing theorems of Desargues and Pappus-Pascal, hierarchy of closing theorems, finite coordinate planes, division rings, finite projective spaces, duality principle, finite Moebius planes, error correcting codes, block design

Literature

- Max Jeger, Endliche Geometrien, ETH Skript 1988
- Albrecht Beutelspacher: Einführung in die endliche Geometrie I,II. Bibliographisches Institut 1983
- Margaret Lynn Batten: Combinatorics of Finite Geometries. Cambridge University Press
- Dembowski: Finite Geometries.

Selection: Analysis

Selection: Numerical Analysis

Selection: Probability Theory, Statistics

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>401-3823-74L</td>
<td>Markov Processes</td>
<td>W</td>
<td>3</td>
<td>1V</td>
<td>R. S. Gvalani</td>
</tr>
</tbody>
</table>
Abstract
This course is meant to serve as an introduction to the theory of Markov processes on finite or countable state spaces. We will discuss what a Markov process is along with associated concepts such as transition probabilities, recurrence, transience, ergodicity, reversibility etc. We will motivate various abstract notions introduced with concrete examples from physics and statistics.

Objective
I. Discrete-time Markov processes, i.e. Markov chains, e.g. the random walk on the integers
II. Transition probabilities and Doeblin's theorem
III. Stationary probabilities and ergodic properties
IV. Continuous-time Markov processes, e.g. the Poisson process
V. Reversibility

Literature
An Introduction to Markov Processes: Daniel W. Stroock

Prerequisites / Competencies

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Analytical Competencies
Problem-solving
Creative Thinking
Critical Thinking

Literature
High-Dimensional Statistics

Content
This course is meant to serve as an introduction to the theory of Markov processes on finite or countable state spaces. We will discuss what a Markov process is along with associated concepts such as transition probabilities, recurrence, transience, ergodicity, reversibility etc. We will motivate various abstract notions introduced with concrete examples from physics and statistics.

Objective
I. Discrete-time Markov processes, i.e. Markov chains, e.g. the random walk on the integers
II. Transition probabilities and Doeblin's theorem
III. Stationary probabilities and ergodic properties
IV. Continuous-time Markov processes, e.g. the Poisson process
V. Reversibility

Literature
An Introduction to Markov Processes: Daniel W. Stroock

Prerequisites / Competencies

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Analytical Competencies
Problem-solving
Creative Thinking
Critical Thinking

401-3627-00L High-Dimensional Statistics

W 4 credits 2V not available

Abstract
"High-Dimensional Statistics" deals with modern methods and theory for statistical inference when the number of unknown parameters is of much larger order than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed.

Objective
Knowledge of methods and basic theory for high-dimensional statistical inference

Content
Lasso and Group Lasso for high-dimensional linear and generalized linear models; Additive models and many smooth univariate functions; Non-convex loss functions and l1-regularization; Stability selection, multiple testing and construction of p-values; Undirected graphical modeling

Literature

Prerequisites / Competencies
Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).

401-4623-00L Time Series Analysis

W 4 credits 2G F. Balabdaoui

Abstract
The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Processes, ARIMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

Objective
The goal of the course is to have a good overview of the different types of time series and the approaches used in their statistical analysis.

Content
This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exhibited by time series is the dependence between successive observations.

The key topics which will be covered as:
Stationarity
Autocorrelation
Trend estimation
Elimination of seasonality
Spectral analysis, spectral densities
Forecasting
ARIMA, ARIMA, Introduction into GARCH models

Literature
The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis

Prerequisites / Competencies
Basic knowledge in probability and statistics

401-0625-01L Applied Analysis of Variance and Experimental Design

W 5 credits 2V+1U L. Meier

Abstract
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial and fractional designs, power.

Objective
Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Content
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial and fractional designs, power.

Literature

Prerequisites / Competencies
Basic knowledge in probability and statistics

401-0649-00L Applied Statistical Regression

W 5 credits 2V+1U M. Dettling

Abstract
This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

Objective
The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

Lectures will be held in English. A script will be available.

### Competencies

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<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<tr>
<td>Personal Competencies</td>
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<td>Self-awareness and Self-reflection</td>
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<tr>
<td>fostered</td>
<td>Self-direction and Self-management</td>
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### Literature

- Faraway (2005): Linear Models with R
- Faraway (2006): Extending the Linear Model with R
- Draper & Smith (1998): Applied Regression Analysis
- Fox (2008): Applied Regression Analysis and GLMs
- Montgomery et al. (2006): Introduction to Linear Regression Analysis

### Prerequisites / notice

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

### Selection: Financial and Insurance Mathematics

In the Bachelor's programme in Mathematics 401-3913-01L Mathematical Foundations for Finance is eligible as an elective course, but only if 401-3888-00L Introduction to Mathematical Finance isn’t recognised for credits (neither in the Bachelor's nor in the Master's programme). For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tr>
<td>401-3922-00L</td>
<td>Life Insurance Mathematics</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>M. Koller</td>
</tr>
<tr>
<td>Abstract</td>
<td>The classical life insurance model is presented together with the important insurance types (insurance on one and two lives, term and endowment insurance and disability). Besides that the most important terms such as mathematical reserves are introduced and calculated. The profit and loss account and the balance sheet of a life insurance company is explained and illustrated.</td>
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| 401-3925-00L | Non-Life Insurance: Mathematics and Statistics | W    | 8    | 4V+1U | M. V. Wüthrich |
| Abstract     | The lecture aims at providing a basis in non-life insurance mathematics which forms a core subject of actuarial science. It discusses collective risk modeling, individual claim size modeling, approximations for compound distributions, ruin theory, premium calculation principles, tariffication with generalized linear models and neural networks, credibility theory, claims reserving and solvency. |
| Objective    | The student is familiar with the basics in non-life insurance mathematics and statistics. This includes the basic mathematical models for insurance liability modeling, pricing concepts, stochastic claims reserving models and ruin and solvency considerations. |
The following topics are treated:
Collective Risk Modeling
Claim Counts Models
Individual Claim Size Modeling
Censoring and Truncation
Approximations for Compound Distributions
Ruin Theory in Discrete Time
Premium Calculation Principles
Tarification
Generalized Linear Models and Neural Networks
Bayesian Models and Credibility Theory
Claims Reserving
Solvency Considerations

Lecture notes
M.V. Wüthrich, Non-Life Insurance: Mathematics & Statistics
http://ssrn.com/abstract=2319328

Literature
M.V. Wüthrich, M. Merz. Statistical Foundations of Actuarial Learning and its Applications

Prerequisites / notice
The exams ONLY take place during the official ETH examination period (no semester end exams), and only in person exams (i.e. no remote exams).

This course will be held in English and counts towards the diploma of “Aktuar SAV”. For the latter, see details under www.actuaries.ch.

Prerequisites: knowledge of probability theory, statistics and applied stochastic processes.

Competencies
Subject-specific Competencies
Concepts and Theories
Methods and Technologies
Analytical Competencies
Decision-making
Data and Digital Technologies
Problem-solving
Project Management

Method-specific Competencies
Concepts and Theories
Techniques and Technologies
Analytical Competencies
Decision-making
Digital Technologies
Problem-solving
Project Management

401-3927-00L Mathematical Modelling in Life Insurance W 4 credits 2V T. J. Peter
Abstract
In life insurance, it is essential to have adequate mortality rates, be it for reserving or pricing purposes. The course provides the classical tools necessary to create mortality tables from scratch as well as modern machine learning approaches to forecast mortality rates. It also covers the basics of survival analysis.

Objective
The course's objective is to provide the students with the understanding and the tools to create mortality tables on their own. Additionally, students should learn the basics of survival analysis.

Content
Following main topics are covered:
- Determining raw mortality rates
- Smoothing techniques
- Trends in mortality rates
- Integration of safety margins
- Stochastic mortality model due to Lee and Carter
- Neural network extension of the Lee-Carter model
- Machine learning for mortality forecasts
- Survival analysis

Lecture notes
Lectures notes and slides will be provided

Prerequisites / notice
The exams ONLY take place during the official ETH examination period.

The course counts towards the diploma of “Aktuar SAV”.

Basic knowledge in probability theory is assumed. Some knowledge in financial mathematics is useful.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Analytical Competencies
Decision-making
Digital Technologies
Problem-solving
Project Management

Method-specific Competencies
Concepts and Theories
Techniques and Technologies
Analytical Competencies
Problem-solving
Project Management

401-3931-00L Responsible Machine Learning with Insurance Applications W 4 credits 2G M. Mayer, C. Lorentzen-Geiser
Abstract
This lecture covers important aspects of applying supervised machine learning models in a responsible way, based on sound statistical theory. The focus is on model interpretability, calibration (bias) assessment, and proper model comparison. The methods are illustrated with actuarial datasets.

Objective
The student is familiar with the main tools of model interpretability, calibration assessment, and model comparison and knows how to apply supervised machine learning in a responsible way.

Content
- Overview of supervised machine learning (statistical learning theory, GLMs, tree based methods, and neural nets; cross-validation)
- Model interpretability methods (partial dependence plots, measures of variable importance, and SHAP)
- Bias/calibration assessment with identification functions
- Model comparison with consistent scoring functions
- Working with dependent observations and further topics

Prerequisites / notice
This course will be held in English and counts towards the diploma of “Aktuar SAV”. For the latter, see details under www.actuaries.ch.

Prerequisites: Good knowledge in statistics/probability theory, statistical modelling and Python (or R) programming are assumed.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Analytical Competencies
Problem-solving
Project Management

Method-specific Competencies
Concepts and Theories
Techniques and Technologies
Analytical Competencies
Problem-solving
Project Management

Selection: Mathematical Physics, Theoretical Physics

Number Title Type ECTS Hours Lecturers
402-0830-00L General Relativity W 10 credits 4V+2U R. Renner
Abstract
Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations of the theory as well as the underlying physical principles and concepts. It covers selected applications, such as the Schwarzschild solution and gravitational waves.
Objective
Basic understanding of general relativity, its mathematical foundations (in particular the relevant aspects of differential geometry), and some of the phenomena it predicts (with a focus on black holes).

Content
Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations, such as differentiable manifolds, the Riemannian and Lorentzian metric, connections, and curvature. It discusses the underlying physical principles, e.g., the equivalence principle, and concepts, such as curved spacetime and the energy-momentum tensor. The course covers some basic applications and special cases, including the Newtonian limit, post-Newtonian expansions, the Schwarzschild solution, light deflection, and gravitational waves.

Literature
Suggested textbooks:
C. Misner, K. Thorne and J. Wheeler: Gravitation
S. Carroll - Spacetime and Geometry: An Introduction to General Relativity
R. Wald - General Relativity
S. Weinberg - Gravitation and Cosmology

402-0822-13L
Introduction to Integrability

W 6 credits 2V+1U  N. Beisert

Abstract
This course gives an introduction to the theory of integrable systems, related symmetry algebras and efficient calculational methods.

Objective
Integrable systems are a special class of physical models that can be solved exactly due to an exceptionally large number of symmetries. Examples of integrable models appear in many different areas of physics including classical mechanics, condensed matter, 2d quantum field theories and lately in string- and gauge theories. They offer a unique opportunity to gain a deeper understanding of generic phenomena in a simplified, exactly solvable setting. In this course we introduce the notion and formulation of integrability in classical and quantum mechanics. We discuss various efficient methods for constructing solutions and eigenstates in these models. Finally, we elaborate on the enhanced symmetries that underly integrable models.

Content
- Classical Integrability
- Algebraic Methods for Integrability
- Classical Spin Chains
- Spectral Curves and Inverse Scattering
- Quantum Spin Chains
- Bethe Ansatz
- Classical and Quantum Algebra

Literature

Competencies
Subject-specific Competencies
Concepts and Theories
Method-specific Competencies
Analytical Competencies
Problem-solving
Social Competencies
Sensitivity to Diversity
Personal Competencies
Adaptability and Flexibility
Critical Thinking

Selection: Mathematical Optimization, Discrete Mathematics

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<tr>
<th>Number</th>
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<td>401-3055-64L</td>
<td>Algebraic Methods in Combinatorics</td>
<td>W</td>
<td>5 credits</td>
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Abstract
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

Objective
The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

Content
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments. Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lecture notes
Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Prerequisites / notice
Students are expected to have a mathematical background and should be able to write rigorous proofs.

401-3054-14L
Probabilistic Methods in Combinatorics

W 5 credits 2V+1U  B. Sudakov

Abstract
This course provides a gentle introduction to the Probabilistic Method, with an emphasis on methodology. We will try to illustrate the main ideas by showing the application of probabilistic reasoning to various combinatorial problems.

Content
The topics covered in the class will include (but are not limited to): linearity of expectation, the second moment method, the local lemma, correlation inequalities, martingales, large deviation inequalities, Janson and Talagrand inequalities and pseudo-randomness.
Selection: Theoretical Computer Science

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
252-1425-00L | Geometry: Combinatorics and Algorithms | W | 8 credits | 3V+2U+2A | B. Gärtner, M. Hoffmann, P. Schnider

Abstract: Geometric structures are useful in many areas, and there is a need to understand their structural properties, and to work with them algorithmically. The lecture addresses theoretical foundations concerning geometric structures. Central objects of interest are triangulations. We study combinatorial (Does a certain object exist?) and algorithmic questions (Can we find a certain object efficiently?).

Objective: The goal is to make students familiar with fundamental concepts, techniques and results in combinatorial and computational geometry, so as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains.

Content: Planar and geometric graphs, embeddings and their representation (Whitney's Theorem, canonical orderings, DCEL), polygon triangulations and the art gallery theorem, convexity in Rd, planar convex hull algorithms (Jarvis Wrap, Graham Scan, Chan's Algorithm), point set triangulations, Delaunay triangulations (Lawson flips, lifting map, randomized incremental construction), Voronoi diagrams, the Crossing Lemma and incidence bounds, line arrangements (duality, Zone Theorem, ham-sandwich cuts), 3-SUM hardness, counting planar triangulations.

Lecture notes: https://people.inf.ethz.ch/~aroysko/AA23

Prerequisites / notice: This course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH.

Literature:

Selection: Further Realms and Some UZH Courses

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
401-3502-72L | Reading Course | W | 2 credits | 4A | Supervisors

Abstract: For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

401-3503-72L | Reading Course | W | 3 credits | 6A | Supervisors

Abstract: For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

401-3504-72L | Reading Course | W | 4 credits | 9A | Supervisors

Abstract: For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

253-4511-00L | Projects in Topological Data Analysis | W | 4 credits | 3G | P. Schnider

Literature:
- Graph Coloring and the Probabilistic Method, by M. Molloy and B. Reed, Springer, 2002.
Each student is expected to collaborate in an international working group with students from the partner universities. Each group works on one of the projects suggested by the lecturers, and is assigned a mentor. At the end of the semester, each working group presents their findings in a written report and an oral presentation.

This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning algorithms. The knowledge is then applied in independent project work to understand and follow-up on recent theoretical ML results.

Students should have a very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as "Introduction to Machine Learning", "Regression", "Statistical Modelling". In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

The project work focuses on current theoretical ML research that aims to understand modern phenomena in machine learning, including but not limited to:
- how overparameterized models generalize (statistically) and converge (computationally)
- complexity measures and approximation theoretic properties of randomly initialized and trained neural networks
- generalization of robust learning (adversarial or distribution-shift robustness)
- private and fair learning

Prerequisites / notice
Successful participation in the course "Introduction to Topological Data Analysis" or equivalent background in topological data analysis is required.

This seminar complements the course "Introduction to Topological Data Analysis". Students get to apply what they learned in the introductory course to concrete projects in the area of topological data analysis. These projects can be of theoretical nature, e.g., the design and analysis of a new algorithm, or applied, such as using methods from topological data analysis on concrete data sets.

### Core Courses and Electives (Mathematics Master)

#### Core Courses (Mathematics Master)

#### Electives (Mathematics Master)

### Electives (only conditionally recognised)

In the Bachelor's programme in Mathematics 401-3913-01L Mathematical Foundations for Finance is eligible as an elective course, but only if 401-3888-00L Introduction to Mathematical Finance isn't recognised for credits (neither in the Bachelor's nor in the Master's programme). For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.
**Content**
The content includes (tentative):
- General guidelines for writing math papers, structure, format etc.
- Mathematical Language
- Ethics
- Good and bad examples
- Technical aspects (LaTeX, how to look up and format citations etc.)
- Possibly a component contributed by the ETH language center on language and presentation skills.
- Exercises or small practical assignments

**401-3913-01L Mathematical Foundations for Finance**

**W 4 credits 3V+2U D. Possamaï**

**Abstract**
First introduction to main modelling ideas and mathematical tools from mathematical finance

**Objective**
This course gives a first introduction to the main modelling ideas and mathematical tools from mathematical finance. It mainly aims at non-mathematicians who need an introduction to the main tools from stochastics used in mathematical finance. However, mathematicians who want to learn some basic modelling ideas and concepts for quantitative finance (before continuing with a more advanced course) may also find this of interest. The main emphasis will be on ideas, but important results will be given with (sometimes partial) proofs.

**Content**
Topics to be covered include
- financial market models in finite discrete time
- absence of arbitrage and martingale measures
- valuation and hedging in complete markets
- basics about Brownian motion
- stochastic integration
- stochastic calculus: Itô's formula, Girsanov transformation, Itô's representation theorem
- Black-Scholes formula

**Lecture notes**
See information on course homepage

**Prerequisites / notice**
Prerequisites: Results and facts from probability theory as in the book "Probability Essentials" by J. Jacod and P. Protter will be used freely. Especially participants without a direct mathematics background are strongly advised to familiarise themselves with those tools before (or very quickly during) the course. (A possible alternative to the above English textbook are the (German) lecture notes for the standard course "Wahrscheinlichkeitsrechnung").

For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.

**Competencies**

- Subject-specific Competencies: Concepts and Theories (assessed)
- Subject-specific Competencies: Techniques and Technologies (fostered)
- Method-specific Competencies: Analytical Competencies (assessed)
- Method-specific Competencies: Decision-making (fostered)
- Method-specific Competencies: Problem-solving (assessed)
- Personal Competencies: Adaptable and Flexible (fostered)
- Personal Competencies: Creative Thinking (fostered)
- Personal Competencies: Critical Thinking (fostered)
- Personal Competencies: Integrity and Work Ethics (fostered)

**Seminars**

**NOTICE:** The number of seminar places is limited, and the special selection procedure should help to allocate the places not primarily according to the registration time. Everybody is waitlisted first when he/she tries to register for such a seminar in myStudies.

Moreover: Only one mathematics seminar can be chosen per semester.

**Notice** also the course unit 401-0002-99L Generic Seminar - Second Priority / Third Priority.

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---
401-0002-99L | Generic Seminar - Second Priority / Third Priority | E- | 0 credits | not available |
401-3620-74L | Student Seminar in Statistics: ... | W | 4 credits | 2S | Y. Chen |
401-3050-72L | Student Seminar in Combinatorics | W | 4 credits | 2S | B. Sudakov |
401-3140-74L | Student Seminar in Numerical Algebraic Geometry | W | 4 credits | 2S | C. Meroni |
401-3940-74L | Student Seminar in Mathematics and Data Science | W | 4 credits | 2S | A. Bandeira, further speakers |

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Port-Hamiltonian Systems: Mathematical Aspects

Number of participants limited to 12.

Abstract
The seminar covers theory and applications of port-Hamiltonian system models based on current literature. The various topics have to be presented by groups of students.

Objective
Participants of the seminar should acquire familiarity with the concept of port-Hamiltonian systems and the relevant mathematical theory for their analysis. They should be enabled to devise and understand port-Hamiltonian models of physical systems.

Content
Port-Hamiltonian provide a mathematical framework for the modeling of complex (multi-physics) systems, of their dynamical behavior, for understanding their stability and effective control. They are based on geometric structure and represent a generalization of Hamiltonian systems towards open systems. The building blocks of port-Hamiltonian systems are thought to interact by exchanging energy. So the main focus of port-Hamiltonian modeling is on accurately representing the flow, storage, and dissipation of energy.

Port-Hamiltonian models are ubiquitous nowadays, used in areas like mechanics, fluid dynamics, thermodynamics, and (electric) circuits. They play a big role in modern control theory and are a highly active field of theoretical and applied research.

This seminar will study a number of monograph chapters and research papers dealing with both theoretical and application aspects of post-Hamiltonian system models.

Topics:

Student groups will be decided and topics will be assigned during the preparatory meeting.


Good skills in linear algebra and ordinary differential equations are required

Preparatory meeting on

Every presentation has to be done jointly by a group of 2-3 students with presenters selected at random. Every participant will have to present on 2-3 occasions.


Competencies

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<thead>
<tr>
<th>Subject-specific Competencies</th>
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<tr>
<td>Media and Digital Technologies</td>
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<tr>
<td>Problem-solving</td>
<td>fostered</td>
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<td>Communication</td>
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<td>Critical Thinking</td>
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<td>Self-awareness and Self-reflection</td>
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Bachelor’s Thesis

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<td>O</td>
<td>0 credits</td>
<td></td>
<td>D. Possamaï</td>
</tr>
<tr>
<td></td>
<td>Target audience: Third year Bachelor students; Master students who cannot document to have received an adequate training in working scientifically.</td>
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</tr>
<tr>
<td></td>
<td>Introduction to scientific writing for students with focus on publication standards and ethical issues, especially in the case of citations (references to works of others.)</td>
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</tr>
<tr>
<td></td>
<td>Learn the basic standards of scientific works in mathematics.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Types of mathematical works</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Publication standards in pure and applied mathematics</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>- Data handling</td>
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<td></td>
<td>- Ethical issues</td>
<td></td>
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<tr>
<td></td>
<td>- Citation guidelines</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

401-2000-01L | Lunch Sessions – Thesis Basics for Mathematics | Z | 0 credits | | Speakers |
| | Details and registration for the optional MathBib training course: https://www.math.ethz.ch/mathbib-schulungen |
| | Optional MathBib training course |

401-3990-10L | Bachelor’s Thesis | O | 8 credits | 17D | Supervisors |
| | Successful participation in the course unit 401-2000-00L Scientific Works in Mathematics is required. |
| | For more information, see https://math.ethz.ch/intranet/students/theses.html |
| | The purpose of the BSc thesis is to deepen knowledge in a certain subject chosen by the student. In their BSc thesis, students should demonstrate their ability to carry out independent work in mathematics and to organize results in a written report. |

Science in Perspective

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-
### Additional Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-5000-00L</td>
<td>Zurich Colloquium in Mathematics</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>A. Bandeira, S. Mishra, R. Pandharipande, University lecturers</td>
</tr>
<tr>
<td>401-5990-00L</td>
<td>Zurich Graduate Colloquium</td>
<td>E-</td>
<td>0</td>
<td>0.5K</td>
<td>University lecturers, further speakers</td>
</tr>
<tr>
<td>401-5960-00L</td>
<td>Colloquium on Mathematics, Computer Science, and Education</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>N. Hungerbühler, M. Akveld, D. Grawehr Morath, D. Komm, P. Spindler</td>
</tr>
<tr>
<td>402-0100-00L</td>
<td>The Zurich Physics Colloquium</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>S. Huber, A. Refregier, University lecturers</td>
</tr>
<tr>
<td>402-0800-00L</td>
<td>The Zurich Theoretical Physics Colloquium</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>J. Renes, University lecturers</td>
</tr>
<tr>
<td>251-0100-00L</td>
<td>Computer Science Colloquium</td>
<td>E-</td>
<td>0</td>
<td>2K</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

**Abstract**

The Graduate Colloquium is an informal seminar aimed at graduate students and postdocs whose purpose is to provide a forum for communicating one's interests and thoughts in mathematics.

**Objective**

The goal of this event is to bring you closer to current day research in all fields of physics. In each semester we have a set of distinguished speakers covering the full range of topics in physics. As a participating student should learn how to follow a research talk. In particular, you should be able to extract key points from a colloquium where you don't necessarily understand every detail that is presented.

**Abstract**

The Zurich Theoretical Physics Colloquium is jointly organized by the University of Zurich and ETH Zurich. Its mission is to bring both students and faculty with diverse interests in theoretical physics together. Leading experts explain the basic questions in their field of research and communicate the fascination for their work.

**Objective**

The Zurich Theoretical Physics Colloquium is jointly organized by the University of Zurich and ETH Zurich. Its mission is to bring both students and faculty with diverse interests in theoretical physics together. Leading experts explain the basic questions in their field of research and communicate the fascination for their work.

**Content**

Renowned international computer scientists take the floor at our distinguished colloquium series, to present topics across all areas of computer science.

---

### Mathematics Bachelor - Key for Type

- **O** Compulsory
- **W+** Eligible for credits and recommended
- **W** Eligible for credits
- **E-** Recommended, not eligible for credits
- **Z** Courses outside the curriculum
- **Dr** Suitable for doctorate
- **P** practical/laboratory course
- **A** independent project
- **D** diploma thesis
- **R** revision course / private study

**ECTS** European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
### Mathematics TC

**Detailed information on the programme at:** [www.ethz.ch/didaktische-ausbildung](http://www.ethz.ch/didaktische-ausbildung)

#### Educational Science

General course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>871-0228-00L</td>
<td><strong>Formation of Knowledge in STEM Fields in Primary and Secondary School</strong> Adresses to students enrolled either in Teaching Diploma* (TD) or Teaching Certificate (TC) (excluding Teaching Diploma Sport). This course unit can only be enroled after successful participation in the course 871-0240-00L &quot;Human Learning (EW 1)&quot;</td>
<td>W</td>
<td>2 credits</td>
<td>1S</td>
<td>U. Markwalder</td>
</tr>
</tbody>
</table>

**Abstract**

Course promotes exchange between student teachers and elementary school teachers in STEM teaching with 3 parts: 1) block seminar (ca. 16 h), 2) collaboration with elementary school teacher in a class (ca. 34 h, with approx. 50% spent in the elementary or middle school class and ca. 50% for preparation), and 3) final report (ca. 10 h). Registration implies participation in all 3 parts.

**Objective**

Deepening the understanding of knowledge formation and learning processes of primary and secondary students from a cognitive and developmental psychology perspective for students. The assistant ship provides didactic experience and exposure to a different school level (more heterogeneous groups such as for example low-performing to very high-performing Children, language problems etc.).

**Content**

Students learn more about the potential and challenges of pupils. They get to know the early stages of knowledge as well as the development of pre-concepts of students in their subject area. The seminar with a phase of cooperation consists of three phases: In the block seminar, pre-concepts are discussed in their own subject as well as theoretical inputs from developmental and cognitive psychology. During the cooperation phase, a teaching task defined by the primary and secondary school teachers is actually undertaken in a class. Finally, a final report is written, which contains a description of the students' level of knowledge. This seminar is only suitable for students who can adapt flexibly to the needs of pupils from lower class levels.

**Prerequisites / notice**

https://www.minterlink.ch/student

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Leadership and Responsibility</td>
<td>assessed</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
</tr>
</tbody>
</table>

**Subject Didactics and Professional Training**

**Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.**

**Enrolment in either Mathematics Didactics I or Mathematics Didactics II (spring semester) is compulsory.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3971-11L</td>
<td><strong>Mathematics Didactics I</strong> Enrolment only possible with matriculation in Mathematics Teaching Diploma or Mathematics TC at ETH or in Mathematics Teaching Diploma at UZH.</td>
<td>W</td>
<td>4 credits</td>
<td>2G</td>
<td>A. Barth</td>
</tr>
</tbody>
</table>

**Abstract**

Students learn about and learn to use findings from empirical research into mathematical didactics and best practice, as well as theoretical approaches to teaching various topics in mathematics. Methodological suggestions are compared and draft tuition concepts discussed.

**Objective**

On the basis of their understanding of mathematics, of the knowledge acquired from research into teaching/learning and subject teaching, and also of best practice, students who have completed this course will be in a position to draft motivating learning arrangements, with cognitive appeal, which trigger and maintain learning processes. The aim here is to implement a corresponding teaching plan, so that the mathematics tuition that is given has a general-education value, on the one hand, and ensures that pupils acquire the fundamental knowledge necessary for studying at university, on the other hand.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>assumed</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>assumed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-9987-00L</td>
<td><strong>Teaching Internship Including Examination Lessons Mathematics</strong> Teaching Internship Mathematics for TC. Repetition of the Teaching Internship is excluded even if Examination Lessons are to be repeated.</td>
<td>O</td>
<td>4 credits</td>
<td>9P</td>
<td>N. Hungerbühler</td>
</tr>
</tbody>
</table>

**Abstract**

Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.

**Objective**

Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.

- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.
The objective is for the students:

- to be able to familiarize themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

Content

Thematische Schwerpunkte

Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.

Lernformen


Lecture notes

Eine kurze Anleitung zur mentorierten Arbeit in Fachdidaktik wird zur Verfügung gestellt.

Literature

Die Literatur ist themenspezifisch. Die Studierenden beschaften sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.

Mentored Work Subject Didactics Mathematics A

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-9983-00L</td>
<td>Mentored Work Subject Didactics in Mathematics for TC and Teaching Diploma</td>
<td>O</td>
<td>2</td>
<td>4A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Abstract

In their mentorized work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

Objective

The objective is for the students:

- to be able to familiarize themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

Content

Thematische Schwerpunkte

Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.

Lernformen


Lecture notes

Eine kurze Anleitung zur mentorierten Arbeit in Fachdidaktik wird zur Verfügung gestellt.

Literature

Die Literatur ist themenspezifisch. Die Studierenden beschaften sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.

Prerequisites / notice

Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.

Specialized Courses in Respective Subject with Educational Focus

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3057-00L</td>
<td>Finite Geometries II</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>N. Hungerbühler</td>
</tr>
</tbody>
</table>

Abstract

Finite geometries I, II: Finite geometries combine aspects of geometry, discrete mathematics and the algebra of finite fields. In particular, we will construct models of axioms of incidence and investigate closing theorems. Applications include test design in statistics, block design, and the construction of orthogonal Latin squares.

Objective

Finite geometries I, II: Students will be able to construct and analyse models of finite geometries. They are familiar with closing theorems of the axioms of incidence and are able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design.

Content

Finite geometries I, II: finite fields, rings of polynomials, affine planes, incidece, Euler’s thirty-six officers problem, design of statistical tests, orthogonal Latin squares, transformation of finite planes, closing theorems of Desargues and Pappus-Pascal, hierarchy of closing theorems, finite coordinate planes, division rings, finite projective planes, duality principle, finite Möbius planes, error correcting codes, block design

Literature

- Max Jeger, Endliche Geometrien, ETH Skript 1988
- Albrecht Beutelspacher: Einführung in die endliche Geometrie I,II. Bibliographisches Institut 1983
- Margaret Lynn Batten: Combinatorics of Finite Geometries. Cambridge University Press
- Dembowski: Finite Geometries.

401-3059-00L | Combinatorics II | W    | 4    | 2G    | N. Hungerbühler |

Abstract

The course Combinatorics I and II is an introduction into the field of enumerative combinatorics.

Objective

Upon completion of the course, students are able to classify combinatorial problems and to apply adequate techniques to solve them.

Content

Contents of the lectures Combinatorics I and II: congruence transformation of the plane, symmetry groups of geometric figures, Euler’s function, Cayley graphs, formal power series, permutation groups, cycles, Bunsine’s lemma, cycle index, Polya’s theorems, applications to graph theory and isomers.

Literature

- Does not take place this semester.
- Albrecht Beutelspacher: Einführung in endliche Geometrie I,II.
- Bibliographisches Institut 1983
- Margaret Lynn Batten: Combinatorics of Finite Geometries. Cambridge University Press
- Dembowski: Finite Geometries.

401-0293-00L | Mathematics III | W    | 5    | 3+2U  | A. Caspar, N. Hungerbühler |

Abstract

Vertiefung der mehrdimensionalen Analyse mit Schwerpunkt in der Anwendung der partiellen Differentialgleichungen, Vertiefung der Linearen Algebra und Einführung in die Systemanalyse und Modellbildung.

Objective

- verstehen Mathematik als Sprache zur Modellbildung und als Werkzeug zur Lösung angewandter Probleme in den Naturwissenschaften.
- können anspruchsvolle Modelle analysieren, Lösungen qualitativ beschreiben oder allfällig explizit berechnen: diskret/kontinuierlich in Zeit, Ebene und Raum.
- können Beispiele und konkrete arithmetische und geometrische Situationen aus Anwendungen mit Methoden der höheren Mathematik interpretieren und bearbeiten.
Einführung Modellbildung

- SIR-Modelle: Ausbreitung von Krankheiten bei Epidemien
- Pocken-Modell: Was ist der Effekt von Impfungen?

Lineare Modelle

- Vektorräume
- Lösungsräume eines Linearen DGL-Systems
- Diagonalisierbarkeit und Normalformen
- Exponential einer Matrix

Fourier-Reihen

- Euklidische Vektorräume
- Orthogonale Projektion
- Anwendungen

Nichtlineare Modelle

- Stationäre Lösungen, Qualitative Aussagen
- Mehrdimensionale Modelle: Räuber-Beute, Lotka-Volterra

Partielle Differentialgleichungen: Vorgänge, die von Raum und Zeit anhängen

- Einführung, Repetition, Beispiele
- Fourier-Methoden: Wärmeleitung, Laplace, Wellengleichung, Filter, Computertomographie

Lecture notes

Buch: "Mathematische Modellbildung in den Life sciences", A. Caspar und N. Hungerbühler

Literature

- Buch: "Mathematische Modellbildung in den Life sciences", A. Caspar und N. Hungerbühler

Prerequisites / notice

Vorlesungen Mathematik I/II

Competencies

Subject-specific Competencies

- Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Problem-solving
- Social Competencies
  - Cooperation and Teamwork
- Personal Competencies
  - Critical Thinking

Mentored Work Specialised Courses in the Respective Subject with an Educational Focus in Mathematics for TC and Teaching Diploma

In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

Abstract

The aim is for the students to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.

- To independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.

- To try out different options for specialist further training in their profession.

Content

Thematic Schwerpunkte:

Lernformen:


Lecture notes

Eine Anleitung zur mentorierten Arbeit in FV wird zur Verfügung gestellt.

Literature

Die Literatur ist themenspezifisch. Sie muss je nach Situation selber beschafft werden oder wird zur Verfügung gestellt.

Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.
**Mathematics TC - Key for Type**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

**Key for Hours**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS** European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Mathematics Teaching Diploma

Detailed information on the programme at: www.ethz.ch/didaktische-ausbildung

▶ Educational Science

Course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

see Educational Science Teaching Diploma

▶ Subject Didactics in Mathematics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3971-11L</td>
<td>Mathematics Didactics I</td>
<td>O</td>
<td>4</td>
<td>2G</td>
<td>A. Barth</td>
</tr>
<tr>
<td></td>
<td><em>Enrolment only possible with matriculation in Mathematics</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Teaching Diploma or Mathematics TC at ETH or in Mathematics Teaching Diploma at LHZ.</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>Students learn about and learn to use findings from empirical research into mathematical didactics and best practice, as well as theoretical approaches to teaching various topics in mathematics. Methodological suggestions are compared and draft tuition concepts discussed.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>On the basis of their understanding of mathematics, of the knowledge acquired from research into teaching/learning and subject teaching, and also of best practice, students who have completed this course will be in a position to draft motivating learning arrangements, with cognitive appeal, which trigger and maintain learning processes. The aim here is to implement a corresponding teaching plan, so that the mathematics tuition that is given has a general-education value, on the one hand, and ensures that pupils acquire the fundamental knowledge necessary for studying at university, on the other hand.</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

| 401-9983-00L | Mentored Work Subject Didactics Mathematics A | O    | 2    | 4A    | Supervisors |
|             | *Mentored Work Subject Didactics in Mathematics for TC and Teaching Diploma* |      |      |       |           |
| Abstract | In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle. |      |      |       |           |
| Objective | The objective is for the students: |      |      |       |           |
|            | - to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too. |      |      |       |           |
|            | - to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use. |      |      |       |           |
| Content | Thematische Schwerpunkte |      |      |       |           |
|          | Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht. |      |      |       |           |
|          | Lernformen |      |      |       |           |
| Literature | Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt. |      |      |       |           |
| Prerequisites / notice | Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden. |      |      |       |           |

| 401-9984-00L | Mentored Work Subject Didactics Mathematics B | O    | 2    | 4A    | Supervisors |
|             | *Mentored Work Subject Didactics in Mathematics for Teaching Diploma and for students upgrading TC to Teaching Diploma.* |      |      |       |           |
| Abstract | In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle. |      |      |       |           |
| Objective | The objective is for the students: |      |      |       |           |
|            | - to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too. |      |      |       |           |
|            | - to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use. |      |      |       |           |
| Content | Thematische Schwerpunkte |      |      |       |           |
|          | Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht. |      |      |       |           |
|          | Lernformen |      |      |       |           |
| Literature | Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt. |      |      |       |           |
| Prerequisites / notice | Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden. |      |      |       |           |

▶ Professional Training in Mathematics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-9970-00L</td>
<td>Introductory Internship Mathematics</td>
<td>O</td>
<td>3</td>
<td>6P</td>
<td>N. Hungerbühler</td>
</tr>
<tr>
<td></td>
<td><em>Enrolment only possible with matriculation in Mathematics</em></td>
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</tr>
<tr>
<td></td>
<td>Teaching Diploma or Mathematics TC at ETH. It is advisable to enrol in this course not prior to the first Mathematics Didactics course and not after the second Mathematics Didactics course.</td>
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</tr>
</tbody>
</table>
Students learn about and learn to use findings from empirical research into mathematical didactics and best practice, as well as theoretical approaches to teaching mathematics. Methodological suggestions are compared and draft tuition concepts discussed.

During the introductory teaching practice, the students sit in on five lessons given by the teacher responsible for their teaching practice, and Right at the start of their training, students acquire initial experience with the observation of teaching, the establishment of concepts for teaching, and also of best practice, students who have completed this course will be in a position to draft motivating learning arrangements, with cognitive appeal, which trigger and maintain learning processes. The aim here is to implement a corresponding teaching plan, so that the mathematics tuition that is given has a general-education value, on the one hand, and ensures that pupils acquire the fundamental knowledge necessary for studying at university, on the other hand.

**Literature**

Wird von der Praktikumslehrperson bestimmt.

**Prerequisites / notice**

This course is to be chosen jointly with 401-3972-00L.

---

**401-3971-99L**

**Objective**

Right at the start of their training, students acquire initial experience with the observation of teaching, the establishment of concepts for teaching and the implementation of teaching. This early confrontation with the complexity of everything that teaching involves helps students decide whether they wish to and, indeed, ought to, continue with the training. It forms a basis for the subsequent pedagogical and subject-didactics training.

**Content**

Students learn about and learn to use findings from empirical research into mathematical didactics and best practice, as well as theoretical approaches to teaching mathematics. Methodological suggestions are compared and draft tuition concepts discussed.

**Prerequisites / notice**

Enrolment only possible with matriculation in Mathematics

Teaching Diploma or Mathematics TC at ETH.

Simultaneous enrolment in Mathematics Didactics - course 401-3971-11L - is compulsory.

**Objective**

On the basis of their understanding of mathematics, of the knowledge acquired from research into teaching/learning and subject teaching, and also of best practice, students who have completed this course will be in a position to draft motivating learning arrangements, with cognitive appeal, which trigger and maintain learning processes. The aim here is to implement a corresponding teaching plan, so that the mathematics tuition that is given has a general-education value, on the one hand, and ensures that pupils acquire the fundamental knowledge necessary for studying at university, on the other hand.

**Prerequisites / notice**

This course is to be chosen jointly with 401-3972-00L.

---

**401-3972-00L**

**Objective**

The teaching practice takes in 50 lessons: 30 are taught by the students, and the students sit in on 20 lessons. The teaching practice lasts 4-6 weeks. It gives students the opportunity to implement the contents of their specialist-subject, educational science and subject-didactics training in the classroom. Students also conduct work assignments in parallel to their teaching practice.

**Content**

The students constantly evaluate their own performance.

**Prerequisites / notice**

This course finds verbindlich am Schluss der Ausbildung, vor dem Ablegen der Prüfungslektion statt. Allfällige fachwissenschaftliche Maßgaben sind ebenfalls vor Antritt des Praktikums zu erfüllen.

---

**401-3998-00L**

**Objective**

The Didaktik-Zertifikat in their Fach under verschiedenen Blickwinkeln einzuschätzen. Sie kennen und beherrschen das unterrichtliche Handwerk. Sie können ein gegebenes Unterrichtsthema für eine Gruppe von Lernenden fachlich und didaktisch korrekt strukturieren und in einer adäquaten Lernumgebung umsetzen. Es gelingt ihnen, die Balance zwischen Anleitung und Offenheit zu finden, sodass die Lernenden sowohl über den nötigen Freiraum wie über ausreichend Orientierung verfügen, um aktiv und effektiv handeln zu können.

**Content**


**Prerequisites / notice**

Das Praktikum findet verbindlich am Schluss der Ausbildung, vor dem Ablegen der Prüfungslektion statt. Allfällige fachwissenschaftliche Maßgaben sind ebenfalls vor Antritt des Praktikums zu erfüllen.

---

**401-1999-00L**

**Objective**

This is a supplement to the Teaching Internship required to obtain a Master of Advanced Studies in Secondary and Higher Education in the corresponding subject. It is aimed at enlarging the already acquired teaching experience. Students observe 10 lessons and teach 15 lessons independently.

**Content**

This course is to be chosen jointly with 401-3972-00L.

---

**401-9991-00L**

**Objective**

In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

**Content**

The examination lesson is conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

**Prerequisites / notice**

Simultaneous enrolment in "Examination Lesson II Mathematics" (401-9991-02L) is compulsory.

---

**401-9991-00L**

**Objective**

On the basis of a specified topic, the candidate shows that they are in a position to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle.

**Content**

Analyzing the tuition they have given with regard to its strengths and weaknesses, and outline improvements.
Upon completion of the course, students are able to classify combinatorial problems and to apply adequate techniques to solve them.

On the basis of a specified topic, the candidate shows that they are in a position to interpret and perform tasks.

The course Combinatorics I and II is an introduction into the field of enumerative combinatorics. By the end of the course, students should

- understand the basic elements and definitions of combinatorics
- construct and analyse models of combinatorial structures
- be able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design
- comprehend the axioms of incidence and are able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design
- apply combinators and combinatorial problems and apply adequate techniques to solve them.

The course Mathematics III is an introduction into the field of linear algebra. By the end of the course, students should

- understand the basic elements and definitions of linear algebra
- construct and analyse models of linear algebra
- be able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design
- comprehend the axioms of incidence and are able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design
- apply combinators and combinatorial problems and apply adequate techniques to solve them.

The course Finite Geometries I, II: Finite geometries combine aspects of geometry, discrete mathematics and the algebra of finite fields. In particular, we will construct models of axioms of incidence and investigate closing theorems. Applications include test design in statistics, block design, and the construction of orthogonal Latin squares.

By the end of the course, students should

- understand the basic elements and definitions of finite geometries
- construct and analyse models of finite geometries
- be able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design
- comprehend the axioms of incidence and are able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design
- apply combinators and combinatorial problems and apply adequate techniques to solve them.

The course Combinatorics II is designed to introduce students to the field of combinatorics. By the end of the course, students should

- understand the basic elements and definitions of combinatorics
- construct and analyse models of combinatorial structures
- be able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design
- comprehend the axioms of incidence and are able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design
- apply combinators and combinatorial problems and apply adequate techniques to solve them.

The course Lineare Algebra und Einführung in die Systemanalyse und Modellbildung is designed to introduce students to the field of linear algebra and system analysis. By the end of the course, students should

- understand the basic elements and definitions of linear algebra and system analysis
- construct and analyse models of linear algebra and system analysis
- be able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design
- comprehend the axioms of incidence and are able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design
- apply combinators and combinatorial problems and apply adequate techniques to solve them.

The course Vertiefung der mehrdimensionalen Analysis mit Schwerpunkt in der Anwendung der partiellen Differentialgleichungen is designed to introduce students to the field of partial differential equations. By the end of the course, students should
Einführung Modellbildung

- SIR-Modelle: Ausbreitung von Krankheiten bei Epidemien
- Pocken-Modell: Was ist der Effekt von Impfungen?

Lineare Modelle

- Vektorräume
- Lösungsräume eines Linearen DGL-Systems
- Diagonalisierbarkeit und Normalformen
- Exponential einer Matrix

Fourier-Reihen

- Euklidische Vektorräume
- Orthogonale Projektion
- Anwendungen

Nichtlineare Modelle

- Stationäre Lösungen, Qualitative Aussagen
- Mehrdimensionale Modelle: Räuber-Beute, Lotka-Volterra

Partielle Differentialgleichungen: Vorgänge, die von Raum und Zeit anhängen

- Einführung, Repetition, Beispiele
- Fourier-Methode: Wärmeleitung, Laplace, Wellengleichung, Filter, Computertomographie

Laplace-Transformation

- Definition und Notation
- Rechenregeln
- Anwendungsbeispiele

Lecture notes

Buch: "Mathematische Modellbildung in den Life Sciences", A. Caspar und N. Hungerbühler

Literature

- Buch: "Mathematische Modellbildung in den Life Sciences", A. Caspar und N. Hungerbühler

Prerequisites / notice

Vorlesungen Mathematik I/II

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Methods and Technologies</th>
<th>Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td></td>
<td></td>
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<tr>
<td>Techniques and Technologies</td>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Method-specific Competencies</th>
<th>Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical Competencies</td>
<td></td>
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<tr>
<td>Decision-making</td>
<td></td>
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<tr>
<td>Problem-solving</td>
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<table>
<thead>
<tr>
<th>Social Competencies</th>
<th>Assessed</th>
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</thead>
<tbody>
<tr>
<td>Cooperation and Teamwork</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Personal Competencies</th>
<th>Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creative Thinking</td>
<td></td>
</tr>
<tr>
<td>Critical Thinking</td>
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</table>

401-9985-00L Mentored Work Specialised Courses in the Respective Subject with an Educational Focus Mathematics A

401-9986-00L Mentored Work Specialised Courses in the Respective Subject with an Educational Focus Mathematics B

Abstract

In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

Objective

The aim is for the students
- to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.
- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.
- To try out different options for specialist further training in their profession.

Content

Thematical Schwerpunkte:

Lernformen:

Lecture notes

Eine Anleitung zur mentorierten Arbeit in FV wird zur Verfügung gestellt.

Literature

Die Literatur ist themenspezifisch. Sie muss je nach Situation selber beschafft werden oder wird zur Verfügung gestellt.

Prerequisites / notice

Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.

401-9985-00L Mentored Work Specialised Courses in the Respective Subject with an Educational Focus Mathematics A

401-9986-00L Mentored Work Specialised Courses in the Respective Subject with an Educational Focus Mathematics B

Abstract

In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1876 of 2653
Finite geometries I, II: Finite geometries combine aspects of geometry, discrete mathematics and the algebra of finite fields. In particular, we will construct models of axioms of incidence and investigate closing theorems. Applications include test design in statistics, block design, and the construction of orthogonal Latin squares.

Upon completion of the course, students are able to classify combinatorial problems and to apply adequate techniques to solve them.

The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.

The students develop the understanding of fundamental scientific concepts such as algorithm, program, complexity, determinism, computation, automata, verification, testing, security of a cryptosystem and secure communication. They reflect on ways to embed them into a scientifically sound and didactically sustainable mathematics course.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support. They encourage the autonomy of the learners, manage to work with diverse target groups and to establish a positive learning environment.

The students are able to try out different options for specialist further training in their profession.

The aim is for the students to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.

The students are able to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.

The students have to try out different options for specialist further training in their profession.

The general goal of the course consists in presenting ways to teach fundamentals of computer science, which are closely related to the axioms of incidence and are able to design statistical tests by using the theory of finite geometries. They are able to construct codes, block design, and the construction of orthogonal Latin squares.

In a semester exercise, the students develop and document an adaptive teaching unit for computer science. They learn to employ the didactics methods and techniques that are introduced at the beginning of the semester.

The students are familiar with the axioms of incidence and are able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design.

The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.
Literature

J. Hromkovic et al.: Lehrwerksreihe "Grundlagen der Informatik für Schweizer Maturitätsschulen"
Lehrwerksreihe "Einfach Informatik"
https://einfachinformatik.inf.ethz.ch/


see Compulsory Elective Courses Teaching Diploma

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-5960-00L</td>
<td>Colloquium on Mathematics, Computer Science, and Education</td>
<td>E-</td>
<td>0 credits</td>
<td></td>
<td>N. Hungerbühler, M. Akveld, D. Grawehr Morath, D. Komm, P. Spindler</td>
</tr>
</tbody>
</table>

Abstract
Didactics colloquium

Mathematics Teaching Diploma - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

Key for Hours

<table>
<thead>
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<th>Type</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Core Courses: Pure Mathematics

### 401-3001-61L Algebraic Topology I

**Title:** Algebraic Topology I  
**Type:** W  
**ECTS:** 7 credits  
**Hours:** 4G  
**Lecturers:** P. Biran

**Abstract:** This is an introductory course in algebraic topology, which is the study of algebraic invariants of topological spaces. Topics covered include: singular homology, cell complexes and cellular homology, the Eilenberg-Steenrod axioms.

**Literature:**

Book can be downloaded for free at: [http://www.math.cornell.edu/~hatcher/AT/ATpage.html](http://www.math.cornell.edu/~hatcher/AT/ATpage.html)

**Prerequisites / notice:**
You should know the basics of point-set topology.

Useful to have (though not absolutely necessary) basic knowledge of the fundamental group and covering spaces (at the level covered in the course "topology").

Some knowledge of differential geometry and differential topology is useful but not strictly necessary.

Some (elementary) group theory and algebra will also be needed.

### 401-3132-00L Commutative Algebra

**Title:** Commutative Algebra  
**Type:** W  
**ECTS:** 9 credits  
**Hours:** 4V+1U  
**Lecturers:** C. Urech

**Abstract:** This course provides an introduction to commutative algebra. It serves in particular as a foundation for modern algebraic geometry.

**Objective:** The topics presented in the course will include:
- Basics facts about rings, ideals, and modules
- Constructions of rings: quotients, polynomial rings, localization
- The prime spectrum of a ring
- Chain conditions, Noetherian/Artinian rings and modules
- The tensor product of modules over commutative rings
- Some homological algebra
- Integral extensions, going up, going down
- Finitely generated algebras over fields, including the Noether Normalization Theorem and the Nullstellensatz
- Discrete valuation rings and some applications
- Dimension theory

**Literature:**
Primary Reference: "Introduction to Commutative Algebra" by M. F. Atiyah and I. G. Macdonald (Addison-Wesley Publ., 1969)

Secondary References:

**Prerequisites / notice:**
Prerequisites: Algebra I/II (or a similar introduction to the basic concepts of ring theory, including field theory).

**Competencies:** Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

**401-3111-72L Number Theory I**

**Title:** Number Theory I  
**Type:** W  
**ECTS:** 7 credits  
**Hours:** 4G  
**Lecturers:** E. Kowalski

**Abstract:** This course will give an introduction to various aspects of number theory, both algebraic and analytic.

**Objective:** The course will present some representative results in important directions of number theory. Students who attend the lecture will acquire a solid background in all aspects of modern number theory, both towards algebraic and analytic directions. They will also learn how to use software such as Pari/GP for experiments in number theory.

**Content:** The course will present some representative results in the following directions, each of which belongs to an important area of number theory:

1. congruences, including the law of Quadratic Reciprocity
2. diophantine approximation (Dirichlet’s Theorem, continued fractions)
3. sums of two and four squares
4. elementary algebraic number theory
5. examples of Diophantine equations
6. the Prime Number Theorem
7. Dirichlet characters and primes in arithmetic progressions
8. Arithmetic functions and their statistical properties

The lecture will emphasize the connections between the topics and their links to current research. Moreover, computer experiments using Pari/GP and other software will be part of the lecture.

**Lecture notes:** The lecturer’s notes will be scanned and available.

**Literature:**
J-P. Serre, "A course in arithmetic"
Ireland and Rosen, "A classical introduction to modern number theory"
Hardy and Wright, "An introduction to the theory of numbers"
Prerequisites / notice
Algebra I and II (Rings, Fields, Galois theory)
Analysis I and II
Integration theory
Complex analysis

Competencies

Subject-specific Competencies
Concepts and Theories
assessed
Techniques and Technologies
Analytical Competencies
assessed
Problem-solving
Method-specific Competencies
Creative Thinking
assessed
Personal Competencies
fostered

401-3226-00L Symmetric Spaces W 7 credits 4G A. Iozzi
Abstract
* Generalities on symmetric spaces: locally and globally symmetric spaces, groups of isometries, examples
* Symmetric spaces of non-compact type: flats and rank, roots and root spaces
* Iwasawa decomposition, Weyl group, Cartan decomposition
* Geometry at infinity

Objective
Learn the basics of symmetric spaces

Core Courses: Applied Mathematics and Further Appl.-Oriented Fields

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3651-00L</td>
<td>Numerical Methods for Elliptic and Parabolic Partial Differential Equations</td>
<td>W</td>
<td>9 credits</td>
<td>4V+1U</td>
<td>J. Nick</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course gives a comprehensive introduction into the numerical treatment of linear and nonlinear elliptic boundary value problems, related eigenvalue problems and linear, parabolic evolution problems. Emphasis is on theory and the foundations of numerical methods. Practical exercises include MATLAB implementations of finite element methods.</td>
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<tr>
<td>Objective</td>
<td>Participants of the course should become familiar with:</td>
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<tr>
<td></td>
<td>* concepts underlying the discretization of elliptic and parabolic boundary value problems</td>
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<td></td>
<td>* analytical techniques for investigating the convergence of numerical methods for the approximate solution of boundary value problems</td>
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<tr>
<td></td>
<td>* methods for the efficient solution of discrete boundary value problems</td>
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<tr>
<td></td>
<td>* implementation aspects of the finite element method</td>
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<tr>
<td>Content</td>
<td>The course will address the mathematical analysis of numerical solution methods for linear and nonlinear elliptic and parabolic partial differential equations. Functional analytic and algebraic (De Rham complex) tools will be provided. Primal, mixed and nonstandard (discontinuous Galerkin, Virtual, Trefftz) discretizations will be analyzed.</td>
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<td>Particular attention will be placed on developing mathematical foundations (Regularity, Approximation theory) for a-priori convergence rate analysis. A-posteriori error analysis and mathematical proofs of adaptivity and optimality will be covered. Implementations for model problems in MATLAB and python will illustrate the theory.</td>
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<td>A selection of the following topics will be covered:</td>
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<td>* Elliptic boundary value problems</td>
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<td>* Galerkin discretization of linear variational problems</td>
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<td>* The primal finite element method</td>
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<td>* Mixed finite element methods</td>
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<td>* Discontinuous Galerkin Methods</td>
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<td>* Boundary element methods</td>
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<td>* Spectral methods</td>
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<td>* Adaptive finite element schemes</td>
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<td>* Singularly perturbed problems</td>
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<td>* Sparse grids</td>
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<td>* Galerkin discretization of elliptic eigenproblems</td>
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<td></td>
<td>* Non-linear elliptic boundary value problems</td>
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<td></td>
<td>* Discretization of parabolic initial boundary value problems</td>
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<td>Additional Literature:</td>
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<tr>
<td></td>
<td>D. Braess: Finite Elements, THIRD Ed., Cambridge Univ. Press, (2007). (Also available in German.)</td>
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</tbody>
</table>

401-3621-00L Fundamentals of Mathematical Statistics W 9 credits 4V+1U J. Ziegel
Abstract
In this course we study the basics of theoretical statistics. The course includes methods for designing estimators, confidence intervals and tests, and various ways to evaluate the accuracy of estimators, confidence intervals and tests. We consider optimality criteria such as admissibility and minimaxity, as well as Bayesian criteria. We will also present the asymptotic point of view.
The aim of this course is to gain insight into the main statistical ideas and concepts. The course considers classical low-dimensional models, with pointers towards today's highly complex models.

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Problem-solving: assessed

**Personal Competencies**
- Creative Thinking: assessed

**401-3622-00L Statistical Modelling**

**W 7 credits 4G M. Kalisch**

**Abstract**
In regression, the dependency of a random response variable on other variables is examined. We consider the theory of linear regression with one or more covariates, high-dimensional linear models, nonlinear models and generalized linear models, robust methods, model choice and nonparametric models. Several numerical examples will illustrate the theory.

**Objective**
Introduction into theory and practice of a broad and popular area of statistics, from a modern viewpoint.

**Content**
In der Regression wird die Abhängigkeit einer beobachteten quantitativen Größe von einer oder mehreren anderen (unter Berücksichtigung zufälliger Fehler) untersucht. Themen der Vorlesung sind: Einfache und multiple Regression, Theorie allgemeiner linearer Modelle, Hoch-dimensionalen Modelle, Ausblick auf nichtlineare Modelle, Querverbindungen zur Varianzanalyse, Modellsuche, Residuenanalyse; Einblicke in Robuste Regression, Durchrechnung und Diskussion von Anwendungsbeispielen.

**Prerequisites / notice**
This is the course unit with former course title "Regression". Credits cannot be recognised for both courses 401-3622-00L Statistical Modelling and 401-0649-00L Applied Statistical Regression in the Mathematics Bachelor and Master programmes (to be precise: one course in the Bachelor and the other course in the Master is also forbidden).

**401-4889-00L Mathematical Finance**

**W 10 credits 4V+2U B. Acciaio**

**Abstract**
Advanced course on mathematical finance:
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- additional topics

**Objective**
Advanced course on mathematical finance, presupposing good knowledge in probability theory and stochastic calculus (for continuous processes).

**Content**
This is an advanced course on mathematical finance for students with a good background in probability. We want to give an overview of main concepts, questions and approaches, and we do this mostly in continuous-time models.

Topics include
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- and probably others

**Lecture notes**
The course is based on different parts from different books as well as on original research literature.

**Literature**
While there are many textbooks on mathematical finance, none of them is ideal to cover the contents of this course. References include the following books:


**Prerequisites / notice**
Prerequisites are the standard courses
- Probability Theory (for which lecture notes are available)
- Brownian Motion and Stochastic Calculus (for which lecture notes are available)
Those students who already attended "Introduction to Mathematical Finance" will have an advantage in terms of ideas and concepts.

This course is the second of a sequence of two courses on mathematical finance. The first course "Introduction to Mathematical Finance" (MF I), 401-3888-00, focuses on models in finite discrete time. It is advisable that the course MF I is taken prior to the present course, MF II.

For an overview of courses offered in the area of mathematical finance, see https://www.math.ethz.ch/imf/education/education-in-stochastic-finance/overview-of-courses.html.
# 401-3901-00L Linear & Combinatorial Optimization

**W** 10 credits 4V+2U  R. Zenklusen

**Abstract**
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

**Objective**
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

**Content**
Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

**Literature**

**Prerequisites / notice**
Solid background in linear algebra.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Techniques and Technologies</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Analytical Competencies</td>
<td>Decision-making</td>
<td>assessed</td>
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<tr>
<td>Media and Digital Technologies</td>
<td>Problem-solving</td>
<td>assessed</td>
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<td>Project Management</td>
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<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Creative Thinking</td>
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<td>Self-direction and Self-management</td>
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# 401-4944-20L Mathematics of Data Science

**W** 8 credits 3V+2U  A. Bandeira

**Abstract**
Mostly self-contained, but fast-paced, introductory masters level course on various theoretical aspects of algorithms that aim to extract information from data.

**Objective**
Introduction to various mathematical aspects of Data Science.

**Content**
These topics lie in overlaps of Mathematics with: Computer Science, Electrical Engineering, Statistics, and/or Operations Research. Most lectures will feature Mathematical Open Problems. The main mathematical tools used will be Probability and Linear Algebra, and a basic familiarity with these subjects is required. There will also be some (although knowledge of these tools is not assumed) Graph Theory, Representation Theory, Applied Harmonic Analysis, among others. The topics treated will include Dimension reduction, Manifold learning, Sparse recovery, Random Matrices, Approximation Algorithms, Community detection in graphs, and several others.

**Lecture notes**

**Prerequisites / notice**
The main mathematical tools used will be Probability, Linear Algebra (and real analysis), and a working knowledge of these subjects is required. In addition to these prerequisites, this class requires a certain degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

We encourage students who are interested in mathematical data science to take both this course and “227-0434-10L Mathematics of Information” taught by Prof. H. Bölcskei. The two courses are designed to be complementary.

A. Bandeira and H. Bölcskei

**Competencies**

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<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Techniques and Technologies</th>
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<tbody>
<tr>
<td>Analytical Competencies</td>
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<td>Media and Digital Technologies</td>
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<td>Self-direction and Self-management</td>
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</table>

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**Bachelor Core Courses: Pure Mathematics**

**Further restrictions apply, but in particular:**

<table>
<thead>
<tr>
<th>401-3531-00L Differential Geometry I can only be recognised for the Master Programme if 401-3532-00L Differential Geometry II has not been recognised for the Bachelor Programme.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analogously for: 401-3461-00L Functional Analysis I - 401-3462-00L Functional Analysis II 401-3001-61L Algebraic Topology I - 401-3002-12L Algebraic Topology II 401-3132-00L Commutative Algebra - 401-3146-12L Algebraic Geometry</td>
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</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1882 of 2653
For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
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<tr>
<td>401-3461-00L</td>
<td>Functional Analysis I</td>
<td>E-</td>
<td>9</td>
<td>4V+1U</td>
<td>M. Burger</td>
</tr>
</tbody>
</table>

**Abstract**

Baire category; Banach and Hilbert spaces, bounded linear operators; basic principles: Uniform boundedness, open mapping/closed graph theorem, Hahn-Banach; convexity; dual spaces; weak and weak* topologies; Banach-Alaoglu; reflexive spaces; compact operators and Fredholm theory; closed graph theorem; spectral theory of self-adjoint operators in Hilbert spaces. Basics of Sobolev spaces.

**Objective**

Acquire a good degree of fluency with the fundamental concepts and tools belonging to the realm of linear Functional Analysis, with special emphasis on the geometric structure of Banach and Hilbert spaces, and on the basic properties of linear maps.

**Literature**

Recommended references include the following:


**Prerequisites / notice**

Solid background on the content of all Mathematics courses of the first two years of the undergraduate curriculum at ETH. Most importantly: fluency with point set topology and measure theory, in part. Lebesgue integration and L^p spaces.

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<th>Number</th>
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<tr>
<td>401-3531-00L</td>
<td>Differential Geometry I</td>
<td>E-</td>
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<td>4V+1U</td>
<td>U. Lang</td>
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</table>

**Abstract**

Introduction to differential manifolds and differential geometry.

**Objective**

Learn to compute, describe, prove, and solve problems in the language of differential geometry.

**Content**

Submanifolds of R^n, immersions, submersions, and embeddings, Sard's Theorem, abstract differentiable manifolds, charts, vector fields and flows, vector bundles, tensor fields, covariant derivatives, parallel transport, Riemannian metrics, geodesics, Riemann curvature tensor. Complete manifolds, Hopf-Rinow theorem. Many examples including curves, surfaces, hyperbolic space, S^3, the unit quaternions, the Gauss-Bonnet theorem, etc.

**Literature**

- John M. Lee: Introduction to Smooth Manifolds
- John M. Lee: Introduction to Riemannian Manifolds

This following books were inherited from before. The only one I know is DoCarmo.

- Manfredo P. do Carmo: Differential Geometry of Curves and Surfaces
- S. Montiel, A. Ros: Curves and Surfaces
- S. Kobayashi: Differential Geometry of Curves and Surfaces
- Wolfgang Kühnel: Differentialgeometrie. Kurven-Flächen-Mannigfaltigkeiten
- Dennis Barden & Charles Thomas: An Introduction to Differential Manifolds

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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 1883 of 2653
The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradoxon and Bell's inequality); Perturbation theory.

Abstract
Basics of probability theory and the theory of stochastic processes in discrete time

Objective
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:
- measure theory formalism and probability theory, Dynkin's lemma and independence, convergence of series of independent random variables, law of large numbers, conditional expectation, martingale convergence theorems, uniform integrability, optional stopping theorem for martingales, the Bienaymè-Galton-Watson process and its R-number, convergence in distribution and the central limit theorem.

Content
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:
- measure theory formalism and probability theory, Dynkin's lemma and independence, convergence of series of independent random variables, law of large numbers, conditional expectation, martingale convergence theorems, uniform integrability, optional stopping theorem for martingales, the Bienaymè-Galton-Watson process and its R-number, convergence in distribution and the central limit theorem.

Prerequisites / notice
- Measure Theory
- Basic notions in probability theory (probability space, conditional probability, Borel-Cantelli, Dynkin Lemma, random variables, expectation, variance, law of large numbers).

Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
  - Creative Thinking: assessed

Literature
- H. Bauer, Probability Theory, de Gruyter 1996
- J. Jacod and P. Protter, Probability essentials, Springer 2004
- D. Williams, Probability with martingales, Cambridge University Press 1991

Lecture notes
will be available in electronic form.

For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

402-0205-00L Quantum Mechanics I

Physics BSc students with programme regulations 2016 need to register for "402-0205-10L Quantenmechanik I"

Abstract

Objective
Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems.

Content
The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradoxon and Bell's inequality); Perturbation theory.

Lecture notes
Auf Moodle

Literature
- G. Baym, Lectures on Quantum Mechanics
- E. Merzbacher, Quantum Mechanics
- L. I. Schiff, Quantum Mechanics
- R. Feynman and A. R. Hibbs, Quantum Mechanics and Path Integrals
- J. J. Sakurai, Modern Quantum Mechanics
- A. Messiah, Quantum Mechanics I
- S. Weinberg: Lectures on Quantum Mechanics
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Electives

For the Master's degree in Applied Mathematics the following additional condition (not manifest in myStudies) must be obeyed: At least 14 of the required 26 credits from core courses and electives must be acquired in areas of applied mathematics and further application-oriented fields.

Electives: Pure Mathematics

Select: Algebra, Number Thy, Topology, Discrete Mathematics, Logic

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<th>Number</th>
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<td>401-3571-74L</td>
<td>Characteristic Classes</td>
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<td>6</td>
<td>3V</td>
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Select: Geometry

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<td>401-3057-00L</td>
<td>Finite Geometries I; II</td>
<td>W</td>
<td>4</td>
<td>2G</td>
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Select: Analysis

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<tr>
<td>401-4494-23L</td>
<td>Calculus of Variations</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>A. Dinis Bacelar Lopes Guerra</td>
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<tr>
<td>401-4355-74L</td>
<td>Nonlinear Analysis and Perturbation Methods</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>M. Badran</td>
</tr>
</tbody>
</table>
Abstract
In this class, we will cover some of the most widely used techniques for tackling nonlinear problems in analysis, specifically in the context of partial differential equations (PDEs). We will explore variational methods, with an emphasis on the min-max technique, perturbation methods, and topological methods such as degree theory.

Objective
The goal of the course is to deepen understanding of the theory of nonlinear PDEs from the perspective of the existence of solutions. We will delve into how functional analysis tools enable us to construct solutions that are not necessarily minimising or variational in nature.

Competencies
Subject-specific Competencies
Concepts and Theories assessed

Selection: Further Realms and Some UZH Courses

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-3502-72L</td>
<td>Reading Course ■ To start an individual reading course, contact an authorised supervisor</td>
<td>W</td>
<td>2</td>
<td>4A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Abstract
For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

401-3503-72L | Reading Course ■ To start an individual reading course, contact an authorised supervisor | W    | 3    | 6A    | Supervisors        |

Abstract
For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

401-3504-72L | Reading Course ■ To start an individual reading course, contact an authorised supervisor | W    | 4    | 9A    | Supervisors        |

Abstract
For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

401-3504-02L | Reading Course (No. 2) ■ To start an individual reading course, contact an authorised supervisor | W    | 4    | 9A    | Supervisors        |

Abstract
For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

Electives: Applied Mathematics and Further Application-Oriented Fields

Selection: Numerical Analysis

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</table>

Abstract
This course is on the numerical approximations of stochastic ordinary differential equations (SDEs) driven by Brownian motions and Lévy processes. SDEs have several applications, for example in financial engineering. The contents cover stochastic processes, stochastic calculus, well-posedness results for SDEs, strong and weak approximations of SDEs, and simulation via Monte Carlo methods.

Objective
The aim of this course is to enable the students to carry out simulations and their mathematical convergence analysis for stochastic models originating from applications such as mathematical finance. For this the course teaches a decent knowledge of the different numerical methods, their underlying ideas, convergence properties and implementation issues.

Content
Brownian motion and Lévy processes
Stochastic integration and stochastic calculus
Stochastic ordinary differential equations (SDEs)
Numerical approximations of SDEs
Stochastic simulation and Monte Carlo methods
Applications to computational finance: Option valuation

Lecture notes
There will be English, typed lecture notes for registered participants in the course.
P. E. Kloeden and E. Platen:
Numerical Solution of Stochastic Differential Equations.

Bertoin, Jean:
Lévy processes.
Cambridge Tracts in Mathematics, 121.
Cambridge University Press.

Cont, Rama; Tankov, Peter:
Financial modelling with jump processes.

Prerequisites / notice

Prerequisites:
Mandatory:
Probability and measure theory,
basic numerical analysis and
basics of MATLAB/Python programming.

a) mandatory courses:
Measure - and Probability Theory I
as covered in courses:
ETH 401-2283-00L Analysis III (Measure Theory)
UZH Kursmodul 10498 Hauptvorlesung: Mass- und Integrationstheorie

b) recommended courses:
Stochastic Processes I

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Abstract
The aim of this course is to review new and fundamental mathematical tools, computational approaches, and inversion and optimal design methods used to address challenging problems in nanophotonics. The emphasis will be on analyzing plasmon resonant nanoparticles, super-focusing & super-resolution of electromagnetic waves, photonic crystals, electromagnetic cloaking, metamaterials, and metasurfaces.

401-4785-00L Mathematical and Computational Methods in Photonics W 7 credits 4G H. Ammari

Autumn Semester 2024
The field of photonics encompasses the fundamental science of light propagation and interactions in complex structures, and its technological applications.

The recent advances in nanoscience present great challenges for the applied and computational mathematics community. In nanophotonics, the aim is to control, manipulate, reshape, guide, and focus electromagnetic waves at nanometer length scales, beyond the resolution limit. In particular, one wants to break the resolution limit by reducing the focal spot and confine light to length scales that are significantly smaller than half the wavelength.

Interactions between the field of photonics and mathematics has led to the emergence of a multitude of new and unique solutions in which today's conventional technologies are approaching their limits in terms of speed, capacity and accuracy. Light can be used for detection and measurement in a fast, sensitive and accurate manner, and thus photonics possesses a unique potential to revolutionize healthcare. Light-based technologies can be used effectively for the very early detection of diseases, with non-invasive imaging techniques or point-of-care applications. They are also instrumental in the analysis of processes at the molecular level, giving a greater understanding of the origin of diseases, and hence allowing prevention along with new treatments. Photonic technologies also play a major role in addressing the needs of our ageing society: from pace-makers to synthetic bones, and from endoscopes to the micro-cameras used in in-vivo processes. Furthermore, photonics are also used in advanced lighting technology, and in improving energy efficiency and quality. By using photonic media to control waves across a wide band of wavelengths, we have an unprecedented ability to fabricate new materials with specific microstructures.

The main objective in this course is to report on the use of sophisticated mathematics in diffractive optics, plasmonics, super-resolution, photonic crystals, and metamaterials for electromagnetic invisibility and cloaking. The book merges highly nontrivial multi-disciplines in order to make a breakthrough in the field of mathematical modelling, imaging, and optimal design of optical nanodevices and nanostructures capable of light enhancement, and of the focusing and guiding of light at a subwavelength scale. We demonstrate the power of layer potential techniques in solving challenging problems in photonics, when they are combined with asymptotic analysis and the elegant theory of Gohberg and Sigal on meromorphic operator-valued functions.

In this course we shall consider both analytical and computational matters in photonics. The issues we consider lead to the investigation of fundamental problems in various branches of mathematics. These include asymptotic analysis, spectral analysis, mathematical imaging, optimal design, stochastic modelling, and analysis of wave propagation phenomena. On the other hand, deriving mathematical foundations, and new and efficient computational frameworks and tools in photonics, requires a deep understanding of the different scales in the wave propagation problem, an accurate mathematical modelling of the nanodevices, and fine analysis of complex wave propagation phenomena. An emphasis is put on mathematically analyzing plasmon resonant nanoparticles, diffractive optics, photonic crystals, super-resolution, and metamaterials.

401-4656-21L AI in the Sciences and Engineering

Objective

Learning objectives:

- Aware of advanced applications of AI in the sciences and engineering
- Familiar with the design, implementation, and theory of these algorithms
- Understand the pros/cons of using AI and deep learning for science
- Understand key scientific machine learning concepts and themes

Content

A selection of the following topics will be presented in the lectures:

1. Key scientific tasks common to many scientific domains, such as simulation, inverse problems, equation discovery, design, and control problems, and issues with traditional methods for solving them
2. Physics-informed neural networks for solving forward, inverse and equation discovery problems related to PDEs
3. Neural operators, including Fourier neural operators and DeepONets, for learning efficient surrogate models, and their theoretical foundations
4. Differentiable scientific algorithms, neural differential equations, and the benefits of hybrid workflows
5. AI for symbolic regression and equation discovery
6. Applications of graph neural networks in science
7. Guest lectures on AI for chemistry and biology
8. Large language models and other Foundation models for scientific discovery

Lecture notes

Lecture slides, recordings, and tutorials will be available on Moodle.

Literature

All the material in the course is based on research articles written in last 1-3 years. The relevant references will be provided.

Prerequisites /

- An understanding of basic machine learning concepts including supervised learning, overfitting/underfitting, optimisation, and neural networks is required; you should understand the main concepts in the ETH 252-0220-00L Introduction to Machine Learning course (but note, completing this course is not a formal requirement)
- Familiar with PDEs and numerical methods for solving them

Competencies

Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies

- Analytical Competencies assessed
- Problem-solving assessed
- Project Management assessed

Social Competencies

- Communication fostered
- Cooperation and Teamwork fostered

Personal Competencies

- Adaptability and Flexibility fostered
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics fostered

401-4652-23L Inverse Problems

Objective

Inverse problems arise in many applications in science & engineering. Typically, a physical model describes a forward problem and the task is to reconstruct from measurements, i.e. to perform inversion. In ill-posed problems, these inversions are troublesome as the inverse lacks e.g. stability. Regularization theory studies the controlled extraction of information from such systems.
I. Discrete-time Markov processes, i.e. Markov chains, e.g. the random walk on the integers.

Topics that we will discuss are:

L. Meier

Title

ECTS

Subject-specific Competencies

This course is meant to serve as an introduction to the theory of Markov processes on finite or countable state spaces. We will discuss fostered

Linear inverse problems, compact operators and singular value decompositions, regularization of linear inverse problems, regularization penalties, regularization parameters and parameter choice rules, iterative regularization schemes and stopping criteria, non-linear inverse problems.

Lecture notes

The lecture notes will be made available during the semester.

Literature


Prerequisites / notice

Analysis, linear algebra, numerical analysis, ideal but not necessary: functional analysis

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Problem-solving

Personal Competencies

Creative Thinking

Critical Thinking

Selection: Probability Theory, Statistics

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
401-3823-74L | Markov Processes | W | 3 credits | 1V | R. S. Gvalani

Abstract

This course is meant to serve as an introduction to the theory of Markov processes on finite or countable state spaces. We will discuss what a Markov process is along with associated concepts such as transition probabilities, recurrence, transience, ergodicity, reversibility etc. We will motivate various abstract notions introduced with concrete examples from physics and statistics.

Objective

I. Discrete-time Markov processes, i.e. Markov chains, e.g. the random walk on the integers

II. Transition probabilities and Doeblin's theorem

III. Stationary probabilities and ergodic properties

IV. Continuous-time Markov processes, e.g. the Poisson process

V. Reversibility

Literature

An Introduction to Markov Processes: Daniel W. Stroock

Prerequisites / notice

Probability and Statistics

Recommended: Analysis III (measure theory)

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Problem-solving

Social Competencies

Self-presentation and Social Influence

Personal Competencies

Creative Thinking

Critical Thinking


Abstract

Introduction to the Bayesian approach to statistics: decision theory, prior distributions, hierarchical Bayes models, empirical Bayes, Bayesian tests and model selection, empirical Bayes, Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods.

Objective

Students understand the conceptual ideas behind Bayesian statistics and are familiar with common techniques used in Bayesian data analysis.

Content

Topics that we will discuss:

- Difference between the frequentist and Bayesian approach (decision theory, principles), priors (conjugate priors, noninformative priors, Jeffreys prior), tests and model selection (Bayes factors, hyper-g priors for regression), hierarchical models and empirical Bayes methods, computational methods (Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods)

Lecture notes

A script will be available in English.

Literature


Additional references will be given in the course.

Prerequisites / notice

Familiarity with basic concepts of frequentist statistics and with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

401-0625-01L | Applied Analysis of Variance and Experimental Design | W | 5 credits | 2V+1U | L. Meier

Abstract

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial and fractional designs, power.

Objective

Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Content

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial and fractional designs, power.

Literature


Prerequisites / notice

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Decision-making

Personal Competencies

Creative Thinking

401-0649-00L | Applied Statistical Regression | W | 5 credits | 2V+1U | M. Dettling

Abstract

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial and fractional designs, power.

Objective

Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Content

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial and fractional designs, power.

Literature


Prerequisites / notice

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Decision-making

Personal Competencies

Creative Thinking
**High-Dimensional Statistics**

This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

### Objective

The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

### Content

The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

### Literature

- Faraway (2005): Linear Models with R
- Faraway (2006): Extending the Linear Model with R
- Draper & Smith (1998): Applied Regression Analysis
- Fox (2008): Applied Regression Analysis and GLMs
- Montgomery et al. (2006): Introduction to Linear Regression Analysis

### Prerequisites / notice

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed
  - Project Management: fostered

- **Social Competencies**
  - Communication: assessed
  - Cooperation and Teamwork: fostered
  - Customer Orientation: fostered
  - Leadership and Responsibility: fostered
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered
  - Negotiation: fostered

- **Personal Competencies**
  - Adaptability and Flexibility: assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

### 401-3627-00L High-Dimensional Statistics

**W 4 credits 2V**

**Abstract**

"High-Dimensional Statistics" deals with modern methods and theory for statistical inference when the number of unknown parameters is much larger than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed.

**Objective**

- Knowledge of methods and basic theory for high-dimensional statistical inference

**Content**

- Lasso and Group Lasso for high-dimensional linear and generalized linear models; Additive models and many smooth univariate functions;
- Non-convex loss functions and l1-regularization; Stability selection, multiple testing and construction of p-values; Undirected graphical modeling

**Literature**


**Prerequisites / notice**

Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).
This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exhibited by time series is the dependence between successive observations.

The key topics which will be covered as:

- Stationarity
- Autocorrelation
- Trend estimation
- Elimination of seasonality
- Spectral analysis, spectral densities
- Forecasting

**Literature**

The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis

**Prerequisites / notice**

Basic knowledge in probability and statistics

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### 401-3612-00L Stochastic Simulation

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<th>Number</th>
<th>Title</th>
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<tr>
<td>401-3612-00L</td>
<td>Stochastic Simulation</td>
<td>W</td>
<td>5 credits</td>
<td>4V+1U</td>
<td>F. Sigrist</td>
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**Abstract**

This course provides an introduction to statistical Monte Carlo methods. It includes applications of simulations in various fields (Bayesian statistics, statistical mechanics, operations research, financial mathematics), algorithms for the generation of random variables (accept-reject, importance sampling), estimating the precision, variance reduction, introduction to Markov chain Monte Carlo.

**Objective**

Stochastic simulation (also called Monte Carlo method) is the experimental analysis of a stochastic model by implementing it on a computer. Probabilities and expected values can be approximated by averaging simulated values, and the central limit theorem gives an estimate of the error of this approximation. The course shows examples of the many applications of stochastic simulation and explains different algorithms used for simulation. These algorithms are illustrated with the statistical software R.

**Content**

Examples of simulations in different fields (computer science, statistics, statistical mechanics, operations research, financial mathematics).


**Lecture notes**

A script will be available in English.

**Literature**


**Prerequisites / notice**

Familiarity with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

### Selection: Financial and Insurance Mathematics

In the Master's programme in Mathematics (direction Mathematics resp. Applied Mathematics 401-3013-01L Mathematical Foundations for Finance is eligible as an elective course resp. applied elective course, but only if 401-3888-00L Introduction to Mathematical Finance isn't recognised for credits (neither in the Bachelor's nor in the Master's programme). For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

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### 401-3925-00L Non-Life Insurance: Mathematics and Statistics

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<tr>
<td>401-3925-00L</td>
<td>Non-Life Insurance: Mathematics and Statistics</td>
<td>W</td>
<td>8 credits</td>
<td>4V+1U</td>
<td>M. V. Wüthrich</td>
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**Abstract**

Does not take place this semester.

The lecture aims at providing a basis in non-life insurance mathematics which forms a core subject of actuarial science. It discusses collective risk modeling, individual claim size modeling, approximations for compound distributions, ruin theory, premium calculation principles, tariffication with generalized linear models and neural networks, credibility theory, claims reserving and solvency.

**Objective**

The student is familiar with the basics in non-life insurance mathematics and statistics. This includes the basic mathematical models for insurance liability modeling, pricing concepts, stochastic claims reserving models and ruin and solvency considerations.

**Content**

The following topics are treated:

- Collective Risk Modeling
- Claim Counts Models
- Individual Claim Size Modeling
- Censoring and Truncation
- Approximations for Compound Distributions
- Ruin Theory in Discrete Time
- Premium Calculation Principles
- Tariffication
- Generalized Linear Models and Neural Networks
- Bayesian Models and Credibility Theory
- Claims Reserving
- Solvency Considerations

**Lecture notes**


**Literature**


**Prerequisites / notice**

The exams ONLY take place during the official ETH examination period (no semester end exams), and only in person exams (i.e. no remote exams).

This course will be held in English and counts towards the diploma of "Aktuar SAV". For the latter, see details under www.actuaries.ch.

**Competencies**

Prerequisites: knowledge of probability theory, statistics and applied stochastic processes.

- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: fostered
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<th>Course Code</th>
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<tr>
<td>401-3922-00L</td>
<td>Life Insurance Mathematics</td>
<td>4</td>
<td>W</td>
<td>M. Koller</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>The classical life insurance model is presented together with the</td>
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<td>important insurance types (insurance on one and two lives, term</td>
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<td>and endowment insurance and disability). Besides that the most</td>
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<td>important terms such as mathematical reserves are introduced and</td>
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<td>calculated. The profit and loss account and the balance sheet of</td>
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<td>a life insurance company is explained and illustrated.</td>
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<td>401-3927-00L</td>
<td>Mathematical Modelling in Life Insurance</td>
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<td>W</td>
<td>T. J. Peter</td>
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<td><strong>Abstract</strong></td>
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<td>In life insurance, it is essential to have adequate mortality rates,</td>
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<td>be it for reserving or pricing purposes. The course provides the</td>
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<td>classical tools necessary to create mortality tables from scratch</td>
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<td>as well as modern machine learning approaches to forecast mortality</td>
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<td>rates. It also covers the basics of survival analysis.</td>
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<td>The course's objective is to provide the students with the</td>
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<td>understanding and the tools to create mortality tables on their own.</td>
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<td>Additionally, students should learn the basics of survival analysis.</td>
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<td>Following main topics are covered:</td>
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<td>- Determining raw mortality rates</td>
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<td>- Smoothing techniques</td>
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<td>- Trends in mortality rates</td>
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<td>- Integration of safety margins</td>
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<td>- Stochastic mortality model due to Lee and Carter</td>
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<td>- Neural network extension of the Lee-Carter model</td>
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<td>- Machine learning for mortality forecasts</td>
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<td>- Survival analysis</td>
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<td><strong>Lecture notes</strong></td>
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<td>Lectures notes and slides will be provided</td>
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<td>- Problem-solving</td>
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<tr>
<td>401-3915-73L</td>
<td>Machine Learning in Finance and Insurance</td>
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<td>P. Cheridito</td>
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<td><strong>Abstract</strong></td>
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<td></td>
<td>This course introduces machine learning methods that can be used</td>
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<td>in finance and insurance applications.</td>
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<td><strong>Objective</strong></td>
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<td>The goal is to learn methods from machine learning that can be</td>
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<td>used in financial and insurance applications.</td>
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<td><strong>Content</strong></td>
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<td>Linear, polynomial, logistic, ridge and lasso regression,</td>
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<td>kernel methods, support vector machines, classification and</td>
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<td>regression trees, random forests, XGBoost, neural networks,</td>
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<td>stochastic gradient descent, autoencoders, graph neural networks,</td>
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<td>transformers, credit analytics, pricing, hedging, insurance claim</td>
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<td>Course material is available on <a href="https://people.math.ethz.ch/~patrickc/mlfi">https://people.math.ethz.ch/~patrickc/mlfi</a></td>
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<td>Literature</td>
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<td>Learning in Finance. Springer.</td>
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<td></td>
<td>Ian Goodfellow, Yoshua Bengio and Aaron Courville (2020). Deep</td>
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<td></td>
<td>Learning, MIT Press.</td>
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<td>Gareth James, Daniela Witten, Trevor Hastie and Robert Tibshirani</td>
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<td>Wiley.</td>
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<td>Mario V. Wüthrich and Michael Merz (2023). Statistical Foundations</td>
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<td>of Actuarial Learning and its Applications. Springer.</td>
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<td><strong>Prerequisites / notice</strong></td>
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<td>The course requires basic knowledge in analysis, linear algebra,</td>
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<tr>
<td>401-3931-00L</td>
<td>Responsible Machine Learning with Insurance Applications</td>
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<td>W</td>
<td>M. Mayer</td>
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<td></td>
<td><strong>Abstract</strong></td>
<td></td>
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<td>C. Lorenzen-Geiser</td>
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<td>This lecture covers important aspects of applying supervised</td>
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<td>machine learning models in a responsible way, based on sound</td>
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<td>statistical theory. The focus is on model interpretability,</td>
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<td>calibration (bias) assessment, and proper model comparison. The</td>
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<td>methods are illustrated with actuarial datasets.</td>
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<td>The student is familiar with the main tools of model</td>
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<td>interpretability, calibration assessment, and model comparison and</td>
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<td>knows how to apply supervised machine learning in a responsible</td>
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<td><strong>Content</strong></td>
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<td>- Overview of supervised machine learning (statistical learning</td>
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<td>theory, GLMs, tree based methods, and neural nets; cross-validation)</td>
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<td>- Model interpretability methods (partial dependence plots,</td>
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<td>measures of variable importance, and SHAP)</td>
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<td>- Bias/calibration assessment with identification functions</td>
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<td>- Model comparison with consistent scoring functions</td>
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<td>- Working with dependent observations and further topics</td>
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<td>For the latter, see details under <a href="http://www.actuaries.ch">www.actuaries.ch</a>.</td>
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<td>Prerequisites: Good knowledge in statistics/probability theory,</td>
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<td>statistical modelling and Python (or R) programming</td>
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Data: 15.06.2024 12:39   Autumn Semester 2024   Page 1892 of 2653
### Quantum Field Theory I

**Number:** 402-0843-00L  
**Title:** Quantum Field Theory I  
**Type:** W  
**ECTS:** 10 credits  
**Hours:** 4V+2U  
**Lecturers:** L. Senatore

**Abstract**  
This course discusses the quantisation of fields in order to introduce a coherent formalism for the combination of quantum mechanics and special relativity. Topics include:  
- Relativistic quantum mechanics  
- Quantisation of bosonic and fermionic fields  
- Interactions in perturbation theory  
- Scattering processes and decays  
- Elementary processes in QED  
- Radiative corrections

**Objective**  
The goal of this course is to provide a solid introduction to the formalism, the techniques, and important physical applications of quantum field theory. Furthermore, it prepares students for the advanced course in quantum field theory (Quantum Field Theory II), and for work on research projects in theoretical physics, particle physics, and condensed-matter physics.

**Lecture notes**  
Will be provided as the course progresses

**Competencies**  
- **Subject-specific Competencies**  
  - Concepts and Theories: assessed  
  - Techniques and Technologies: fostered  
- **Method-specific Competencies**  
  - Analytical Competencies: assessed  
  - Problem-solving: assessed  
  - Project Management: fostered  
- **Social Competencies**  
  - Communication: fostered  
  - Cooperation and Teamwork: fostered  
  - Customer Orientation: fostered  
  - Leadership and Responsibility: fostered  
  - Self-presentation and Social Influence: fostered  
  - Sensitivity to Diversity: fostered  
  - Negotiation: fostered  
- **Personal Competencies**  
  - Adaptability and Flexibility: fostered  
  - Creative Thinking: fostered  
  - Critical Thinking: assessed  
  - Integrity and Work Ethics: fostered  
  - Self-awareness and Self-reflection: fostered  
  - Self-direction and Self-management: fostered

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### Statistical Physics

**Number:** 402-0861-00L  
**Title:** Statistical Physics  
**Type:** W  
**ECTS:** 10 credits  
**Hours:** 4V+2U  
**Lecturers:** M. Sigrist

**Abstract**  
This lecture covers the concepts of classical and quantum statistical physics. Several techniques such as second quantization formalism for fermions, bosons, photons and phonons as well as mean field theory and self-consistent field approximation. These are used to discuss phase transitions, critical phenomena and superfluidity.  

**Objective**  
This lecture gives an introduction in the basic concepts and applications of statistical physics for the general use in physics and, in particular, as a preparation for the theoretical solid state physics.

**Content**  
- Kinetic approach to statistical physics: H-theorem, detailed balance and equilibrium conditions.  
- Classical statistical physics: microcanonical ensembles, canonical ensembles and grandcanonical ensembles, applications to simple systems.  
- Quantum statistical physics: density matrix, ensembles, Fermi gas, Bose gas (Bose-Einstein condensation), photons and phonons.  
- Identical quantum particles: many body wave functions, second quantization formalism, equation of motion, correlation functions, selected applications, e.g. Bose-Einstein condensate and coherent state, phonons in elastic media and melting.  
- One-dimensional interacting systems.  
- Phase transitions: mean field approach to Ising model, Gaussian transformation, Ginzburg-Landau theory (Ginzburg criterion), self-consistent field approach, critical phenomena, Peierls' arguments on long-range order.  

**Lecture notes**  
Lecture notes available in English.

**Literature**  
No specific book is used for the course. Relevant literature will be given in the course.

**Prerequisites / notice**  
Knowledge in basic thermodynamics and quantum mechanics.

**Competencies**  
- **Subject-specific Competencies**  
  - Concepts and Theories: assessed  
  - Techniques and Technologies: fostered  
- **Method-specific Competencies**  
  - Analytical Competencies: assessed  
  - Critical Thinking: assessed  
  - Problem-solving: fostered  
- **Personal Competencies**  
  - Adaptability and Flexibility: fostered  
  - Creative Thinking: fostered  
  - Integrity and Work Ethics: fostered  
  - Self-awareness and Self-reflection: fostered  
  - Self-direction and Self-management: fostered

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### General Relativity

**Number:** 402-0830-00L  
**Title:** General Relativity  
**Type:** W  
**ECTS:** 10 credits  
**Hours:** 4V+2U  
**Lecturers:** R. Renner

**Abstract**  
Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations of the theory as well as the underlying physical principles and concepts. It covers selected applications, such as the Schwarzschild solution and gravitational waves.

**Objective**  
Basic understanding of general relativity, its mathematical foundations (in particular the relevant aspects of differential geometry), and some of the phenomena it predicts (with a focus on black holes).
Introduction to String Theory is an attempt to quantise gravity and unite it with the other fundamental forces of nature. It is related to numerous interesting concepts and theories. This course provides an introduction to the basics of string theory in a simplified, exactly solvable setting. In this course we introduce the notion and formulation of integrability in classical and quantum mechanics. We discuss various efficient methods for constructing solutions and eigenstates in these models. Finally, we elaborate on the enhanced symmetries that underly integrable models.

Content
- Classical Integrability
- Algebraic Methods for Integrability
- Classical Spin Chains
- Spectral Curves and Inverse Scattering
- Quantum Spin Chains
- Bethe Ansatz
- Classical and Quantum Algebra

Literature
- C. Gomez, M. Ruiz-Altaba, G. Sierra, "Quantum Groups In Two-Dimensional Physics", Cambridge University Press (1996)

Competencies
- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies
- Social Competencies: Sensitivity to Diversity
- Personal Competencies: Adaptability and Flexibility

Prerequisites
- Recommended: Quantum Field Theory I (in parallel)

402-0897-00L Introduction to String Theory

Abstract
String theory is an attempt to quantise gravity and unite it with the other fundamental forces of nature. It is related to numerous interesting topics and questions in quantum field theory. In this course, an introduction to the basics of string theory is provided.

Objective
Within this course, a basic understanding and overview of the concepts and notions employed in string theory shall be given. More advanced topics will be touched upon towards the end of the course briefly in order to foster further research.

Content
- mechanics of point particles and extended objects
- string modes and their quantisation; higher dimensions, supersymmetry
- critical dimension and no-ghost theorem
- D-branes, T-duality
- two-dimensional conformal field theories

Literature

Prerequisites / notice
Recommended: Quantum Field Theory I (in parallel)

Competencies
- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies
- Social Competencies: Sensitivity to Diversity
- Personal Competencies: Adaptability and Flexibility

>Selection: Mathematical Optimization, Discrete Mathematics

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<th>Number</th>
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<tr>
<td>401-3055-64L</td>
<td>Algebraic Methods in Combinatorics</td>
<td>W</td>
<td>5</td>
<td>2V+1U</td>
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Abstract
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

Objective
The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://people.inf.ethz.ch/~aroeyskoe/AA23

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Students are expected to have a mathematical background and should be able to write rigorous proofs.

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<tr>
<td>401-3054-14L</td>
<td>Probabilistic Methods in Combinatorics</td>
<td>W</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>B. Sudakov</td>
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**Abstract**

This course provides a gentle introduction to the Probabilistic Method, with an emphasis on methodology. We will try to illustrate the main ideas by showing the application of probabilistic reasoning to various combinatorial problems.

**Content**

The topics covered in the class will include (but are not limited to): linearity of expectation, the second moment method, the local lemma, correlation inequalities, martingales, large deviation inequalities, Janson and Talagrand inequalities and pseudo-randomness.

**Literature**

- Graph Coloring and the Probabilistic Method, by M. Molloy and B. Reed, Springer, 2002.

### Selection: Theoretical Computer Science, Discrete Mathematics

**Number** 252-1425-00L  
**Title** Geometry: Combinatorics and Algorithms  
**Type** W  
**ECTS** 8  
**Hours** 3V+2U+2A  
**Lecturers** B. Gärtner, M. Hoffmann, P. Schneider

**Abstract**

Geometric structures are useful in many areas, and there is a need to understand their structural properties, and to work with them algorithmically. The lecture addresses theoretical foundations concerning geometric structures. Central objects of interest are triangulations. We study combinatorial (Does a certain object exist?) and algorithmic questions (Can we find a certain object efficiently?)

**Objective**

The goal is to make students familiar with fundamental concepts, techniques and results in combinatorial and computational geometry, so as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains.

In particular, we want to prepare students for conducting independent research, for instance, within the scope of a thesis project.

**Content**

Planar and geometric graphs, embeddings and their representation (Whitney's Theorem, canonical orderings, DCEL), polygon triangulations and the art gallery theorem, convexity in R^d, planar convex hull algorithms (Jarvis Wrap, Graham Scan, Chan's Algorithm), point set triangulations, Delaunay triangulations (Lawson flips, lifting map, randomized incremental construction), Voronoi diagrams, the Crossing Lemma and incidence bounds, line arrangements (duality, Zone Theorem, ham-sandwich cuts), 3-SUM hardness, counting planar triangulations.

**Lecture notes**


**Prerequisites / notice**

Prerequisites: The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semester of Bachelor Studies at ETH.

Outlook: In the following spring semester there is a seminar "Geometry: Combinatorics and Algorithms" that builds on this course. There are ample possibilities for Semester-, Bachelor- and Master Thesis projects in the area.

**Number** 263-4500-00L  
**Title** Advanced Algorithms  
**Type** W  
**ECTS** 9  
**Hours** 3V+2U+3A  
**Lecturers** J. Lengler, B. Häupler, M. Probst

**Abstract**

This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms, sketching and streaming algorithms, and online algorithms.

**Objective**

The course familiarizes the students with some of the main tools and techniques in modern subareas of algorithm design.

The lectures will cover modern topics in algorithm design and analysis, including the following: graph sparsifications while preserving cuts or distances, various approximation algorithms techniques and concepts, metric embeddings and probabilistic tree embeddings, online algorithms, multiplicative weight updates, streaming algorithms, sketching algorithms.

**Lecture notes**

https://people.inf.ethz.ch/~aroeyskoe/AA23

**Prerequisites / notice**

This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations. E.g., having passed the course Algorithms, Probability, and Computing (APC) is recommended, though not required formally. If you are not sure whether you're ready for this class or not, please consult the instructor.

**Competencies**

- Subject-specific Competencies
- Method-specific Competencies

Concepts and Theories  
Analytical Competencies  
Decision-making  
Problem-solving

**Number** 227-0417-00L  
**Title** Information Theory I  
**Type** W  
**ECTS** 6  
**Hours** 4G  
**Lecturers** A. Lapidoth

**Abstract**

This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equipartition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.
**Objective**

The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

**Content**

The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

**Literature**

T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

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### Selection: Further Realms and Some UZH Courses

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<tr>
<td>401-3502-72L</td>
<td>Reading Course ■</td>
<td>W</td>
<td>2</td>
<td>4A</td>
<td>Supervisors</td>
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*To start an individual reading course, contact an authorised supervisor [here](https://www.ethz.ch/content/dam/ethz/special-interest/math/department/Intranet/Students/Study_Administration/Theses_Reading_Courses/berechtigungsliste.pdf) and register your reading course in myStudies.*

**Abstract**

For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

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<td>401-3503-72L</td>
<td>Reading Course ■</td>
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<td>Supervisors</td>
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<td>401-3504-72L</td>
<td>Reading Course ■</td>
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<td>9A</td>
<td>Supervisors</td>
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**Abstract**

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<td>401-3504-02L</td>
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<td>9A</td>
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**Abstract**

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<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10</td>
<td>3V+2U+4A</td>
<td>C. Cotrini Jimenez</td>
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**Abstract**

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

**Content**

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

**Topics covered in the lecture include:**

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

**Lecture notes**

No lecture notes, but slides will be made available on the course webpage.
Communication

Analytical Competencies

Guarantees for Machine Learning

Subject-specific Competencies

Creative Thinking


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

263-5300-00L Guarantees for Machine Learning W 7 credits 3V+1U+2A F. Yang

Does not take place this semester.

Abstract

This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning algorithms. The knowledge is then applied in independent project work to understand and follow-up on recent theoretical ML results.

Objective

By the end of the semester students should be able to

- understand a good fraction of theory papers published in the typical ML venues. For this purpose, students will learn common mathematical techniques from statistical learning in the first part of the course and apply this knowledge in the project work
- critically examine recently published work in terms of relevance and find impactful (novel) research problems. This will be an integral part of the project work and involves experimental as well as theoretical questions
- outline a possible approach to prove a conjectured theorem by e.g. reducing to more solvable subproblems. This will be practiced in individual exercises, homeworks and potentially in the final project
- effectively communicate and present the problem motivation, new insights and results to a technical audience. This will be primarily learned via the final presentation and report as well as during peer-grading of peer talks.

Content

This course touches upon foundational methods in statistical learning theory aimed at proving theoretical guarantees for machine learning algorithms. It touches on the following topics:

- concentration bounds
- uniform convergence and empirical process theory
- regularization for non-parametric statistics (e.g. in RKHS, neural networks)
- high-dimensional learning
- computational and statistical learnability (information-theoretic, PAC, SQ)
- overparameterized models, implicit bias and regularization

The project work focuses on current theoretical ML research that aims to understand modern phenomena in machine learning, including but not limited to:

- how overparameterized models generalize (statistically) and converge (computationally)
- complexity measures and approximation theoretic properties of randomly initialized and trained neural networks
- generalization of robust learning (adversarial or distribution-shift robustness)
- private and fair learning

Prerequisites / notice

Students should have a very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as "Introduction to Machine Learning", "Regression", "Statistical Modelling". In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

Competencies

Subject-specific Competencies Concepts and Theories assessed

Method-specific Competencies Analytical Competencies assessed

Problem-solving assessed

Social Competencies

Communication assessed

Cooperation and Teamwork assessed

Personal Competencies

Creative Thinking assessed

Critical Thinking assessed

263-5210-00L Probabilistic Artificial Intelligence W 8 credits 3V+2U+2A A. Krause

Abstract

This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective

How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content

Topics covered:

- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice

Solid basic knowledge in statistics, algorithms and programming.

The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.
### Neural Network Theory

**Number**: 227-0423-00L  
**Title**: Neural Network Theory  
**ECTS**: 4 credits  
**Lecturers**: H. Bölcskei

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Method-specific Competencies</td>
<td>Techniques and Technologies</td>
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<td>Social Competencies</td>
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<td>Personal Competencies</td>
<td>Cooperation and Teamwork Fostered</td>
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**Abstract**
The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation theorems, capacity of separating surfaces, generalization, fundamental limits of deep neural network learning, VC dimension.

**Objective**
After attending this lecture, participating in the exercise sessions, and working on the homework problem sets, students will have acquired a working knowledge of the mathematical foundations of neural networks.

**Content**
1. Universal approximation with single- and multi-layer networks
2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory
3. Fundamental limits of deep neural network learning
4. Geometry of decision surfaces
5. Separating capacity of nonlinear decision surfaces
6. Vapnik-Chervonenkis (VC) dimension
7. VC dimension of neural networks
8. Generalization error in neural network learning

**Lecture notes**
Detailed lecture notes are available on the course web page: https://www.mins.ee.ethz.ch/teaching/int/

**Prerequisites / notice**
This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

### Projects in Topological Data Analysis

**Number**: 263-4511-00L  
**Title**: Projects in Topological Data Analysis  
**ECTS**: 4 credits  
**Lecturers**: P. Schnider

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<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories Fostered</th>
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<td>Method-specific Competencies</td>
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<td>Social Competencies</td>
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<td>Personal Competencies</td>
<td>Cooperation and Teamwork Assessed</td>
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**Abstract**
This seminar complements the course "Introduction to Topological Data Analysis". Students of the seminar will collaborate with students from international universities on concrete projects in topological data analysis, both theoretical and applied.

**Objective**
Each student is expected to collaborate in an international working group with students from the partner universities. Each group works on one of the projects suggested by the lecturers, and is assigned a mentor. At the end of the semester, each working group presents their findings in a written report and an oral presentation.

**Content**
This seminar complements the course Introduction to Topological Data Analysis. Students get to apply what they learned in the introductory course to concrete projects in the area of topological data analysis. These projects can be of theoretical nature, e.g., the design and analysis of a new algorithm, or applied, such as using methods from topological data analysis on concrete data sets.

**Prerequisites / notice**
Successful participation in the course "Introduction to Topological Data Analysis" or equivalent background in topological data analysis is required.

### Electives (Direction Applied Mathematics MSc Only)

Electives from applied mathematics and further application-oriented fields that are only eligible for credits for the Master's degree in Applied Mathematics.

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<tr>
<th>Number</th>
<th>Title</th>
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<tbody>
<tr>
<td>151-0532-00L</td>
<td>Nonlinear Dynamics and Chaos I</td>
<td>W</td>
<td>4</td>
<td>4G</td>
<td>G. Haller</td>
</tr>
</tbody>
</table>

**Abstract**
Basic facts about nonlinear systems: stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

**Objective**
This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.

**Content**
1. Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
2. Near equilibrium dynamics: Linear and Lyapunov stability
3. Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations
4. Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
5. Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

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In the Master's programme in Mathematics (direction Mathematics resp. Applied Mathematics 401-3913-01L Mathematical Foundations for Finance is eligible as an elective course resp. applied elective course, but only if 401-3888-00L Introduction to Mathematical Finance isn't recognised for credits (neither in the Bachelor's nor in the Master's programme). For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits. 

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<tr>
<th>Number</th>
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<tr>
<td>401-3913-01L</td>
<td>Mathematical Foundations for Finance</td>
<td>W</td>
<td>4 credits</td>
<td>3V+2U</td>
<td>D. Possamaï</td>
</tr>
</tbody>
</table>

Abstract
First introduction to main modelling ideas and mathematical tools from mathematical finance.

Objective
This course gives a first introduction to the main modelling ideas and mathematical tools from mathematical finance. It mainly aims at non-mathematicians who need an introduction to the main tools from stochastics used in mathematical finance. However, mathematicians who want to learn some basic modelling ideas and concepts for quantitative finance (before continuing with a more advanced course) may also find this of interest. The main emphasis will be on ideas, but important results will be given with (sometimes partial) proofs.

Content
Topics to be covered include:
- financial market models in finite discrete time
- absence of arbitrage and martingale measures
- valuation and hedging in complete markets
- basics about Brownian motion
- stochastic integration
- stochastic calculus: Itô's formula, Girsanov transformation, Itô's representation theorem
- Black-Scholes formula

Lecture notes
See information on course homepage

Prerequisites
See information on course homepage

Competencies

Application Area
Only necessary and eligible for the Master degree in Applied Mathematics.

One of the application areas specified must be selected for the category Application Area for the Master degree in Applied Mathematics. At least 8 credits are required in the chosen application area. Credits from other application areas cannot be recognised for further application areas.

Atmospherical Physics

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1221-00L</td>
<td>Dynamics of Large-Scale Atmospheric Flow</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>H. Wernli, J. Riboldi</td>
</tr>
</tbody>
</table>

Abstract
This lecture course is about the fundamental aspects of the dynamics of extratropical weather systems (quasi-geostrophic dynamics, potential vorticity, Rossby waves, baroclinic instability). The fundamental concepts are formally introduced, quantitatively applied and illustrated with examples from the real atmosphere. Exercises (quantitative and qualitative) form an essential part of the course.

Objective
Understanding of dynamic processes of large-scale atmospheric flow and their mathematical-physical formulation.

Content
Dynamical Meteorology is concerned with the dynamical processes of the earth's atmosphere. The fundamental equations of motion in the atmosphere will be discussed along with the dynamics and interactions of synoptic system - i.e. the low and high pressure systems that determine our weather. The motion of such systems can be understood in terms of quasi-geostrophic theory. The lecture course provides a derivation of the mathematical basis along with some interpretations and applications of the concept.

Lecture notes
Dynamics of large-scale atmospheric flow

Literature
- Pichler H., Dynamik der Atmosphäre, Bibliographisches Institut, 456 pp. 1997

Biological Fluid Dynamics

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>636-0017-00L</td>
<td>Computational Biology</td>
<td>W</td>
<td>6 credits</td>
<td>3G+2A</td>
<td>T. Vaughan, C. Magnus, T. Stadler</td>
</tr>
</tbody>
</table>
Abstract
The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Objective
Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:
- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics
Attendees will apply these concepts to a number of applications yielding biological insight into:
- epidemiology
- pathogen evolution
- macroevolution of species

Content
The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e., we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e., we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g., HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes
Lecture slides will be available on moodle.

Literature
The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:
- Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.

Prerequisites / notice
Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place in Basel before the start of the semester.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed
Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed
Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed

636-0007-00L Computational Systems Biology W 6 credits 3V+2U J. Stelling

Abstract
Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

Objective
The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

Content
Biological systems exhibit emergent properties that are hidden within their individual components and cannot be deduced from them individually. We start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

Lecture notes
http://www.csb.ethz.ch/education/lectures.html

Literature

636-0009-00L Evolutionary Dynamics W 6 credits 2V+1U+2A N. Beenenwinkel

Abstract
Evolutionary dynamics is concerned with the mathematical principles according to which life has evolved. This course offers an introduction to mathematical modeling of evolution, including deterministic and stochastic models, with an emphasis on tumor evolution.

Objective
The goal of this course is to understand and to appreciate mathematical models and computational methods that provide insight into the evolutionary process in general and tumor evolution in particular. Students should analyze and evaluate models and their application critically and be able to design new models.

Content
Evolution is the one theory that encompasses all of biology. It provides a single, unifying concept to understand the living systems that we observe today. We will introduce several types of mathematical models of evolution to describe gene frequency changes over time in the context of different biological systems, focusing on asexual populations. Viruses and cancer cells provide the most prominent examples of such systems and they are at the same time of great biomedical interest. The course will cover some classical mathematical population genetics and population dynamics, and also introduce several new approaches. This is reflected in a diverse set of mathematical concepts which make their appearance throughout the course, all of which are introduced from scratch. Topics covered include the quasispecies equation, evolution of HIV, evolutionary game theory, evolutionary stability, evolutionary graph theory, tumor evolution, stochastic tunneling, genetic progression of cancer, diffusion theory, fitness landscapes, branching processes, and evolutionary escape.

Lecture notes
No.

Literature

Prerequisites / notice
Prerequisites: Basic mathematics (linear algebra, calculus, probability)
Introduction to Dynamic Programming and Optimal Control.

Financial Risk Management in Social and Pension Insurance

Investment returns are an important source of funding for social and pension insurance, and financial risk is an important threat to stability. Managing financial risk in social and pension insurance is, therefore, the task of reconciling the contradictory dimensions of risk and return of financial assets. Risk and return cannot be separated from one another and, hence, asset management and risk management cannot be separated either. Managing financial risk in social and pension insurance is, therefore, the task of reconciling the contradictory dimensions of risk and return of financial assets.

1. Required return for a sustainable funding of the institution,
2. Risk-taking capability of the institution,
3. Returns available from financial assets in the market,
4. Risks incurred by investing in these assets.

This task must be accomplished under a number of constraints. Financial risk management in social insurance also means reconciling the long time horizon of the promised insurance benefits with the short time horizon of financial markets and financial risk.

It is not the goal of this lecture to provide the students with any cookbook recipes that can readily be applied without further reflection. The goal is rather to enable the students to develop their own understanding of the problems and possible solutions associated with the management of financial risks in social and pension insurance.

To this end, a rigorous intellectual framework will be developed and a powerful set of mathematical tools from the fields of actuarial mathematics and quantitative risk management will be applied. When analyzing the properties of financial assets, an empirical viewpoint will be taken using statistical tools and considering real-world data.

This course counts towards the diploma of "Aktuar SAV".

The exams ONLY take place during the official ETH examination period.
### Competencies

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<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
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<tr>
<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Customer Orientation</td>
<td>Creative Thinking</td>
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<td>Problem-solving</td>
<td>Leadership and Responsibility</td>
<td>Critical Thinking</td>
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<td>Self-presentation and Social Influence</td>
<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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### Resource and Environmental Economics

<table>
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<th>Abstract</th>
<th>Competencies</th>
<th>Literature</th>
<th>Content</th>
<th>Objective</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relationship between economy and environment, market failures, external effects and public goods, contingent valuation, internalisation of externalities, economics of non-renewable resources, economics of renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.</td>
<td>Subject-specific Competencies</td>
<td>A. Miftakhova, A. Minabutdinov</td>
<td>The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit-analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power. When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.</td>
<td>A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.</td>
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### Principles of Microeconomics

<table>
<thead>
<tr>
<th>Abstract</th>
<th>Competencies</th>
<th>Literature</th>
<th>Content</th>
<th>Objective</th>
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<tbody>
<tr>
<td>The course introduces basic principles, problems and approaches of microeconomics. This provides students with a reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a fair distribution.</td>
<td>Subject-specific Competencies</td>
<td>M. Filippini</td>
<td>The learning objectives of the course are: (1) Students must be able to discuss basic principles, problems and approaches in microeconomics. (2) Students can analyse and explain simple economic principles in a market using supply and demand graphs. (3) Students can contrast different market structures and describe firm and consumer behaviour. (4) Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole. (5) Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics. (6) Students can apply simple mathematical concepts on economic problems.</td>
<td>The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a fair distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture &quot;Principles of Microeconomics&quot; is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.</td>
</tr>
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</table>

### Topics covered by the course are:

- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade

### Lecture notes

Lecture notes, exercises and reference material can be downloaded from Moodle.
Literature

For students taking only the course 'Principles of Microeconomics' there is a shorter version of the same book:

Complementary:

Prerequisites / notice
GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: fostered

363-0565-00L Principles of Macroeconomics

Abstract
This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

Objective
This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to everyday economic problems.

Content
This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

Lecture notes
The course Moodle page contains announcements, course information and lecture slides.

Literature

This book can also be used for the course '363-0503-00L Principles of Microeconomics' (Filippini).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: fostered

363-1021-00L Monetary Policy

Abstract
The main aim of this course is to analyse the goals of monetary policy and to review the instruments available to central banks in order to pursue these goals. It will focus on the transmission mechanisms of monetary policy and the differences between monetary policy rules and discretionary policy. It will also make connections between theoretical economic concepts and current real-world issues.
Objective
This lecture will introduce the fundamentals of monetary economics and explain the working and impact of monetary policy. The main aim of this course is to describe and analyze the goals of monetary policy and to review the instruments available to central banks in order to pursue these goals. It will focus on the transmission mechanisms of monetary policy, the effectiveness of monetary policy actions, the differences between monetary policy rules and discretionary policy, as well as in institutional issues concerning central banks, transparency of monetary authorities and monetary policy in a monetary union framework. Moreover, we discuss the implementation of monetary policy in practice and the design of optimal policy.

Content
For the functioning of today's economy, central banks and their policies play an important role. Monetary policy is the policy adopted by the monetary authority of a country, the central bank. The central bank controls either the interest rate payable on very short-term borrowing or the money supply, often targeting inflation or the interest rate to ensure price stability and general trust in the currency. This monetary policy course looks into today's major questions related to policies of central banks. It provides insights into the monetary policy process using core economic principles and real-world examples.

Lecture notes
The course Moodle page contains announcements, course information and lecture slides.

Literature
The course will be based on chapters of:

Prerequisites / notice
Basic knowledge in international economics and a good background in macroeconomics.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

363-1017-00L Risk and Insurance Economics

Abstract
The course covers the economics of risk and insurance, in particular the following topics will be discussed:
2) individual decision making under risk
3) models of insurance demand, risk sharing, insurance supply
4) information issues in insurance markets
5) advanced topics in microeconomics and behavioral economics
5) the macroeconomic role of insurers and insurance regulation

Objective
The course introduces students to basic microeconomic models of risk attitudes and highlight the role insurance can – or cannot – play for individuals facing risks.

Content
Everyday, we take decisions involving risks. These decisions are driven by our perception of and our appetite for risk. Insurance plays a significant role in people's risk-management strategies.

In the first part of this lecture, we discuss a normative decision concept, Expected Utility theory, and compare it with empirically observed behaviour.

Students then learn about the rationale for individuals to purchase insurance, and for companies to offer it. We derive the optimal level of insurance demand and discuss how it depends on our model's underlying assumptions.

We then discuss the consequences of information asymmetries in insurance markets and the consequences for insurance supply.

Finally, we discuss refinements in decision theory that help account for observed behaviours that don't fit with the basic models of microeconomic theory. For example, we'll explore how behavioural economics can be leveraged by the insurance industry.

Literature
Main literature:
- Handbook of the Economics of Risk and Uncertainty, Volume1;

Further readings:

References will be given on a topic-by-topic basis during the course.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

Personal Competencies
- Critical Thinking: assessed
- Self-direction and Self-management: fostered

Finance

Number Title Type ECTS Hours Lecturers
401-8913-00L Advanced Corporate Finance I (University of Zurich) W 6 credits 4G University lecturers

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming
Abstract

This course develops and refines tools for evaluating investments (capital budgeting), capital structure, and corporate securities. The course seeks to deepen students' understanding of the link between corporate finance theory and practice.

Objective

This course develops and refines tools for evaluating investments (capital budgeting), capital structure, and corporate securities. With respect to capital structure, we start with the famous Miller and Modigliani irrelevance proposition and then move on to study the effects of taxes, bankruptcy costs, information asymmetries between firms and the capital markets, and agency costs. In this context, we will also study how leverage affects some central financial ratios that are often used in practice to assess firms and their stock. Other topics include corporate cash holdings, the use and pricing of convertible bonds, and risk management. The latter two topics involve option pricing. With respect to capital budgeting, the course pays special attention to tax effects in valuation, including in the estimation of the cost of capital. We will also study payout policy (dividends and share repurchases). The course seeks to deepen students' understanding of the link between corporate finance theory and practice. Various cases will be assigned to help reach this objective.

Content

Topics covered
1. Capital structure: Perfect markets and irrelevance
2. Risk, leverage, taxes, and the cost of capital
3. Leverage and financial ratios
4. Payout policy: Dividends and share repurchases
5. Capital structure: Taxes and bankruptcy costs
6. Capital structure: Information asymmetries, agency costs, cash holdings
7. Valuation: DCF, adjusted present value and WACC
8. Valuation using options
9. The use and pricing of convertible bonds
10. Corporate risk management

261-5111-00L Asset Management: Advanced Investments (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: MFOEC207

Mind the enrolment deadlines at UZH:

Abstract

Comprehension and application of advanced portfolio theory

Objective

Comprehension and application of advanced portfolio theory

Content

The theoretical part of the lecture consists of the topics listed below.

- Standard Markowitz Model and Extensions MV Optimization, MV with Liabilities and CAPM.
- The Crux with MV Resampling, regression, Black-Litterman, Bayesian, shrinkage, constrained and robust optimization.
- Downside and Coherent Risk Measures Definition of risk measures, MV optimization under VaR and ES constraints.
- Risk Budgeting Equal risk contribution, most diversified portfolio and other concentration indices
- Regime Switching and Asset Allocation An introduction to regime switching models and its intuition.
- Strategic Asset Allocation Introducing a continuous-time framework, solving the HJB equation and the classical Merton problem.

363-1017-00L Risk and Insurance Economics

W 3 credits 2G

H. Schernberg

Abstract

The course covers the economics of risk and insurance, in particular the following topics will be discussed:
2) individual decision making under risk
3) models of insurance demand, risk sharing, insurance supply
4) information issues in insurance markets
5) advanced topics in microeconomics and behavioral economics
5) the macroeconomic role of insurers and insurance regulation

Objective

The course introduces students to basic microeconomic models of risk attitudes and highlight the role insurance can – or cannot – play for individuals facing risks.

Content

Everyday, we take decisions involving risks. These decisions are driven by our perception of and our appetite for risk. Insurance plays a significant role in people's risk-management strategies.

In the first part of this lecture, we discuss a normative decision concept, Expected Utility theory, and compare it with empirically observed behaviour.

Students then learn about the rationale for individuals to purchase insurance, and for companies to offer it. We derive the optimal level of insurance demand and discuss how it depends on our model's underlying assumptions.

We then discuss the consequences of information asymmetries in insurance markets and the consequences for insurance supply.

Finally, we discuss refinements in decision theory that help account for observed behaviours that don't fit with the basic models of microeconomic theory. For example, we'll explore how behavioural economics can be leveraged by the insurance industry.
Image Processing and Computer Vision

**Number** 227-0447-00L

**Title** Image Analysis and Computer Vision

**Type** W

**ECTS** 6 credits

**Hours** 3V+1U

**Lecturers** E. Konukoglu, E. Erdil, F. Yu

**Abstract**


**Objective**

Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

**Content**

This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

**Lecture notes** Course material Script, computer demonstrations, exercises and problem solutions

**Prerequisites / notice** Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

Information and Communication Technology

**Number** 227-0105-00L

**Title** Introduction to Estimation and Machine Learning

**Type** W

**ECTS** 6 credits

**Hours** 4G

**Lecturers** H.-A. Loeliger

**Abstract**

Mathematical basics of estimation and machine learning, with a view towards applications in signal processing.

**Objective**

Students master the basic mathematical concepts and algorithms of estimation and machine learning.

**Content**

Review of probability theory; basics of statistical estimation; least squares and linear learning; Hilbert spaces; singular-value decomposition; kernel methods, neural networks, and more

**Lecture notes** Lecture notes will be handed out as the course progresses.

**Prerequisites / notice** solid basics in linear algebra and probability theory

**Number** 227-0101-00L

**Title** Discrete-Time and Statistical Signal Processing

**Type** W

**ECTS** 6 credits

**Hours** 4G

**Lecturers** H.-A. Loeliger

**Abstract**

The course is about some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.

**Objective**

The course is about some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust "inversion" of a linear filter.

**Content**

1. Discrete-time linear systems and filters: state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.

2. The discrete Fourier transform and its use for digital filtering.

3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.

**Lecture notes** Lecture Notes

**Number** 227-0417-00L

**Title** Information Theory I

**Type** W

**ECTS** 6 credits

**Hours** 4G

**Lecturers** A. Lapidoth

**Abstract**

This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.
Objective
The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

Content
The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

Literature
T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

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Machine Learning

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<th>Number</th>
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<tr>
<td>263-5210-00L</td>
<td>Probabilistic Artificial Intelligence</td>
<td>W</td>
<td>8</td>
<td>3V+2U+2A</td>
<td>A. Krause</td>
</tr>
</tbody>
</table>

Abstract
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics. The course is designed for graduate students.

Objective
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice
Solid basic knowledge in statistics, algorithms and programming.

The material covered in the course “Introduction to Machine Learning” is considered as a prerequisite.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication

Personal Competencies
- Cooperation and Teamwork
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

263-3210-00L Deep Learning W 8 credits 3V+2U+2A T. Hofmann

Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://ml2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/ss19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18

252-3005-00L Natural Language Processing W 7 credits 3V+3U+1A R. Cotterrell

Abstract
This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Objective
The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

Content
This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Literature
Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

401-4656-21L AI in the Sciences and Engineering W 6 credits 2V+2U S. Mishra
AI is having a profound impact on science by accelerating discoveries across physics, chemistry, biology, and engineering. This course aims to present a highly topical selection of AI applications across these fields. Emphasis will be placed on using AI, particularly deep learning, to understand systems modelled by PDEs, and key scientific machine learning concepts and themes will be discussed.

**Objective**

Learning objectives:

- Aware of advanced applications of AI in the sciences and engineering
- Familiar with the design, implementation, and theory of these algorithms
- Understand the pros/cons of using AI and deep learning for science
- Understand key scientific machine learning concepts and themes

**Content**

A selection of the following topics will be presented in the lectures:

1. Key scientific tasks common to many scientific domains, such as simulation, inverse problems, equation discovery, design, and control problems, and issues with traditional methods for solving them
2. Physics-informed neural networks for solving forward, inverse and equation discovery problems related to PDEs
3. Neural operators, including Fourier neural operators and DeepONets, for learning efficient surrogate models, and their theoretical foundations
4. Differentiable scientific algorithms, neural differential equations, and the benefits of hybrid workflows
5. AI for symbolic regression and equation discovery
6. Applications of graph neural networks in science
7. Guest lectures on AI for chemistry and biology
8. Large language models and other Foundation models for scientific discovery

Applications using these techniques will be illustrated across fluid dynamics, wave physics, medical physics, molecular design, and computational biology. Several examples where AI algorithms outperform traditional scientific workflows will be shown.

**Lecture notes**

Lecture slides, recordings, and tutorials will be available on Moodle.

**Literature**

All the material in the course is based on research articles written in last 1-3 years. The relevant references will be provided.

- An understanding of basic ML concepts including supervised learning, overfitting/underfitting, optimisation, and neural networks is required; you should understand the main concepts in the ETH 252-0220-00L Introduction to Machine Learning course (but note, completing this course is not a formal requirement)
- Familiar with PDEs and numerical methods for solving them
- Basic competence in Python and some practical familiarity with deep learning frameworks (e.g. PyTorch, TensorFlow, or Keras)

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Problem-solving: assessed
  - Project Management: fostered

- **Social Competencies**
  - Communication: fostered
  - Cooperation and Teamwork: fostered

- **Personal Competencies**
  - Adaptability and Flexibility: fostered
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered

**Material Modelling and Simulation**

**Quantum Chemistry**

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<th>Number</th>
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<tr>
<td>529-0003-01L</td>
<td>Advanced Quantum Chemistry</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>M. Reiher, T. Weymuth</td>
</tr>
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</table>

**Abstract**

Advanced, but fundamental topics central to the understanding of theory in chemistry and for solving actual chemical problems with a computer.

**Objective**

The aim of the course is to provide an in-depth knowledge of theory and method development in theoretical chemistry. It will be shown that this is necessary in order to be able to solve actual chemical problems on a computer with quantum chemical methods.

The relativistic re-derivation of all concepts known from (nonrelativistic) quantum mechanics and quantum-chemistry lectures will finally explain the form of all operators in the molecular Hamiltonian - usually postulated rather than deduced. From this, we derive operators needed for molecular spectroscopy (like those required by magnetic resonance spectroscopy). Implications of other assumptions in standard non-relativistic quantum chemistry shall be analyzed and understood, too. Examples are the Born-Oppenheimer approximation and the expansion of the electronic wave function in a set of pre-defined many-electron basis functions (Slater determinants). Overcoming these concepts, which are so natural to the theory of chemistry, will provide deeper insights into many-particle quantum mechanics. Also revisiting the workhorse of quantum chemistry, namely density functional theory, with an emphasis on open-shell electronic structures (radicals, transition-metal complexes) will contribute to this endeavor. It will be shown how these insights allow us to make more accurate predictions in chemistry in practice - at the frontier of research in theoretical chemistry.

**Content**

1) Introductory lecture: basics of quantum mechanics and quantum chemistry
2) Einstein's special theory of relativity and the (classical) electromagnetic interaction of two charged particles
3) Klein-Gordon And Dirac equation; the Dirac hydrogen atom
4) Numerical methods based on the Dirac-Fock-Coulomb Hamiltonian, two-component and scalar relativistic Hamiltonians
5) Response theory and molecular properties, derivation of property operators, Breit-Pauli-Hamiltonian
6) Relativistic effects in chemistry and the emergence of spin
7) Spin in density functional theory
8) New electron-correlation theories: Tensor network and matrix product states, the density matrix renormalization group

**Lecture notes**

A set of detailed lecture notes will be provided, which will cover the whole course.
Subject-specific Competencies assessed

- Economic Dynamics and Complexity

Title: Concepts and Theories

2) F. Schwab|l: Quantenmechanik für Fortgeschrittene (QM II), Springer-Verlag, 1997
3) R. McWeeny: Methods of Molecular Quantum Mechanics, Academic Press, 1992
https://doi.org/10.1063/1.5129672

Note also the standard textbooks:
A) A. Szabo, N.S. Ostlund. Quantum Chemistry, Pearson
B) I. N. Levine, Quantum Chemistry, Pearson

Prerequisites / notice
- Strongly recommended (preparatory) courses are: quantum mechanics and quantum chemistry

➡ Systems Design

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<tr>
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<tbody>
<tr>
<td>363-0541-00L</td>
<td>Economic Dynamics and Complexity</td>
<td>W</td>
<td>3</td>
<td>3G</td>
<td>F. Schweitzer, L. Verginer</td>
</tr>
</tbody>
</table>

Abstract
What causes economic business cycles? How are limited resources, competition, and cooperation reflected in growth dynamics? To answer such questions, we combine macroeconomic models and methods of nonlinear dynamics. We study the role of bifurcations and control parameters for dynamic stability. Feedback cycles and coupled dynamics are reasons for limited predictability, instability and chaos.

Objective
Successful participant of the course is able to:
- understand the importance of different modeling approaches
- formalize and solve one- and two-dimensional nonlinear models
- identify critical conditions for stability and dynamic transitions
- analyze macroeconomic models of business cycles, supply and demand
- apply formal concepts to model economic growth and competition

Content
System theory sees the economy as a complex adaptive system. What does this mean for economic modeling?

We focus on two sources of complexity: (a) nonlinear dynamics, which is captured in this course, “Economic Dynamics and Complexity” and (b) collective interactions, which is captured in the course “Agent-Based Modeling of Economic Systems” (in spring).

Our approach to economic dynamics combines insights from different disciplines: macroeconomics studying business cycles and growth, system dynamics rooted general system theory and cybernetics, and nonlinear dynamics using applied mathematics.

We start with a comparison of different modeling approaches, to highlight the problems and challenges of system modeling. The subsequent lectures then introduce different one- and two-dimensional nonlinear models with applications in economics, such as models of supply and demand, business cycles, growth and competition. Emphasis is on the formal analysis of these models using methods from applied mathematics and tools for solving coupled differential equations.

Weekly self-study tasks are used to apply the concepts introduced in the lectures. We practice how to solve nonlinear models formally and numerically and how to interpret the results.

Lecture notes
The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.

Prerequisites / notice
Students should be familiar with nonlinear differential equations and should have basic programming skills. All necessary details to solve nonlinear models will be provided in the course. The course will not build on mathematical proofs, optimization, statistics, efficient numerical computation and other specialized skills.

➡ Theoretical Physics

In the Master's programme in Applied Mathematics 402-0205-00L Quantum Mechanics I is eligible as a course unit in the application area Theoretical Physics, but only if 402-0224-00L Theoretical Physics wasn't or isn't recognised for credits (neither in the Bachelor's nor in the Master's programme).

For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studensekretariat) after having received the credits.

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<tbody>
<tr>
<td>402-0809-00L</td>
<td>Introduction to Computational Physics</td>
<td>W</td>
<td>8</td>
<td>2V+2U</td>
<td>A. Adelmann</td>
</tr>
</tbody>
</table>
Abstract
This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

Objective
Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

Content
Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

Competencies
Subject-specific Competencies
- Concepts and Theories
Method-specific Competencies
- Analytical Competencies

Literature recommendations and references are included in the lecture notes.

Lecture notes
Lecture notes and slides are available online and will be distributed if desired.

Prerequisites / notice
Lecture and exercise lessons in English, exams in German or in English
General Relativity

Abstract
Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations of the theory as well as the underlying physical principles and concepts. It covers selected applications, such as the Schwarzschild solution and gravitational waves.

Objective
Basic understanding of general relativity, its mathematical foundations (in particular the relevant aspects of differential geometry), and some of the phenomena it predicts (with a focus on black holes).

Content
Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations, such as differentiable manifolds, the Riemannian and Lorentzian metric, connections, and curvature. It discusses the underlying physical principles, e.g., the equivalence principle, and concepts, such as curved spacetime and the energy-momentum tensor. The course covers some basic applications and special cases, including the Newtonian limit, post-Newtonian expansions, the Schwarzschild solution, light deflection, and gravitational waves.

Literature
Suggested textbooks:
- C. Misner, K. Thorne and J. Wheeler: Gravitation
- S. Carroll - Spacetime and Geometry: An Introduction to General Relativity
- R. Wald - General Relativity
- S. Weinberg - Gravitation and Cosmology

Electives Theoretical Physics

Transportation Science

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<th>Number</th>
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<th>Lecturers</th>
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<tr>
<td>101-0417-00L</td>
<td>Transport Planning Methods</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>E. Heinen</td>
</tr>
</tbody>
</table>

Abstract
The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis. Examples of such planning problems are the estimation of traffic volumes, prediction of estimated utilization of new public transport lines, and evaluation of effects (e.g. change in emissions of a city) triggered by building new infrastructure and changes to operational regulations.

To cope with that, the problem is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis. Interim lab session take place regularly to guide and support students with the applied part of the course.

Lecture notes
Moodle platform (enrollment needed)

Literature

Seminars and Semester Papers

Seminars

NOTICE: The number of seminar places is limited, and the special selection procedure should help to allocate the places not primarily according to the registration time. Everybody is waitlisted first when he/she tries to register for such a seminar in myStudies. Moreover: Only one mathematics seminar can be chosen per semester. In case you need to attend 2 seminars in this semester, please take contact with the Study Administration (email: studiensekretariat@math.ethz.ch).

Notice also the course unit 401-0002-99L Generic Seminar - Second Priority / Third Priority.
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0002-99L</td>
<td>Generic Seminar - Second Priority / Third Priority</td>
<td>E-</td>
<td>0</td>
<td>not available</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Here you can indicate seminars of second and third priority if you cannot be admitted to your preferred seminar. Use the &quot;Group assignment&quot; in myStudies.</td>
<td></td>
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</tr>
<tr>
<td>401-3050-72L</td>
<td>Student Seminar in Combinatorics</td>
<td>W</td>
<td>4</td>
<td>2S</td>
<td>B. Sudakov</td>
</tr>
<tr>
<td>Abstract</td>
<td>The seminar will consist of student presentations and will cover a variety of topics in modern-day combinatorics. The seminar is aimed at third year bachelor students or master students with a background in combinatorics (e.g. the Graph Theory course).</td>
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<tr>
<td>Objective</td>
<td>The seminar's aim is to acquaint students with interesting results, proofs and techniques in combinatorics and graph theory, and to give them the opportunity to work with advanced research papers and practice their presentation skills.</td>
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<tr>
<td>401-3140-74L</td>
<td>Student Seminar in Numerical Algebraic Geometry</td>
<td>W</td>
<td>4</td>
<td>2S</td>
<td>C. Meroni</td>
</tr>
<tr>
<td>Abstract</td>
<td>Numerical algebraic geometry is a research area that aims to use numerical methods to solve systems of polynomial equations. Sometimes, these numerical algorithms can be turned into theoretical, exact proofs, as we will see. The lectures will cover two major research directions in numerical algebraic geometry: the theory of normal forms and homotopy continuation methods.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<td></td>
<td>Concepts and Theories</td>
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<td>fostered</td>
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<td></td>
<td>Techniques and Technologies</td>
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<td>fostered</td>
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<td>Method-specific Competencies</td>
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<td></td>
<td>Problem-solving</td>
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<td>fostered</td>
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<td></td>
<td>Social Competencies</td>
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<tr>
<td></td>
<td>Communication</td>
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<td></td>
<td>Cooperation and Teamwork</td>
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<td>fostered</td>
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<tr>
<td></td>
<td>Personal Competencies</td>
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<tr>
<td></td>
<td>Adaptability and Flexibility</td>
<td></td>
<td></td>
<td></td>
<td>fostered</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td></td>
<td></td>
<td></td>
<td>fostered</td>
</tr>
<tr>
<td>401-3620-74L</td>
<td>Student Seminar in Statistics: ...</td>
<td>W</td>
<td>4</td>
<td>2S</td>
<td>Y. Chen</td>
</tr>
<tr>
<td>Number of participants limited to 24.</td>
<td>Number of participants limited to 24.</td>
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</tr>
<tr>
<td>Mainly for students from the Mathematics Bachelor and Master Programmes who, in addition to the introductory course unit 401-2604-00L Probability and Statistics, have heard at least one core or elective course in statistics.</td>
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<tr>
<td>Also offered in the Master Programmes Statistics resp. Data Science.</td>
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<tr>
<td>401-3940-74L</td>
<td>Student Seminar in Mathematics and Data Science: Statistical-to-Computational Gaps</td>
<td>W</td>
<td>4</td>
<td>2S</td>
<td>A. Bandeira, further speakers</td>
</tr>
<tr>
<td>401-3650-74L</td>
<td>Port-Hamiltonian Systems: Mathematical Aspects</td>
<td>W</td>
<td>4</td>
<td>2S</td>
<td>R. Hiptmair</td>
</tr>
<tr>
<td>Number of participants limited to 12.</td>
<td>Number of participants limited to 12.</td>
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<tr>
<td>Abstract</td>
<td>The seminar covers theory and applications of port-Hamiltonian system models based on current literature. The various topics have to be presented by groups of students.</td>
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<tr>
<td>Objective</td>
<td>Participants of the seminar should acquire familiarity with the concept of port-Hamiltonian systems and the relevant mathematical theory for their analysis. They should be enabled to devise and understand port-Hamiltonian models of physical systems.</td>
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</tr>
<tr>
<td>Content</td>
<td>Port-Hamiltonian provide a mathematical framework for the modeling of complex (multi-physics) systems, of their dynamical behavior, for understanding their stability and effective control. They are based on geometric structure and represent a generalization of Hamiltonian systems towards open systems. The building blocks of port-Hamiltonian systems are thought to interact by exchanging energy. So the main focus of port-Hamiltonian modeling is on accurately representing the flow, storage, and dissipation of energy.</td>
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<tr>
<td>Literature</td>
<td>Good skills in linear algebra and ordinary differential equations are required</td>
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<tr>
<td>Prerequisites / notice on</td>
<td>Preparatory meeting on</td>
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<tr>
<td>Competencies</td>
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<td></td>
<td>Concepts and Theories</td>
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<td>assessed</td>
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<tr>
<td></td>
<td>Analytical Competencies</td>
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<td>assessed</td>
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<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td></td>
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<td></td>
<td>Problem-solving</td>
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<td>fostered</td>
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<td>Social Competencies</td>
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<td>Communication</td>
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<tr>
<td></td>
<td>Cooperation and Teamwork</td>
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<td></td>
<td>Personal Competencies</td>
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<td>Critical Thinking</td>
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<td>assessed</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
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<td>assessed</td>
</tr>
<tr>
<td>401-3650-73L</td>
<td>Numerical Analysis Seminar</td>
<td>W</td>
<td>4</td>
<td>2S</td>
<td>C. Schwab</td>
</tr>
<tr>
<td>Does not take place this semester.</td>
<td>Does not take place this semester.</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1912 of 2653
### Semester Papers

There are several course units "Semester Paper" that are all equivalent. If, during your studies, you write several semester papers, choose among the different numbers in order to be able to obtain credits again.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3750-01L</td>
<td>Semester Paper ■ Successful participation in the course unit 401-2000-00L</td>
<td>W</td>
<td>8 credits</td>
<td>11A</td>
<td>Supervisors</td>
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<tr>
<td></td>
<td>Scientific Works in Mathematics is required.</td>
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<td>For more information, see</td>
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<td></td>
<td><a href="https://math.ethz.ch/intranet/students/theses.html">https://math.ethz.ch/intranet/students/theses.html</a></td>
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<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Semester Papers help to deepen the students' knowledge of a specific subject area. Students are offered a selection of topics. These papers serve to develop the students' ability for independent mathematical work as well as to enhance skills in presenting mathematical results in writing.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>There are several course units &quot;Semester Paper&quot; that are all equivalent. If, during your studies, you write several semester papers, choose among the different numbers in order to be able to obtain credits again.</td>
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</tr>
<tr>
<td>401-3750-02L</td>
<td>Semester Paper (No. 2) ■ Successful participation in the course unit 401-2000-00L</td>
<td>W</td>
<td>8 credits</td>
<td>11A</td>
<td>Supervisors</td>
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<tr>
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<td>Scientific Works in Mathematics is required.</td>
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<td>For more information, see</td>
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<td></td>
<td><a href="https://math.ethz.ch/intranet/students/theses.html">https://math.ethz.ch/intranet/students/theses.html</a></td>
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<tr>
<td>Abstract</td>
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<tr>
<td>Prerequisites / notice</td>
<td>There are several course units &quot;Semester Paper&quot; that are all equivalent. If, during your studies, you write several semester papers, choose among the different numbers in order to be able to obtain credits again.</td>
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<tr>
<td>401-3750-03L</td>
<td>Semester Paper (No. 3) ■ Successful participation in the course unit 401-2000-00L</td>
<td>W</td>
<td>8 credits</td>
<td>11A</td>
<td>Supervisors</td>
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<tr>
<td></td>
<td>Scientific Works in Mathematics is required.</td>
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<td>For more information, see</td>
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<td><a href="https://math.ethz.ch/intranet/students/theses.html">https://math.ethz.ch/intranet/students/theses.html</a></td>
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<tr>
<td>Abstract</td>
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<tr>
<td>Prerequisites / notice</td>
<td>There are several course units &quot;Semester Paper&quot; that are all equivalent. If, during your studies, you write several semester papers, choose among the different numbers in order to be able to obtain credits again.</td>
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</tbody>
</table>

### Science in Perspective

Two credits are needed from the "Science in Perspective" programme with language courses excluded if three credits from language courses have already been recognised for the Bachelor's degree. see https://ethz.ch/content/dam/ethz/common/docs/weisungsammlung/files-en/science-in-perspective.pdf (Eight credits must be acquired in this category: normally six during the Bachelor's degree programme, and two during the Master's degree programme. A maximum of three credits from language courses from the range of the Language Center of the University of Zurich and ETH Zurich may be recognised. In addition, only advanced courses (level B2 upwards) in the European languages English, French, Italian and Spanish are recognised. German language courses are recognised from level C2 upwards.)

- see Science in Perspective: Language Courses ETH/UZH
- see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-MATH

### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-2000-00L</td>
<td>Scientific Works in Mathematics</td>
<td>O</td>
<td>0 credits</td>
<td>D. Possamaï</td>
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<tr>
<td></td>
<td>Target audience:</td>
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<td></td>
<td>Third year Bachelor students; Master students who cannot document to have received an adequate training in working scientifically.</td>
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<tr>
<td>Abstract</td>
<td>Introduction to scientific writing for students with focus on publication standards and ethical issues, especially in the case of citations (references to works of others.)</td>
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<tr>
<td>Objective</td>
<td>Learn the basic standards of scientific works in mathematics.</td>
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<tr>
<td>Content</td>
<td>- Types of mathematical works</td>
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<td></td>
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<td></td>
<td>- Publication standards in pure and applied mathematics</td>
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<tr>
<td></td>
<td>- Data handling</td>
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<td></td>
<td>- Ethical issues</td>
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<td></td>
<td>- Citation guidelines</td>
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<tr>
<td>401-2000-01L</td>
<td>Lunch Sessions – Thesis Basics for Mathematics Students</td>
<td>Z</td>
<td>0 credits</td>
<td></td>
<td>Speakers</td>
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<td></td>
<td>Details and registration for the optional MathBib training course: <a href="https://www.math.ethz.ch/mathbib-schulungen">https://www.math.ethz.ch/mathbib-schulungen</a></td>
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<tr>
<td>Abstract</td>
<td>Optional MathBib training course</td>
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<tr>
<td>401-4990-00L</td>
<td>Master's Thesis ■ Only students who fulfil the following criteria are allowed to begin with their Master's thesis: a. successful completion of the Bachelor's programme; b. fulfilling of any additional requirements necessary to gain admission to the Master's programme.</td>
<td>O</td>
<td>30 credits</td>
<td>57D</td>
<td>Supervisors</td>
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<tr>
<td></td>
<td>Successful participation in the course unit 401-2000-00L</td>
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</table>
Scientific Works in Mathematics is required. For more information, see https://math.ethz.ch/intranet/students/theses.html

Abstract

The master's thesis concludes the study programme. Writing up the master's thesis allows students to independently produce a major piece of work on a mathematical topic. It generally involves consulting the literature, solving any ensuing problems, and putting together the results in writing.

Additional Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-5000-00L</td>
<td>Zurich Colloquium in Mathematics</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>A. Bandeira, S. Mishra, R. Pandharipande, University lecturers</td>
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<tr>
<td>401-5990-00L</td>
<td>Zurich Graduate Colloquium</td>
<td>E-</td>
<td>0</td>
<td>0.5K</td>
<td>University lecturers, further speakers</td>
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<tr>
<td>401-4530-00L</td>
<td>Geometry Graduate Colloquium</td>
<td>E-</td>
<td>0</td>
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<td>Speakers</td>
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<tr>
<td>401-5110-00L</td>
<td>Number Theory Seminar</td>
<td>E-</td>
<td>0</td>
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<td>Ö. Imamoglu, E. Kowalski, G. Wüstholz, S. Zerbes</td>
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<tr>
<td>401-5350-00L</td>
<td>Analysis Seminar</td>
<td>E-</td>
<td>0</td>
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<td>F. Da Lio, N. Hungerbühler, T. Ilmanen, L. Kobel-Keller, S. Mayboroda, J. Serra, University lecturers</td>
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<td>401-5370-00L</td>
<td>Ergodic Theory and Dynamical Systems</td>
<td>E-</td>
<td>0</td>
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<td>M. Akka Ginosar, M. Einsiedler, University lecturers</td>
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<tr>
<td>401-5530-00L</td>
<td>Geometry Seminar</td>
<td>E-</td>
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<td>1K</td>
<td>M. Burger, M. Einsiedler, U. Lang, further speakers</td>
</tr>
<tr>
<td>401-5580-00L</td>
<td>Symplectic Geometry Seminar</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>P. Biran, A. Cannas da Silva</td>
</tr>
<tr>
<td>401-5530-00L</td>
<td>Talks in Mathematical Physics</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>M. Gaberdiel, G. M. Graf, P. Hintz, T. H. Willwacher</td>
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<tr>
<td>401-5650-00L</td>
<td>Zurich Colloquium in Applied and Computational Mathematics</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>R. Alalfi, H. Ammari, R. Hiptmair, S. Mishra, C. Schwab</td>
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<tr>
<td>401-5600-00L</td>
<td>Seminar on Stochastic Processes</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>A. Nikeghbali</td>
</tr>
<tr>
<td>401-5620-00L</td>
<td>Research Seminar on Statistics</td>
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<td>0</td>
<td>1K</td>
<td>Y. Chen, N. Meinhausen, J. Peters, J. Ziegel, A. Bandeira, R. Furrer, T. Hothorn</td>
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<tr>
<td>401-5680-00L</td>
<td>Foundations of Data Science Seminar</td>
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<td>0</td>
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<td>A. Bandeira, H. Bölcskei, J. Peters, F. Yang</td>
</tr>
<tr>
<td>401-5660-00L</td>
<td>DACO Seminar</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>A. Bandeira, R. Weismantel, R. Zenklusen</td>
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<tr>
<td>401-5910-00L</td>
<td>Talks in Financial and Insurance Mathematics</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>B. Acciaio, P. Cheridito, D. Possamai, J. Teichmann</td>
</tr>
<tr>
<td>401-5960-00L</td>
<td>Colloquium on Mathematics, Computer Science, and</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>N. Hungerbühler, M. Akveld,</td>
</tr>
</tbody>
</table>
Abstract

Subject didactics for mathematics and computer science teachers.

D. Gruehr Morath, D. Komm, P. Spindler

Abstract

Didactics colloquium

Research colloquium

The goal of this event is to bring you closer to current day research in all fields of physics. In each semester we have a set of distinguished speakers covering the full range of topics in physics. As a participating student should learn to follow a research talk. In particular, you should be able to extract key points from a colloquium where you don't necessarily understand every detail that is presented.

Abstract

Research colloquium

The Zurich Theoretical Physics Colloquium is jointly organized by the University of Zurich and ETH Zurich. Its mission is to bring both students and faculty with diverse interests in theoretical physics together. Leading experts explain the basic questions in their field of research and communicate the fascination for their work.

Abstract

Computer Science Colloquium

Invited talks, covering the entire scope of computer science. External Listeners are welcome at no charge. A detailed schedule is published at the beginning of each semester.

Objective

Top international computer scientists take the floor at the distinguished computer science colloquium. Our guest speakers present impacting topics across various areas of the discipline. The colloquium series is held every semester and also includes inaugural and farewell lectures of the department’s professors. The colloquium is a noteworthy event for all graduate students. Outside attendance is equally welcome.

Content

Renowned international computer scientists take the floor at our distinguished colloquium series, to present topics across all areas of computer science.

Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>406-2004-AAL</td>
<td>Algebra II</td>
<td>E-</td>
<td>6 credits</td>
<td>13R</td>
<td>Ö. Imamoglu</td>
</tr>
<tr>
<td>406-2005-AAL</td>
<td>Algebra I and II</td>
<td>E-</td>
<td>12 credits</td>
<td>26R</td>
<td>Ö. Imamoglu, L. Halbeisen</td>
</tr>
</tbody>
</table>

Prerequisites / notice

Algebra I, in Rotman’s book this corresponds to the topics treated in the Chapters A3 and A4.

Literature

Joseph J. Rotman, "Advanced Modern Algebra" third edition, part 1, Graduate Studies in Mathematics, Volume 165
American Mathematical Society

Galois Theory is the topic treated in Chapter A5.

Or: Chapters I to III, that is, Sections 1-16 of the book
Patrick Morandi: Field and Galois Theory, Springer 1996

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies assessed

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies assessed

Basic notions and examples of groups;
Subgroups, Quotient groups and Homomorphisms,
Group actions and applications

Basic notions and examples of rings;
Ring Homomorphisms,
ideals, and quotient rings, rings of fractions
Euclidean domains, Principal ideal domains, Unique factorization domains

Basic notions and examples of fields;
Field extensions, Algebraic extensions, Classical straight edge and compass constructions

Fundamentals of Galois theory
Representation theory of finite groups and algebras

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>ECTS</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>406-2303-AAL</td>
<td>Complex Analysis</td>
<td>6</td>
<td>13R</td>
<td>Ö. Imamoglu</td>
</tr>
<tr>
<td>406-2554-AAL</td>
<td>Topology</td>
<td>7</td>
<td>15R</td>
<td>E. Kowalski</td>
</tr>
<tr>
<td>406-2604-AAL</td>
<td>Probability and Statistics</td>
<td>8</td>
<td>17R</td>
<td>F. Balabdaoui</td>
</tr>
</tbody>
</table>

**Complex Analysis**

- Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
- Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**

Complex functions of one variable, Cauchy-Riemann equations, Cauchy theorem and integral formula, singularities, residue theorem, index of closed curves, analytic continuation, conformal mappings, Riemann mapping theorem.

**Literature**

- R. Remmert: Theory of Complex Functions. Springer Verlag
- E. Hille: Analytic Function Theory. AMS Chelsea Publication

**Topology**

- Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
- Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**

Topological spaces, continuous maps, connectedness, compactness, metric spaces, quotient spaces, homotopy, fundamental group and covering spaces, van Kampen Theorem.

**Literature**

- Jänich: Topology
- Hatcher: Algebraic Topology

**Probability and Statistics**

- Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
- Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**

- Probability spaces
- Discrete models, Random walk
- Conditional probabilities, independence
- Continuous models
- Limit theorems
- Methods of moments
- Maximum likelihood estimation
- Hypothesis testing
- Confidence intervals
- Introductory Bayesian statistics
- Linear regression model

**Objective**

The first part of the course gives an overview of the main concepts needed to understand probability theory (sample spaces, discrete models, random walk, continuous models and limit theorems such as the Laws of Large Numbers and the Central limit theorem). It will be based on the German script "Wahrscheinlichkeitsrechnung und Statistik".

The second part covers some fundamental results of mathematical statistics including estimation methods, hypothesis testing as well as the linear regression model. For this part, we will use the script "Statistics for Mathematics". Both scripts are available at https://www.stat.math.ethz.ch/~fadouab/

**Content**

- Chapters 1-5 (Probabilities and events, Discrete and continuous random variables, Generating functions) and Sections 7.1-7.5 (Convergence of random variables) from the book "Probability and Random Processes". Most of this material is also covered in Chap. 1-5 of "Mathematical Statistics and Data Analysis", on a slightly easier level.


**Lecture notes**

- (*) Wahrscheinlichkeitsrechnung und Statistik
- (*) Statistics for Mathematics

Both scripts can be found at https://www.stat.math.ethz.ch/~fadouab/
### Literature

### 401-2003-AAL Algebra I
- **Enrolment:** ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
- **Credits:** 7 credits
- **ECTS:** 15R
- **Instructor:** L. Halbeisen

### Prerequisites / notice
- Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.
- The precise content changes with the examiner. Candidates must therefore contact the examiner in person before studying the material.

### 401-2283-AAL Analysis III (Measure Theory)
- **Enrolment:** ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
- **Credits:** 6 credits
- **ECTS:** 13R
- **Instructor:** F. Da Lio

### 401-2464-AAL Analysis IV (Fourier Theory and Hilbert Spaces)
- **Enrolment:** ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
- **Credits:** 6 credits
- **ECTS:** 13R
- **Instructor:** M. Iacobelli

### 401-2465-AAL Analysis III and IV (Measure Theory / Fourier Theory and Hilbert Spaces)
- **Enrolment:** ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
- **Credits:** 12 credits
- **ECTS:** 26R
- **Instructor:** F. Da Lio, M. Iacobelli

### 401-2334-AAL Mathematical Methods of Physics II
- **Enrolment:** ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
- **Credits:** 6 credits
- **ECTS:** 13R
- **Instructor:** T. H. Willwacher

### Mathematics Master - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>E-</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
</tr>
</tbody>
</table>
|     |                       | E-     | Recommended, not eligible for credits
|     |                       | Z      | Courses outside the curriculum
|     |                       | Dr     | Suitable for doctorate

### Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
</table>
| V   | lecture               | P      | practical/laboratory course
| G   | lecture with exercise | A      | independent project
| U   | exercise              | D      | diploma thesis
| S   | seminar               | R      | revision course / private study
| K   | colloquium            |        |

### ECTS
- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
Micro- and Nanosystems Master

Core Courses

Devices and Systems

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0166-00L</td>
<td>Analog Integrated Circuits</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>T. Jang</td>
</tr>
</tbody>
</table>

**Abstract**
This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies.

**Objective**
Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.

**Content**
- Review of bipolar and MOS devices and their small-signal equivalent circuit models.
- Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc.
- Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors.
- The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.

**Lecture notes**
Handouts of presented slides. No script but an accompanying textbook is recommended.

**Literature**

Energy Conversion and Quantum Phenomena

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0913-00L</td>
<td>Introduction to Photonics</td>
<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>R. Quidant, J. Ortega Arroyo</td>
</tr>
</tbody>
</table>

**Abstract**
This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

**Objective**
Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practice. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.
### Content

1. Introduction to nanophotonics
2. Wave physics for nanophotonics
3. Characterization of nanomaterials
4. Semiconductors
5. Nonlinear crystals
6. Photonic integrated circuits
7. Optical quantum devices
8. Plasmonics
9. Metasurfaces
10. Graphene & 2D Materials
11. Nanocomposites

### Lecture notes

Slides and book chapter will be available for downloading.

### Literature

References will be given during the lecture.

### Prerequisites / notice

Basics of solid-state physics (i.e. energy bands) can help.

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>fostered</td>
</tr>
<tr>
<td>Decision-making</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td>Leadership and Responsibility</td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Leadership and Responsibility</td>
<td>fostered</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
</tr>
</tbody>
</table>

### 402-0595-00L Semiconductor Nanostructures

**Abstract**

The course covers the foundations of semiconductor nanostructures, e.g., materials, band structures, bandgap engineering and doping, field-effect transistors. The physics of the quantum Hall effect and of common nanostructures based on two-dimensional electron gases will be discussed, i.e., quantum point contacts, Aharonov-Bohm rings and quantum dots.

**Objective**

At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:
1. The integer quantum Hall effect
2. Conductance quantization in quantum point contacts
3. the Aharonov-Bohm effect
4. Coulomb blockade in quantum dots

**Content**

1. Introduction and overview
2. Semiconductor crystals: Fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k.p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

**Lecture notes**


**Literature**

In addition to the lecture notes, the following supplementary books can be recommended:

**Prerequisites / notice**

The lecture is suitable for all physics students, students of Quantum Engineering, and students of Micro- and Nanosystems beyond the bachelor of science degree. Basic knowledge of solid state physics is a prerequisite. Very ambitioned students in the third year of Physics may be able to follow. The lecture can be chosen as part of the PhD-program. The course is taught in English.
### Material, Surfaces and Properties

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0509-00L</td>
<td>Acoustics in Fluid Media: From Robotics to Additive Manufacturing</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>D. Ahmed</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>The course will provide you with the fundamentals of the new and exciting field of ultrasound-based microrobots to treat various diseases. Furthermore, we will explore how ultrasound can be used in additive manufacturing for tissue constructs and robotics.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The course is designed to equip students with skills in the design and development of ultrasound-based manipulation devices and microrobots for applications in medicine and additive manufacturing.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobots to surface acoustic wave devices</td>
<td></td>
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</tr>
<tr>
<td><strong>Literature</strong></td>
<td>Microscale Acoustofluidics, T. Laurell and A. Lenshof, Ed., Royal Society of Chemistry, 2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.</td>
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<tr>
<td><strong>Competencies</strong></td>
<td><strong>Subject-specific Competencies</strong></td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<td><strong>Method-specific Competencies</strong></td>
<td>Analytical Competencies</td>
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<td></td>
<td></td>
<td>Media and Digital Technologies</td>
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<td></td>
<td>Decision-making</td>
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<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Project Management</td>
<td>fostered</td>
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<tr>
<td></td>
<td><strong>Social Competencies</strong></td>
<td>Communication</td>
<td>fostered</td>
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<td></td>
<td></td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<td></td>
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<td>Customer Orientation</td>
<td>fostered</td>
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<td></td>
<td>Leadership and Responsibility</td>
<td>fostered</td>
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<td></td>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
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<td>Negotiation</td>
<td>fostered</td>
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<tr>
<td></td>
<td><strong>Personal Competencies</strong></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<td>Self-direction and Self-management</td>
<td>assessed</td>
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<tr>
<td>151-0524-00L</td>
<td>Continuum Mechanics I</td>
<td>W+</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>A. E. Ehret</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The lecture deals with constitutive models that are relevant for the design and analysis of components and structures. These include anisotropic linear elasticity, linear viscoelasticity, plasticity and viscoplasticity. The basic concepts of homogenization and laminate theory are introduced. Theoretical models are complemented by examples of engineering applications and experiments.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>After successful completion of the course students are able to</td>
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<tr>
<td></td>
<td>• explain basic theories for solving continuum mechanics problems</td>
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<td>• proficiently apply these theories by solving application-related academic examples</td>
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<td>• relate the theories and examples to real engineering applications and challenges</td>
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<td>• distinguish between different mechanical behaviors of materials</td>
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<td>• systematically select appropriate constitutive theories suitable to analyze and model these materials</td>
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<tr>
<td><strong>Content</strong></td>
<td>Anisotropic Elasticity, Linear Elastic and Linear Viscous Material Behavior, Viscoelasticity, Micro-Macro Modelling, Laminate Theory, Plasticity, Viscoplasticity, Examples of Engineering Applications, Comparison with Experiments</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>yes</td>
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<tr>
<td><strong>Competencies</strong></td>
<td><strong>Subject-specific Competencies</strong></td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td></td>
<td><strong>Method-specific Competencies</strong></td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Decision-making</td>
<td>fostered</td>
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<td></td>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
<td></td>
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<tr>
<td></td>
<td><strong>Social Competencies</strong></td>
<td>Communication</td>
<td>fostered</td>
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<tr>
<td></td>
<td></td>
<td>Cooperation and Teamwork</td>
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<tr>
<td>327-0505-00L</td>
<td>Surfaces and Interfaces I: Fundamentals, Analytics and Applications</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>L. Isa, M. P. Heuberger</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>This course teaches the basics of surface and interface science and technology, including surface modifications and forces. It covers various analytical techniques to study surface and interface properties, and explores phenomena of applied relevance like friction, lubrication, phoresis, and wetting where surfaces play a crucial role.</td>
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Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main

Physical Modelling and Simulation

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<th>Lecturers</th>
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<tr>
<td>227-2037-00L</td>
<td>Physical Modelling and Simulation</td>
<td>W+</td>
<td>6 credits</td>
<td>4G</td>
<td>J. Smajic</td>
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</table>

Objective

- understand and explain the importance of surfaces and interfaces in a broad range of phenomena and applications.

Content

- Introduction to surfaces and interfaces
- Structure of surfaces over different length scales: from macroscopic roughness to atomic structure
- Surface modifications
- Adsorption and adsorption models
- Surface forces
- Basic physical concepts
- Thermodynamics of surfaces and interfaces
- Measurement of intermolecular and surface forces
- Dynamics and history effects
- Surface analytics: X-ray Photoelectron Spectroscopy (XPS) – principles and modern developments
- Surface analytics: Secondary Ion Mass Spectroscopy (SIMS) and IR Spectroscopy – Principles and examples
- Atomic Force Microscopy (AFM): Principles and modes of operation
- Tribology: Adhesion, Friction and Lubrication
- Contact mechanics
- Micro and macroscale friction
- Boundary lubrication
- Wetting
- Contact angles
- Phoretic phenomena
- Electric double layer and electrophoresis
- Electro-osmosis
- Other types of phoresis
- Case studies

Lecture notes

Script Download: https://moodle-app2.let.ethz.ch/course/view.php?id=17455

Literature

Script Download: https://moodle-app2.let.ethz.ch/course/view.php?id=17455


Prerequisites / notice

Chemistry:
- General undergraduate chemistry including basic chemical kinetics and thermodynamics

Physics:
- General undergraduate physics including basic theory of interatomic and intermolecular forces, atomic and crystalline structure of materials and their mechanical and electronic properties

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Personal Competencies
- Creative Thinking
- Critical Thinking

Modelling and Simulation

Physical Modelling and Simulation

This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.

Objective

Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

Content

The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or choose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

Laboratory Course

Embedded MEMS Lab

Practical course: Students are introduced to the process steps required for the fabrication of MEMS (Micro Electro Mechanical System) and carry out the fabrication and testing steps in the clean rooms by themselves. Additionally, they learn the requirements for working in clean rooms. Processing and characterization will be documented and analyzed in a final report.

Objective

Students learn the individual process steps that are required to make a MEMS (Micro Electro Mechanical System). Students carry out the process steps themselves in laboratories and clean rooms. Furthermore, participants become familiar with the special requirements (cleanliness, safety, operation of equipment and handling hazardous chemicals) of working in the clean rooms and laboratories. The entire production, processing, and characterization of the MEMS is documented and evaluated in a final report.
Content
With guidance from a tutor, the individual silicon microsystem process steps that are required for the fabrication of an accelerometer are carried out:
- Photolithography, dry etching, wet etching, sacrificial layer etching, various cleaning procedures
- Packaging and electrical connection of a MEMS device
- Testing and characterization of the MEMS device
- Written documentation and evaluation of the entire production, processing and characterization

Lecture notes
A document containing theory, background and practical course content is distributed at the Introductory lecture day of the course.

Literature
The document provides sufficient information for the participants to successfully participate in the course.

Prerequisites / notice
Participating students are required to attend all scheduled lectures and meetings of the course.

For safety and efficiency reasons the number of participating students is limited. We regret to restrict access to this course by the following rules:

Priority 1: master students of the master's program in "Micro and Nanosystems"

Priority 2: master students of the master's program in "Mechanical Engineering" with a specialization in Microsystems and Nanoscale Engineering (MAVT-tutors Profs Daraio, Dual, Hierold, Koumoutsakos, Nelson, Norris, Poulikakos, Pratsinis, Stemmer), who attended the bachelor course *151-0621-00L Microsystems Technology* successfully.

Priority 3: master students, who attended the bachelor course *151-0621-00L Microsystems Technology* successfully.

Priority 4: all other students (PhD, bachelor, master) with a background in silicon or microsystems process technology.

If there are more students in one of these priority groups than places available, we will decide by (in following order) best achieved grade from 151-0621-00L Microsystems Technology, registration to this practicum at previous semester, and by drawing lots.

Students will be notified at the first lecture of the course (introductory lecture) as to whether they are able to participate.

The course is offered in autumn and spring semester.

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<tr>
<td>151-0409-00L</td>
<td>Multiphysics Modeling and Simulation</td>
<td>W</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>C. I. Roman</td>
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Abstract
This class introduces both theoretical and practical aspects related to the modeling and simulation of multiphysics systems. Students will learn how to set up multiphysics models systematically, and therefore reduce time-consuming trial-and-error. Comsol Multiphysics will be utilized to apply the concepts learned during the lectures to solve exercises.

Objective
As information technology continues its fast-paced evolution, solid-state devices and systems increase in complexity. Engineers and scientists are thus increasingly facing the need to model and simulate their problems numerically where analytic textbook solution cease to exist. Moreover, boundaries between traditional disciplines are harder to maintain, as a proper description of the system might involve phenomena from several domains. Examples include—but not limited to—mechatronics which relies on mechanical, electrical and electronic engineering, and transducers (sensors and actuators) which are by definition devices that convert signals from one physical domain to another. Simulation platforms such as Comsol Multiphysics have truly opened the way to easy multi-domain numerical simulation, offering tools that cover all operations from geometry definition, to meshing, to physics and boundary conditions setting to simulation and result post-processing and analysis in a unified, domain-independent fashion. However, this high degree of freedom has its price, as inexperienced users may face cryptic error messages, incomprehensible or even incorrect results. It is the mission of this course to show how to properly set up a problem by exposing some of the most common misconceptions and pitfalls in multiphysics modeling. Good practices will be taught that should simplify the modeling process and increase the likelihood of correct results. Examples will mainly come from the fields of mechanics (continuum solid mechanics), electromagnetism (electrostatics and conductive media), heat transfer (conductive not convective) and combinations of these domains.

Content
- Recap of ordinary and partial differential equations
- The Finite Element Method (and the Method of Lines)
- Numerical solvers
- Geometry simplification and discretization
- Continuous and discrete symmetries
- Approximate and simplified formulations; domains of applicability
- Boundary conditions and constraints
- Solution-appropriate discretization; hp-refinement, local/global adaptive meshing
- Ramping of nonlinearities and couplings
- Coupling and segregation of multiphysics

Lecture notes
Lecture handouts will be posted online.
### Dynamic Behavior of Materials

**Abstract**
Lectures and computer labs concerned with the modeling of the deformation response and failure of engineering materials (metals, polymers and composites) subject to extreme loadings during manufacturing, crash, impact and blast events.

**Objective**
Students will learn to apply, understand and develop computational models of a large spectrum of engineering materials to predict their dynamic deformation response and failure in finite element simulations. Students will become familiar with important dynamic testing techniques to identify material model parameters from experiments. The ultimate goal is to provide the students with the knowledge and skills required to engineer modern multi-material solutions for high performance structures in automotive, aerospace and naval engineering.

**Content**
Topics include temperature and strain rate dependent elasto-plasticity, dynamic brittle and ductile fracture; impulse transfer, impact and wave propagation in solids; computational aspects of material model implementation; simulation of dynamic failure of structures.

**Lecture notes**
The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

**Prerequisites / notice**
Course in continuum mechanics (mandatory), finite element method (recommended).

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### Nonlinear Dynamics and Chaos I

**Abstract**
Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

**Objective**
This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.

**Content**
(1) Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.

(2) Near equilibrium dynamics: Linear and Lyapunov stability

(3) Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations

(4) Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.

(5) Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

**Lecture notes**
The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

**Prerequisites / notice**
- Prerequisites: Analysis, linear algebra and a basic course in differential equations.

### Embedded Control Systems

**Abstract**
This course provides a comprehensive overview of embedded control systems. The concepts introduced are implemented and verified on a microprocessor-controlled haptic device.

**Objective**
Familiarize students with main architectural principles and concepts of embedded control systems.
Molecular sensors are used in everyday life in health care, environmental monitoring, food safety, space and other fields. Sources of molecular information, its transport and fundamental concepts of molecular sensing will be discussed. In the scope of group projects, the acquired knowledge will be applied and deepened in case studies.

Subjects covered in lectures and practical lab exercises include:
- The application of C-programming on a microprocessor
- Digital I/O and serial communication
- Quadrature decoding for wheel position sensing
- Queued analog-to-digital conversion to interface with the analog world
- Pulse width modulation
- Timer interrupts to create sampling time intervals
- System dynamics and virtual worlds with haptic feedback
- Introduction to rapid prototyping

This course is restricted to 33 students due to limited lab infrastructure. Interested students please contact Marianne Schmid Daners (E-Mail: marischm@ethz.ch) After your reservation has been confirmed please register online at www.mystudies.ethz.ch

Detailed information can be found on the course website http://www.idsc.ethz.ch/education/lectures/embedded-control-systems.html

### 151-0621-00L Microsystems I: Process Technology and Integration

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<tr>
<th>W</th>
<th>6 credits</th>
<th>3V+2U</th>
<th>M. Haluska, C. Hierold</th>
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<tr>
<td><strong>Objective</strong></td>
<td>Students are introduced to the fundamentals of micromachining, the basics of micromachining and silicon process technology and will learn about the fabrication of Microsystems and -devices by a sequence of defined processing steps (process flow).</td>
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| **Content** | - Introduction to Microsystems technology (MST) and micro electro mechanical systems (MEMS)  
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.  
- Specific micromachining technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties. |
| **Lecture notes** | Handouts (available online) |
| **Literature** | - S.M. Sze: Semiconductor Devices, Physics and Technology  
- W. Menz, J. Mohr, O.Paul: Microsystems Technology  
- Hong Xiao: Introduction to Semiconductor Manufacturing Technology  
- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications |

### 151-0642-00L Seminar on Micro and Nanosystems

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| **Objective** | Scientific presentations from the field of Micro- and Nanosystems  
In particular, the seminar addresses students, who are interested in scientific work in the field of Micro- and Nanosystem technologies, or who have started already with it. Respectively, current examples in the research will be discussed. |
| **Content** | Current themes in the field of Micro- and Nanosystem technologies using the examples of intern and extern research groups, as well as ongoing themes of study-, diplom- and doctoral thesis will be introduced and discussed. The scope of the seminar is broadened by occasional guest speakers. |

### 151-0941-00L Molecular Sensors: From Fundamentals to Health and Environmental Applications

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<th>A. Günntner, P. Gerber</th>
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<td><strong>Abstract</strong></td>
<td>Molecular sensors are used in everyday life in health care, environmental monitoring, food safety, space and other fields. Sources of molecular information, its transport and fundamental concepts of molecular sensing will be discussed. In the scope of group projects, the acquired knowledge will be applied and deepened in case studies.</td>
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| **Objective** | After the course, the students will:  
• know the requirements and merits of molecular sensors for health, environmental and other emerging applications (e.g. space)  
• understand transport phenomena of molecular information & surface interactions and know how to quantitatively describe these  
• understand fundamental sensing concepts for the detection and quantification of molecular analytes  
• know concepts of signal processing  
• be capable to apply the learnt knowledge to conceive and engineer sensor concepts and systems  
• know how to investigate sensor-related literature and present scientific data |

This course consists of a theoretical and a project-based learning block. In the first 10 semester weeks, theoretical knowledge will be provided through lectures and deepened in corresponding exercises. In the last 4 weeks, the students will apply the learned concepts through group projects to investigate case studies. The outcome will be present.

### Content
- Transport of Molecular Information; Surface Interactions; Sensor Fundamentals; Chemoresistive Sensing; Electrochemical Sensing; Mass-sensitive; Capacitive Sensing; Signal Processing; Medical Requirements for Molecular Sensing

### Lecture notes
Hand-outs will be provided to each lecture including the exercises and their solutions.
## Solid State Electronics and Optics

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### Abstract
"Solid State Electronics" is an introductory condensed matter physics course covering crystal structure, electron models, classification of metals, semiconductors, and insulators, band structure engineering, thermal and electronic transport in solids, magneto-resistance, and optical properties of solids.

### Objective
Understand the fundamental physics behind the mechanical, thermal, electric, magnetic, and optical properties of materials.

### Prerequisites / notice
Undergraduate physics, mathematics, semiconductor devices

### Content
- Transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model).
- Hydrodynamic model, physical characterization of silicon (intrinsic properties, scattering processes), mobility of cold and hot carriers, recombination (Shockley-Read-Hall statistics, Auger recombination), impact ionization, metal-semiconductor contact, metal-insulator-semiconductor structure, and heterojunctions.
- The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

### Lecture notes
The script (in book style) is sufficient. Further reading will be recommended in the lecture.

### Prerequisites / notice

## Semiconductor Devices: Physical Bases and Simulation

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### Abstract
The course addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical simulation. Necessary basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided. Computer simulations of the most important devices and of interesting physical effects supplement the lectures.

### Objective
The course aims at the understanding of the principle physics of modern semiconductor devices, of the foundations in the physical modeling of transport and its numerical simulation. During the course also basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided.

### Content
The main topics are: transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model), physical characterization of silicon (intrinsic properties, scattering processes), mobility of cold and hot carriers, recombination (Shockley-Read-Hall statistics, Auger recombination), impact ionization, metal-semiconductor contact, metal-insulator-semiconductor structure, and heterojunctions.

The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

### Lecture notes
The script (in book style) is sufficient. Further reading will be recommended in the lecture.

### Prerequisites / notice

## Linear System Theory

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### Abstract
The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.

### Objective
Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

### Content
- Proof techniques and practices.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

### Lecture notes
Available on the course Moodle platform.

### Prerequisites / notice
Sufficient mathematical maturity, in particular in linear algebra, analysis.
Content
- Lagrangian and Hamiltonian: Symmetries and Poisson Brackets
- Postulates of QM: Hilbert Spaces and Operators
- Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator
- Density Operator
- Spin: Qubits, Bloch Equations, and NMR
- Entanglement
- Symmetries and Corresponding Operators
- Schrödinger’s Wave Mechanics: Electrons in a Periodic Potential and Energy Bands
- Harmonic Oscillator: Creation and Annihilation Operators
- Identical Particles: Bosons and Fermions
- Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER
- Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener

Objective
This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers.

Abstract
This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers. The way the exam is done allows for the different interests of the two groups.

The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

Content
At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during the whole term to analyze circuits on a system level (analog continuous-time, analog discrete-time, mixed-signal and digital) and understand how signals propagate through them. The theory and CMOS implementation of active Filters is then discussed in detail using the example of Gm-C filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators follows. The link to the practical design of circuits and systems is done with an overview over different quality measures and figures of merit used in scientific literature and datasheets. Finally, an introduction to discrete-time and mixed-domain filters and circuits is given, including sensor read-out amplifiers, correlated double sampling, and chopping, and an introduction to sigma-delta A/D and D/A conversion on a system level.

This lecture does not go down to the details of transistor implementations. The lecture "227-0166-00L Analog Integrated Circuits" complements this lecture very well in that respect.

Lecture notes
No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

Literature

Supplementary material will be uploaded in Moodle.

Prerequisites / notice
The course has been intentionally conceived to be self-consistent with respect to QM for those master students not having encountered it in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) QM introduction course like the D-ITET "Physics II".

A solid base of Analysis I & II as well as of Linear Algebra is really helpful.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity assessed
Negotiation fostered

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

227-0468-00L Analog Signal Processing and Filtering W 6 credits 2V+2U H. Schmid

Suitable for Master Students as well as Doctoral Students.

Authors

Isadore H. Schmid

Autumn Semester 2024
In this course, students will learn about the leading contenders for post-silicon storage-class and main memory technologies. Decades of assessment and research have yielded several efficient memory device working principles, including phase-change of the structure (PCM), materials conversion (OxRAM), ion diffusion (CBRAM), magnetic properties (STT-MRAM, MTJ), and ferroelectricity (FRAM, FeFET). Currently, these memory technologies are transitioning from research to industry, and are predicted to have at least niche applications in the ever-growing hardware market. Some technologies, such as PCM, may even eventually surpass silicon-based flash memory, providing better performance and unique features. Students will have the opportunity to compare emerging memory technologies with state-of-the-art SSD Flash, DRAM, and SRAM, as well as evaluate their potential. Through critical thinking discussions, students will acquire important skills for assessing the strengths and limitations of these emerging technologies. The course is organized as a series of lectures, focusing on selected memory technologies. This class also includes practical laboratory sessions for the PCM research topics. Students will spend 2 hours per week in the class or laboratory and additional 2-3 hours per week to prepare for the exam. Lecture notes will be made available on the website.

The goal of this course is to understand both the standard and the ultimate quantum limits of measurement precision. Does not take place this semester.

The lecture starts with summarizing the relevant fundamentals of the treatment of noisy signals. We familiarize ourselves with the concept of measurement imprecision in light-based measurement systems. To this end, we consider the process of photodetection and discuss the inevitable result of the interaction of the probe with the system under investigation. We discuss the “standard quantum limit” as it arises from the balance of measurement imprecision and backaction, before turning to approaches to overcome it and reach the fundamental “Heisenberg limit”. The course emphasizes the connection between the taught concepts and current state-of-the-art research carried out in the field of optomechanics. Exercises serve to consolidate our understanding and insight.

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227-0621-00L Emerging Memory Technologies W 3 credits 1V+1U M. Yarema

Abstract
This course focuses on the current state and prospects of memory technologies, emerging beyond the silicon transistor era. We explore resistive PCM and RRAM, magnetic MRAM and ferroelectric FRAM memories, covering physics, device aspects and the latest research in the field. Through interactive lectures and laboratory sessions, students gain up-to-date knowledge and compare emerging memory techs.

Objective
In this course, students will learn about the leading contenders for post-silicon storage-class and main memory technologies. Decades of research have yielded several efficient memory device working principles, including phase-change of the structure (PCM), materials conversion (OxRAM), ion diffusion (CBRAM), magnetic properties (STT-MRAM, MTJ), and ferroelectricity (FRAM, FeFET). Currently, these memory technologies are transitioning from research to industry, and are predicted to have at least niche applications in the ever-growing hardware market. Some technologies, such as PCM, may even eventually surpass silicon-based flash memory, providing better performance and unique features.

Content
The course is organized as a series of lectures, focusing on selected memory technologies. This class also includes practical laboratory sessions for the PCM research topics. Students will spend 2 hours per week in the class or laboratory and additional 2-3 hours per week to prepare for the exam.

Literature
Lecture notes will be made available on the website.

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227-0653-00L Quantum Measurements and Optomechanics W 4 credits 2V+1U M. Frimmer

Abstract
The measurement process is at the heart of both science and engineering. The limitations of measurement precision is ultimately dictated by the laws of quantum mechanics. This course provides the knowledge necessary to understand current state-of-the-art quantum measurement systems operating at their fundamental limits with a particular focus on optomechanical implementations.

Objective
The lecture starts with summarizing the relevant fundamentals of the treatment of noisy signals. We familiarize ourselves with the concept of measurement imprecision in light-based measurement systems. To this end, we consider the process of photodetection and discuss the statistical fluctuations arising from the quantization of the electromagnetic field into photons. We exemplify our insights at hand of concrete examples, such as homodyne and heterodyne photodetection. Furthermore, we focus on the process of measurement backaction, the inevitable result of the interaction of the probe with the system under investigation. We discuss the “standard quantum limit” as it arises from the balance of measurement imprecision and backaction, before turning to approaches to overcome it and reach the fundamental “Heisenberg limit”. The course emphasizes the connection between the taught concepts and current state-of-the-art research carried out in the field of optomechanics. Exercises serve to consolidate our understanding and insight.

Prerequisites / notice
Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.

Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria ...) and of the main properties of linear systems is necessary.

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Lecture notes The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the technical content.

Details: https://people.ee.ethz.ch/~haschmid/aswik/
We start with the angular spectrum representation of fields to understand the classical resolution limit. We continue with the theory of the following carbon-based materials:

\[ 2V + 1U + 1A \]

In addition to the slides, the following supplementary books can be recommended:

- **Concepts and Theories**
- **Communication**
- **Adaptability and Flexibility**
- **Creative Thinking**
- **Critical Thinking**
- **Integrity and Work Ethics**
- **Self-awareness and Self-reflection**
- **Self-direction and Self-management**

Lecture slides are distributed every week. In addition, relevant scientific articles and book chapters will be provided for self-study.

Nano-Optics is the study of light-matter interaction at the sub-wavelength scale. It is an flourishing field of fundamental and applied research enabled by the rapid advance of nanotechnology. Nano-optics embraces topics such as plasmonics, optical antennas, optical trapping and manipulation, and high/super-resolution imaging and spectroscopy. We will start with the angular spectrum representation of fields to understand the classical resolution limit. We continue with the theory of strongly focused light, the point spread function, and resolution criteria of conventional microscopy, before turning to super-resolution techniques, based on near- and far-fields. We introduce the local density of states and approaches to control spontaneous emission rates in inhomogeneous environments, including optical antennas. Finally, we touch upon optical forces and their applications in optical tweezers.

For each material, we will discuss:
- Electronic structure and charge transport properties
- Material synthesis and characterization
- Device integration and characterization

The course also includes a presentation by each student in which a related scientific publication is discussed. This presentation is compulsory and accounts for 50% of the grade.

The course includes a presentation by each student in which a related scientific publication is discussed. This presentation is compulsory and accounts for 50% of the grade.

227-0663-00L Nano-Optics W 6 credits 2V+2U M. Frimmer

Abstract
Nano-Optics is the study of light-matter interaction at the sub-wavelength scale. It is an flourishing field of fundamental and applied research enabled by the rapid advance of nanotechnology. Nano-optics embraces topics such as plasmonics, optical antennas, optical trapping and manipulation, and high/super-resolution imaging and spectroscopy.

Objective
Understanding concepts of light localization and light-matter interactions on the sub-wavelength scale.

Content
We start with the angular spectrum representation of fields to understand the classical resolution limit. We continue with the theory of strongly focused light, the point spread function, and resolution criteria of conventional microscopy, before turning to super-resolution techniques, based on near- and far-fields. We introduce the local density of states and approaches to control spontaneous emission rates in inhomogeneous environments, including optical antennas. Finally, we touch upon optical forces and their applications in optical tweezers.

Prerequisites / notice
- Electromagnetic fields and waves (or equivalent)
- Physics I+II

227-1033-00L Neuromorphic Engineering I W 6 credits 2V+3U T. Deilbrück, G. Indiveri, S.-C. Liu, M. Payvand

Registration in this class requires the permission of the instructors. Class size will be limited to available lab spots. Preference is given to students that require this class as part of their major.

Information for UZH students:

Enrolment to this course unit only possible at ETH. No enrolment to module INI404 at UZH.
This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Understanding of the characteristics of neuromorphic circuit elements.

Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time simulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

This course provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ programming techniques and scientific software libraries. Based on an overview over the hardware components of PCs and supercomputer, optimization methods for scientific simulation codes are explained.

This course focuses on the progress in the field of wearable and unobtrusive technologies for sports and health. Topics as monitoring heart health and blood pressure, biofeedback and improvement of motor skills and performance are covered. The focus lies on learning about the principles and design of the new generation of non-invasive technologies in fitness-, athletic and medical applications.

This course focuses on the latest technologies for monitoring the cardiac cycle and blood pressure. The module starts by succinctly providing background information on cardiac physiology and then briefly introduces conventional technologies used in daily practice. This module subsequently focuses on the latest technologies and the latest data analysis techniques to monitor the cardiac cycle for assisting individuals in sport activities or monitoring their health conditions.

The course consists of two modules.

Module 1: Movement.

This module provides the scientific background needed to understand the principles that current technologies investigating movement rely on. The latest technological advancements to track parameters of gait and movement and provide feedback on motion during sport, rehabilitation or at work will be investigated. The focus will be on wearable-related (e.g., textile-based) technologies.

Module 2: Cardiac.

This course focuses on the latest technologies for monitoring the cardiac cycle and blood pressure. The module starts by succinctly providing background information on cardiac physiology and then briefly introduces conventional technologies used in daily practice. This module subsequently focuses on the latest technologies and the latest data analysis techniques to monitor the cardiac cycle for assisting individuals in sport activities or monitoring their health conditions.

Students should be proficient in programming (any language).

- Note: assignments will be in MATLAB. Students are expected to learn MATLAB on their own if not experienced with this programming language.

- Course prerequisites:
  - For Biomedical Engineering Master’s: none
  - For ITET Master’s: none
  - For D-NAV Master’s: none
  - For D-HEST Master’s and PhD students:
    - If BSc in electrical/mechanical engineering or computer science: none
    - If any other BSc program: 376-0022-00L (Imaging and Computing in Medicine) or 376-1983-00L (Foundations of Data Science)

This lecture provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ programming techniques and scientific software libraries. Based on an overview over the hardware components of PCs and supercomputer, optimization methods for scientific simulation codes are explained.

The goal of the course is that students learn basic and advanced programming techniques and scientific software libraries as used and applied for scientific simulations.

This course provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ programming techniques and scientific software libraries. Based on an overview over the hardware components of PCs and supercomputer, optimization methods for scientific simulation codes are explained.

The topics covered in the course will include quantum circuits, gate decomposition and universal sets of gates, efficiency of quantum circuits, quantum algorithms (Shor, Grover, Deutsch-Josza,...), stabilizer-based quantum error correction, fault-tolerant designs, the BB84 quantum key distribution protocol, and simple methods of quantum metrology.
Basic aspects of surface science. Understanding of principles of the most important experimental methods used in research concerned with surface science, material science and catalysis are considered and their application is demonstrated on practical examples.


Throughout the past 20 years the field of quantum information science has entered the domain of information technology in more and more prominent ways. Enormous progress in the physical sciences and in engineering and technology has allowed us to build novel types of information processors based on the concepts of quantum physics. In these processors information is stored in the quantum state of physical systems forming quantum bits (qubits). The interaction between qubits is controlled and the resulting states are read out on the level of single quanta in order to process information. Realizing such challenging tasks is believed to allow constructing an information processor much more powerful than a classical computer. This task is taken on by academic labs, startups and major industry. The aim of this class is to give a thorough introduction to physical implementations pursued in current research for realizing quantum information processors. The field of quantum information science is one of the fastest growing and most active domains of research in modern physics.

Introduction to experimental systems for quantum information processing (QIP).

- Quantum bits
- Coherent Control
- Measurement
- Decoherence
- QIP with
- Ions
- Superconducting Circuits
- Photons
- NMR
- Rydberg atoms
- NV-centers
- Quantum dots

Lecture notes
Course material may be available at www.qudev.ethz.ch and on the Moodle platform for the course. More details to follow.

Literature
Quantum Computation and Quantum Information
Michael Nielsen and Isaac Chuang
Cambridge University Press

Prerequisites / notice
The class will be taught in English language.

Basic knowledge of concepts of quantum physics and quantum systems, e.g. from courses such as Physics III, Quantum Mechanics I and II or courses on topics such as atomic physics, solid state physics, quantum electronics are considered helpful.

More information on this class can be found on the web site www.qudev.ethz.ch

529-0611-01L Molecular Aspects of Catalysts and Surfaces

6 credits

Abstract
Basic elements of surface science important for materials and catalysis research. Physical and chemical methods important for research in surface science, material science and catalysis are considered and their application is demonstrated on practical examples.

Objective
Methods which are covered embrace: Gas adsorption and surface area analysis, IR-Spectroscopy, X-ray diffraction, X-ray photoelectron spectroscopy, X-ray absorption, solid state NMR, Electron Microscopy and others.

529-0643-01L Process Design and Development

6 credits

Abstract
The course is focused on the design of Chemical Processes, with emphasis on the preliminary stages of the design approach, where process creation and quick selection among many alternatives are important. The main concepts behind more detailed process design and process simulation are also examined.

Objective
The course is focused on the design of Chemical Processes, with emphasis on the preliminary stage of the design approach, where process creation and quick selection among many alternatives are important. The main concepts behind more detailed process design and process simulation are also examined.

Content
Process creation: heuristics vs. mathematical programming.
Heuristics for reaction and separation operations, heat transfer and pressure change.
Introduction to optimization in process engineering and the modeling software GAMS.
Process economic evaluation: equipment sizing and costing, time value of money, cash flow calculations.
Process integration: sequencing of distillation columns using mixed-integer linear programming (MILP), and synthesis of heat exchanger networks using mixed-integer nonlinear programming (MINLP).
Batch processes: scheduling, sizing, and inventories.
Principles of molecular design using mixed-integer programming.

Lecture notes
no script
## Literature

### Main books

### Other references

## Prerequisites / notice

Prerequisite: Basic knowledge on unit operations, mainly reaction engineering and distillation. It is recommended that the student takes the module "Process Simulation and Flowsheeting" before "Process Design and Development", but it is not mandatory.

## 701-1239-00L Aerosols I: Physical and Chemical Principles

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<td>M. Gysel Beer, D. Bell, E. Weingartner</td>
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### Abstract
Aerosols I deals with basic physical and chemical properties of aerosol particles. The importance of aerosols in the atmosphere and in other fields is discussed.

### Objective

#### Physical and chemical principles:
The students...
- know the processes and physical laws of aerosol dynamics.
- understand the thermodynamics of phase equilibria and chemical equilibrium.
- know the photo-chemical formation of particulate matter from inorganic and organic precursor gases.

#### Experimental methods:
The students...
- know the most important chemical and physical measurement instruments.
- understand the underlying chemistry and physics.

#### Environmental impacts:
The students...
- know the major sources of atmospheric aerosols, their chemical composition and key physical properties.
- know the most important climate impacts of atmospheric aerosols.
- are aware of the health impacts of atmospheric aerosols.

### Lecture notes
Material is distributed during the lecture.

### Literature

### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

## 752-3103-00L Food Rheology

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<td>P. A. Fischer</td>
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### Abstract
Rheology is the science of flow and deformation of matter such as polymers, dispersions (emulsions, foams, suspensions), and colloidal systems. The fluid dynamical basis, measuring techniques (rheometry), and the flow properties of different fluids (Newtonian, non-Newtonian, viscoelastic) are introduced and discussed.

### Objective
The course provides an introduction on the link between flow and structural properties of flowing material. Rheometrical techniques and appropriate measuring protocols for the characterization of complex fluids will be discussed. The concept of rheological constitutive equations and the application to different material classes are established.

### Content
Lectures will be given on general introduction (4h), fluid dynamics (2h), complex flow behavior (4h), influence of temperature (2h), rheometers (4h), rheological tests (6h) and structure and rheology of complex fluids (4h).

### Lecture notes
Notes will be handed out during the lectures.

### Literature
Provided in the lecture notes.
### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

- **Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Problem-solving

- **Personal Competencies**
  - Creative Thinking
  - Critical Thinking

### Multidisciplinary Courses

The students are free to choose individually Master's courses from the Course Catalogue of ETH Zurich, ETH Lausanne and the Universities of Zurich (https://www.uzh.ch/cmsssl/en/studies/application/chmobilityin.html) and St. Gallen.

Course Catalogue of ETH Zurich

### Science in Perspective

- see Science in Perspective: Language Courses ETH/UZH
- see Science in Perspective: Type A: Enhancement of Reflection Capability

### Semester Project

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<td>Semester Project Micro- and Nanosystems</td>
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<td>8 credits</td>
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</table>

**Abstract**
The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

**Objective**
The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's programme.

### Industrial Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1090-00L</td>
<td>Industrial Internship</td>
<td>O</td>
<td>8 credits</td>
<td></td>
<td>external organisers</td>
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</table>

**Abstract**
The main objective of the minimum twelve-week internship is to expose Master's students to the industrial work environment. The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

**Objective**
The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-1006-00L</td>
<td>Master's Thesis Micro- and Nanosystems</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Professors</td>
</tr>
</tbody>
</table>

**Abstract**
Master's programs are concluded by the master's thesis. The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem. The subject of the master's thesis, as well as the project plan and roadmap, are proposed by the tutor and further elaborated with the student.

**Objective**
The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem.

### Micro- and Nanosystems Master - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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### Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
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</tr>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Exchange Students

Courses for Exchange Students

Prepare a study plan

In case the course catalogue of the upcoming semester is not available yet, please expect it to be like the year before. You can study at ETH Zurich as an exchange student for 1 or 2 semesters, starting in the autumn or in the spring semester. Exchange students may choose courses from different curricula and years, provided that at least two thirds of all courses are taken in the ETH Zurich department they are registered in. Please be sure to coordinate your schedule with your home university.

Exam sessions and End-of-semester examinations

Like all ETH Zurich students, exchange students are obliged to sit their exams during the official examination periods. Students are requested to be present at ETH Zurich during these periods. You are therefore expected to plan your studies, internships, jobs, and financial means accordingly.

Research Project

The courses below are only available for exchange students.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>900-0015-00L</td>
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<tr>
<td>900-0020-00L</td>
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<td>900-0025-00L</td>
<td>25 Credit Project</td>
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<td>54A</td>
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<td>900-0030-00L</td>
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<tr>
<td>900-0060-00L</td>
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Additional Courses

by individual arrangement

Exchange Students - Key for Type

<table>
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<tbody>
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</tbody>
</table>

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Basics of Instrumentation, Measurement, and Analysis (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI502

Mind the enrolment deadlines at UZH:

Registration in this class requires the permission of the instructors. Class size will be limited to available lab spots. Preference is given to students that require this class as part of their major.

Abstract

Experimental data are always as good as the instrumentation and measurement, but never any better. This course provides the very basics of instrumentation relevant to neurophysiology and neuromorphic engineering, it consists of two parts: a common introductory part involving analog signals and their acquisition (Part I), and a more specialized second part (Part II).

Objective

The goal of Part I is to provide a general introduction to the signal acquisition process. Students are familiarized with basic lab equipment such as oscilloscopes, function generators, and data acquisition devices. Different electrical signals are generated, visualized, filtered, digitized, and analyzed using Matlab (Mathworks Inc.) or Labview (National Instruments).

In Part II, the students are divided into small groups to work on individual measurement projects according to availability and interest. Students single-handedly solve a measurement task, making use of their basic knowledge acquired in the first part. Various signal sources will be provided.

Prerequisites / notice

For each part, students must hand in a written report and present a live demonstration of their measurement setup to the respective supervisor. The supervisor of Part I is the teaching assistant, and the supervisor of Part II is task specific. Admission to Part II is conditional on completion of Part I (report + live demonstration).

Reports must contain detailed descriptions of the measurement goal, the measurement procedure, and the measurement outcome. Either confidence or significance of measurements must be provided. Acquisition and analysis software must be documented.

Journal Club (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI702

Mind the enrolment deadlines at UZH:

Abstract

The Neuroinformatics Journal club is a weekly meeting during which students present current research papers. The presentation is followed by a general discussion.

Objective

The Neuroinformatics Journal club aims to train students to present cutting-edge research clearly and efficiently. It leads students to learn about current topics in neurosciences and neuroinformatics, to search the relevant literature and to critically and scholarly appraise published papers. The students learn to present complex concepts and answer critical questions.

Content

Relevant current papers in neurosciences and neuroinformatics are covered.

Competencies

Subject-specific Competencies: Concepts and Theories, Techniques and Technologies.

Method-specific Competencies: Analytical Competencies, Decision-making.

Social Competencies: Communication, Cooperation and Teamwork.

Personal Competencies: Adaptability and Flexibility, Creative Thinking, Critical Thinking, Integrity and Work Ethics, Self-awareness and Self-reflection, Self-direction and Self-management.

Neuroinformatics - Colloquia (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI701

Mind the enrolment deadlines at UZH:

Abstract

The colloquium in Neuroinformatics is a series of lectures given by invited experts. The lecture topics reflect the current themes in neurobiology and neuromorphic engineering that are relevant for our institute.

Objective

The goal of these talks is to provide insight into recent research results. The talks are not meant for the general public, but really aimed at specialists in the field.

Content

The topics depend heavily on the invited speakers, and thus change from week to week. All topics concern neural computation and their implementation in biological or artificial systems.

Readings in Neuroinformatics (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI703

Mind the enrolment deadlines at UZH:

Abstract

Readings in Neuroinformatics is a weekly meeting during which students present current research papers. The presentation is followed by a general discussion.

Objective

The goal of these talks is to provide insight into recent research results. The talks are not meant for the general public, but really aimed at specialists in the field.

Content

Relevant current papers in neurosciences and neuroinformatics are covered.
It is commonplace that scientists rarely cite literature that is older than 10 years and when they do, they usually cite one paper that serves as the representative for a larger body of work that has long since been incorporated anonymously in textbooks. Even worse, many authors have not even read the papers they cite in their own publications. This course, ‘Foundations of Neuroscience’ is one antidote. Thirteen major areas of research have been selected. They cover the key concepts that have led to our current ideas of how the nervous system is built and functions. Unusually, we will explore these areas of research by reading the original publications, instead of reading a digested summary from a textbook or review. By doing this, we will learn how the discoveries were made, what instrumentation was used, how the scientists interpreted their own findings, and how their work, often over many decades and linked together with related findings from many different scientists, generate the current views of mechanism and structure of the nervous system. We will read different original papers and explore the conceptual links between them and discuss the ‘sociology’ of science. We will also explore the personalities of the scientists and the context in which they made their seminal discoveries. Each week, course members will be given original papers to read for homework and they will write a short abstract for each paper. We will then meet weekly with the course leader and an assistant for an hour-or-so long interactive seminar. An intimate knowledge of the papers will be assumed so that the discussion does not center simply on an explication of the contents of the papers. Assessment will be in the form of assignments throughout the semester.

It is commonplace that scientists rarely cite literature that is older than 10 years and when they do, they usually cite one paper that serves as the representative for a larger body of work that has long since been incorporated anonymously in textbooks. Even worse, many authors have not even read the papers they cite in their own publications. This course, ‘Foundations of Neuroscience’ is one antidote. Thirteen major areas of research have been selected. They cover the key concepts that have led to our current ideas of how the nervous system is built and functions. Unusually, we will explore these areas of research by reading the original publications, instead of reading a digested summary from a textbook or review. By doing this, we will learn how the discoveries were made, what instrumentation was used, how the scientists interpreted their own findings, and how their work, often over many decades and linked together with related findings from many different scientists, generate the current views of mechanism and structure of the nervous system. We will read different original papers and explore the conceptual links between them and discuss the ‘sociology’ of science. We will also explore the personalities of the scientists and the context in which they made their seminal discoveries. Each week, course members will be given original papers to read for homework and they will write a short abstract for each paper. We will then meet weekly with the course leader and an assistant for an hour-or-so long interactive seminar. An intimate knowledge of the papers will be assumed so that the discussion does not center simply on an explication of the contents of the papers. Assessment will be in the form of assignments throughout the semester.

### Systems Neurosciences

#### Elective Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0421-00L</td>
<td>Learning in Deep Artificial and Biological Neuronal Networks</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>B. Grewé</td>
</tr>
</tbody>
</table>

#### Abstract

Deep-Learning (DL) a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods.

#### Objective

The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today’s neuroscience papers.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today’s neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to ‘error backpropagation’ in order to train neuronal networks
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

#### Content

Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al, 2015, Silver et al., 2018), ANNs are still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data samples (data they have not been trained on). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.
Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocoedic properties of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enigmas and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feed-forward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.
The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today’s neuroscience papers.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today’s neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to ‘error backpropagation’ in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al, 2015, Silver et al., 2018). ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.

This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Understanding the characteristics of neuromorphic circuit elements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>227-1037-00L</td>
<td>Introduction to Neuroinformatics</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U+1A</td>
<td>V. Mante, B. Grewe, G. Indiveri, M. Payvand</td>
</tr>
</tbody>
</table>

**Abstract**

The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.

**Objective**

Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

**Content**

This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

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**Neurotechnologies and Neuromorphic Engineering**

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<tbody>
<tr>
<td>227-1033-00L</td>
<td>Neurocomputing I</td>
<td>W</td>
<td>6 credits</td>
<td>2V+3U</td>
<td>T. Delbrück, G. Indiveri, S.-C. Liu, M. Payvand</td>
</tr>
</tbody>
</table>

**Abstract**

This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

Adaptability and Flexibility
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

**227-0393-10L**  
**Bioelectronics and Biosensors**  
W 6 credits 2V+2U J. Vörös, M. F. Yanik

**Abstract**
The course introduces bioelectricity and the sensing concepts that enable obtaining information about neurons and their networks. The sources of electrical fields and currents in the context of biological systems are discussed. The fundamental concepts and challenges of measuring bioelectronic signals and the basic concepts to record optogenetically modified organisms are introduced.

**Objective**
During this course the students will:
- learn the basic concepts in bioelectronics including the sources of bioelectronic signals and the methods to measure them
- be able to solve typical problems in bioelectronics
- learn about the remaining challenges in this field

**Content**
Lecture topics:

1. Introduction
2. Sources of bioelectronic signals
3. Membrane and Transport
4. Action potential and Hodgkin-Huxley
5. Detection and Noise
6. Measuring currents in solutions, nanopore sensing and patch clamp pipettes
7. Measuring potentials in solution and core conductance model
8. Measuring electronic signals with wearable electronics, ECG, EEG
9. Measuring mechanical signals with bioelectronics

10. Functional electric stimulation
11. In vivo electrophysiology
12. Measuring neurons optically, fundamentals of optical microscopy
13. Fluorescent probes and scanning microscopy, optogenetics, in vivo microscopy
14. Measuring biochemical signals

**Lecture notes**
A detailed script is provided to each lecture including the exercises and their solutions.

**Literature**
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

**Prerequisites / notice**
The course requires an open attitude to the interdisciplinary approach of bioelectronics. In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Conceptual and Theoretical Knowledge</th>
<th>Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
<td>Assessed</td>
<td></td>
</tr>
<tr>
<td>Analytical Competencies</td>
<td>Assessed</td>
<td></td>
</tr>
<tr>
<td>Decision-making</td>
<td>Fostered</td>
<td></td>
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<tr>
<td>Media and Digital Technologies</td>
<td>Fostered</td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
<td>Assessed</td>
<td></td>
</tr>
<tr>
<td>Project Management</td>
<td>Fostered</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Method-specific Competencies</th>
<th>Technique, Application, and Systematic Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negotiation</td>
<td>Fostered</td>
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</tbody>
</table>

**Social Competencies**

<table>
<thead>
<tr>
<th>Communication</th>
<th>Fostered</th>
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</thead>
<tbody>
<tr>
<td>Cooperation and Teamwork</td>
<td>Fostered</td>
</tr>
<tr>
<td>Customer Orientation</td>
<td>Fostered</td>
</tr>
<tr>
<td>Leadership and Responsibility</td>
<td>Fostered</td>
</tr>
<tr>
<td>Self-presentation and Social Influence</td>
<td>Fostered</td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td>Fostered</td>
</tr>
</tbody>
</table>

**Personal Competencies**

<table>
<thead>
<tr>
<th>Adaptability and Flexibility</th>
<th>Fostered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creative Thinking</td>
<td>Assessed</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>Assessed</td>
</tr>
<tr>
<td>Integrity and Work Ethics</td>
<td>Fostered</td>
</tr>
<tr>
<td>Self-awareness and Self-reflection</td>
<td>Fostered</td>
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<tr>
<td>Self-direction and Self-management</td>
<td>Fostered</td>
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</tbody>
</table>

**Electives**

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-0151-00L</td>
<td>Linear Algebra</td>
<td>W</td>
<td>5 credits</td>
<td>3V+2U</td>
<td>V. C. Gradinaru</td>
</tr>
</tbody>
</table>
401-2813-00L Programming Techniques for Scientific Simulations I

Abstract
This lecture provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ programming techniques and scientific software libraries. Based on an overview over the hardware components of PCs and supercomputer, optimization methods for scientific simulation codes are explained.

Objective
The goal of the course is that students learn basic and advanced programming techniques and scientific software libraries as used and applied for scientific simulations.

Lecture notes
Lecture notes and slides are available online and will be distributed if desired.

Literature
Lecture recommendations and references are included in the lecture notes.

Prerequisites / notice
Lecture and exercise lessons in english, exams in German or in English

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Creative Thinking
- Critical Thinking

402-0809-00L Introduction to Computational Physics

Abstract
This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and supercomputers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

Objective
Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

Content
Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

Lecture notes
Lecture notes and slides are available online and will be distributed if desired.

Literature
Lecture recommendations and references are included in the lecture notes.

Prerequisites / notice
Lecture and exercise lessons in english, exams in German or in English

Competencies
Subject-specific Competencies
- Concepts and Theories

Method-specific Competencies
- Analytical Competencies

402-0341-00L Medical Physics I

Abstract
Introduction to the fundamentals of medical radiation physics. Functional chain due to radiation exposure from the primary physical effect to the radiobiological and medically manifest secondary effects. Dosimetric concepts of radiation protection in medicine. Mode of action of radiation sources used in medicine and its illustration by means of Monte Carlo simulations.

Literature
K. Nipp / D. Stoffer, Lineare Algebra, vdf Hochschulverlag, 5. Auflage 2002

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Creative Thinking
- Critical Thinking
Objective
Understanding the functional chain from primary physical effects of ionizing radiation to clinical radiation effects. Dealing with dose as a quantitative measure of medical exposure. Getting familiar with methods to generate ionizing radiation in medicine and learn how they are applied for medical purposes. Eventually, the lecture aims to show the students that medical physics is a fascinating and evolving discipline where physics can directly be used for the benefit of patients and the society.

Content
The lecture is covering the basic principles of ionizing radiation and its physical and biological effects. The physical interactions of photons as well as charged particles will be reviewed and their consequences for medical applications will be discussed. The concept of Monte Carlo simulation will be introduced in the excercises and will help the student to understand the characteristics of ionizing radiation in simple and complex situations. Fundamentals in dosimetry will be provided in order to understand the physical and biological effects of ionizing radiation. Deterministic as well as stochastic effects will be discussed and fundamental knowledge about radiation protection will be provided. In the second part of the lecture series, we will cover the generation of ionizing radiation. By this means, the x-ray tube, the clinical linear accelerator, and different radioactive sources in radiology, radiotherapy and nuclear medicine will be addressed. Applications in radiology, nuclear medicine and radiotherapy will be described with a special focus on the physics underlying these applications.

Lecture notes
A script will be provided.

Prerequisites / notice
For students of the MAS in Medical Physics (Specialization A) the performance assessment is offered at the earliest in the second year of the studies.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

227-1047-00L
Consciousness: From Philosophy to Neuroscience (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

Lecture notes
Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.s.html

Abstract
This seminar reviews the philosophical and phenomenological as well as the neurobiological aspects of consciousness. The subjective features of consciousness are explored, and modern research into its neural substrate, particularly in the visual domain, is explained. Emphasis is placed on students developing their own thinking through a discussion-centered course structure.

Content
The course's goal is to give an overview of the contemporary state of consciousness research, with emphasis on the contributions brought by modern cognitive neuroscience. We aim to clarify concepts, explain their philosophical and scientific backgrounds, and to present experimental protocols that shed light on a variety of consciousness related issues.

Prerequisites / notice
None

We display articles pertaining to the issues we cover in the class on the course's webpage.

Since we are all experts on consciousness, we expect active participation and discussions!

402-0674-00L
Physics in Medical Research: From Atoms to Cells

Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.

Objectives
The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering. Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical quantities are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopies.

252-0535-00L
Advanced Machine Learning

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

**Fundamentals:**
What is data?
Bayesian Learning
Computational learning theory

**Supervised learning:**
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks

**Unsupervised learning:**
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation
Learning Dynamical Systems

**Lecture notes**
No lecture notes, but slides will be made available on the course webpage.

**Literature**

**Prerequisites / notice**
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

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**Master's Thesis and Semester Papers/Seminars**

#### Option 1: Long Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1041-01L</td>
<td>NSC Master's Thesis (long) and Exam (University of Zurich)</td>
<td>W</td>
<td>45 credits</td>
<td>96D</td>
<td>M. F. Yanik</td>
</tr>
</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI503

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

Only students who fulfil the following criteria are allowed to begin with their master thesis:

- a. successful completion of the bachelor programme;
- b. fulfilling of any additional requirements necessary to gain admission to the master programme.

**Abstract**
The Master thesis concludes the study programme. Thesis work should prove the students' ability to independent, structured and scientific working.

**Objective**
see above

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#### Option 2: Short Master's Thesis and Semester Papers/Seminars

#### Short Master Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1041-02L</td>
<td>NSC Master's Thesis (short) and Exam (University of Zurich)</td>
<td>W</td>
<td>29 credits</td>
<td>62D</td>
<td>M. F. Yanik</td>
</tr>
</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI504

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html
Only students who fulfill the following criteria are allowed to begin with their master thesis:
a. successful completion of the bachelor programme;
b. fulfilling of any additional requirements necessary to gain admission to the master programme.

Abstract
The Master thesis concludes the study programme. Thesis work should prove the students’ ability to independent, structured and scientific working.

Objective
see above

Semester Papers/Seminars

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1036-01L</td>
<td>NSC Master Short Project I (University of Zurich)</td>
<td>W</td>
<td>8 credits</td>
<td>17A</td>
<td>M. F. Yanik</td>
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<tr>
<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<tr>
<td></td>
<td>UZH Module Code: INI505</td>
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<td></td>
<td>Mind the enrolment deadlines at UZH:</td>
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<tr>
<td>Abstract</td>
<td>Usually a student selects the topic of a Master Short Project in consultation with his or her mentor.</td>
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<tr>
<td>Objective</td>
<td>see above</td>
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<tr>
<td>227-1036-02L</td>
<td>NSC Master Short Project II (University of Zurich)</td>
<td>W</td>
<td>8 credits</td>
<td>17A</td>
<td>M. F. Yanik</td>
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<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<td></td>
<td>UZH Module Code: INI506</td>
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<td>Mind the enrolment deadlines at UZH:</td>
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<tr>
<td>Abstract</td>
<td>Usually a student selects the topic of a Master Short Project in consultation with his or her mentor.</td>
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<tr>
<td>Objective</td>
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</tbody>
</table>

Neural Systems and Computation Master - Key for Type

| O          | Compulsory        |         | E-   | Recommended, not eligible for credits |
| W+         | Eligible for credits and recommended                                |         | Z    | Courses outside the curriculum     |
| W          | Eligible for credits                                             |         | Dr   | Suitable for doctorate             |

Key for Hours

| V          | lecture           |         | P    | practical/laboratory course       |
| G          | lecture with exercise |       | A    | independent project               |
| U          | exercise          |         | D    | diploma thesis                    |
| S          | seminar           |         | R    | revision course / private study   |
| K          | colloquium        |         |      |                                     |

ECTS European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
# Nuclear Engineering Master

MSc Nuclear Engineering is a joint program of EPF Lausanne and ETH Zurich. The first semester takes place in Lausanne. Students therefore have to enroll at EPFL.

For more information about the curriculum and courses see: https://www.epfl.ch/education/master/programs/nuclear-engineering/

## Core Courses

### 1. Semester (EPFL)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-2011-00L</td>
<td>Physics of Nuclear Reactors (EPFL)</td>
<td>O</td>
<td>6</td>
<td>6G</td>
<td>external organisers</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>In this course, one acquires an understanding of the basic neutronics interactions occurring in a nuclear fission reactor and, as such, the conditions for establishing and controlling a nuclear chain reaction.</td>
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<td>By the end of the course, the student must be able to:</td>
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<td></td>
<td>- Élaborate on neutron diffusion equation</td>
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<td>- Systematize nuclear reaction cross sections</td>
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<td></td>
<td>- Formulate approximations to solving the diffusion equation for simple systems</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>- Brief review of nuclear physics</td>
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<td></td>
<td>- Historical: Constitution of the nucleus and discovery of the neutron</td>
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<td></td>
<td>- Nuclear reactions and radioactivity - Cross sections - Differences between fusion and fission.</td>
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<tr>
<td></td>
<td>- Nuclear fission</td>
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<td></td>
<td>- Characteristics - Nuclear fuel - Introductory elements of neutronics.</td>
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<td></td>
<td>- Fissile and fertile materials - Breeding.</td>
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<td></td>
<td>- Neutron diffusion and slowing down</td>
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<td>- Monoenergetic neutrons - Angular and scalar flux</td>
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<td></td>
<td>- Diffusion theory as simplified case of transport theory - Neutron slowing down through elastic scattering.</td>
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<td>- Multiplying media (reactors)</td>
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<td>- Multiplication factors - Criticality condition in simple cases,</td>
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<td></td>
<td>- Reactor kinetics</td>
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<td></td>
<td>- Point reactor model: prompt and delayed transients - Practical</td>
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<tr>
<td></td>
<td>applications.</td>
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<td></td>
<td>- Reactivity variations and control</td>
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<td></td>
<td>- Short, medium and long term reactivity changes ? Different means of</td>
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<tr>
<td></td>
<td>control.</td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<tr>
<td></td>
<td>Distributed documents, recommended book chapters</td>
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<td></td>
<td><strong>Prerequisites / notice</strong></td>
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<tr>
<td></td>
<td>Prerequisite for: Reactor Experiments</td>
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<tr>
<td>151-2013-00L</td>
<td>Radiation and Reactor Experiments (EPFL)</td>
<td>O</td>
<td>6</td>
<td>4G</td>
<td>external organisers</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>The reactor experiments course aims to introduce the students to radiation detection techniques and nuclear reactor experiments. The core of the course is the unique opportunity to conduct reactor experiments, as the control rod calibration, and approach to critical.</td>
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<tr>
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<td><strong>Objective</strong></td>
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<td>To gain hands-on experience in the conduction of nuclear radiation</td>
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<td>measurements, as also in the execution and analysis of reactor physics</td>
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<td>experiments using the CROCUS reactor.</td>
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<td>- Radiation detector systems, alpha and beta particles</td>
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<td>- Radiation detector systems, gamma spectroscopy</td>
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<td>- Introduction to neutron detectors (He-3, BF3)</td>
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<td>- Slowing-down area (Fermi age) of Pu-Be neutrons in H2O</td>
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<td>- Approach-to-critical experiments</td>
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<td>- Buckling measurements</td>
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<td>- Control rod calibration</td>
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<td><strong>Prerequisites / notice</strong></td>
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<td>Prerequisite for: Special Topics in Reactor Physics (2nd sem.)</td>
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<tr>
<td>151-2043-00L</td>
<td>Radiation Biology, Protection and Applications (EPFL)</td>
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<td>4</td>
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<td>external organisers</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td>An introductory course in the basic concepts of radiation detection and interactions and energy deposition by ionizing radiation in matter, radiotracer production and its applications in medicine, industry and research. The course includes presentations, lecture notes, problem sets and seminars.</td>
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By the end of the course, the student must be able to:

1. Explain the basic physics principles that underpin radiotherapy, e.g., types of radiation, atomic structure, etc.
2. Explain the interaction mechanisms of ionizing radiation at keV and MeV energies with matter.
3. Explain the principles of radiation dosimetry.
4. Explain the principles of therapeutic radiation physics including X-rays, electron beam physics, radioactive sources, use of unsealed sources and Brachytherapy.
5. Describe how to use radiotherapy equipment both for tumor localization, planning and treatment.
6. Define quality assurance and quality control, in the context of radiotherapy and the legal requirements.
7. Explain the principles and practice of radiation protection, dose limits, screening and protection mechanisms.

By the end of the course, the student must be able to:

1. Formulate the operating point of a hydraulic turbomachine
2. Specify a type of hydraulic turbine
3. Sketch the layout of a hydraulic turbomachine
4. Select appropriately the dimensions of a hydraulic turbomachine
5. - Turbomachine equations, mechanical power balance in a hydraulic machines, moment of momentum balance applied to the runner/impeller, generalized Euler equation.
6. - Hydraulic characteristic of a reaction turbine, a Pelton turbine and a pump, losses and efficiencies of a turbomachine, real hydraulic characteristics.
7. - Similitude laws, non dimensional coefficients, reduced scale model testing, scale effects.
8. - Cavitation, hydraulic machine setting, operating range, adaptation to the piping system, operating stability, start stop transient operation,
9. - Reaction turbine design: general procedure, general project layout, design of a Francis runner, design of the spiral casing and the
10. - Pelton turbine design: general procedure, project layout, injector design, bucket design, mechanical problems.
11. - Centrifugal pump design: general architecture, energetic loss model in the diffuser and/or the volute, volute design, operating stability, slides handout Handbook.

By the end of the course, the student must be able to:

- Identify the main technological challenges of fusion
- Identify the main physics challenges on the way to fusion
- Design the main elements of a fusion reactor
- Identify the main technological challenges of fusion

By the end of the course, the student must be able to:

- Nuclear fusion and plasma physics
- The plasma state and its collective effects
- Charged particle motion and collisional effects
- Fluid description of a plasma
- Plasma equilibrium and stability
- Magnetic confinement: Tokamak and Stellarator
- Waves in plasma
- Wave-particle interactions
- Heating and non inductive current drive by radio frequency waves
- Heating and non inductive current drive by neutral particle beams
- Material science and technology: Low and high Temperature superconductor - Properties of material under irradiation
- Some nuclear aspects of a fusion reactor: Tritium production
- Licensing a fusion reactor: safety, nuclear waste
- Inertial confinement

By the end of the course, the student must be able to:

- Cavitation, Hydroacoustic, Master Project.
- Handout and Scientific Litterature from LMH, Industry, International Association

Prerequisites / notice

- No enrolment to this course at ETH Zurich. Book the corresponding module directly at EPFL.
- Basic knowledge of electricity and magnetism, and of simple concepts of fluids

By the end of the course, the student must be able to:

- Select appropriately the dimensions of a hydraulic turbomachine
- Sketch the layout of a hydraulic turbomachine
- Specify a type of hydraulic turbine
- Formulate the operating point of a hydraulic turbomachine
- Nuclear Fusion and Plasma Physics (EPFL)
- No enrolment to this course at ETH Zurich. Book the corresponding module directly at EPFL.

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No enrolment to this course at ETH Zurich. Book the corresponding module directly at EPFL.
### Abstract
The course presents basic physics ideas underlying the workings of modern accelerators. We will examine key features and limitations of these machines as used in accelerator driven sciences like high energy physics, materials and life sciences.

### Objective
By the end of the course, the student must be able to:
- Design basic linear and non-linear charged particles optics
- Elaborate basic ideas of physics of accelerators
- Use a computer code for optics design
- Optimize accelerator design for a given application
- Estimate main beam parameters of a given accelerator

### Content
- Overview, history and fundamentals
- Transverse particle dynamics (linear and nonlinear)
- Longitudinal particle dynamics
- Linear accelerators
- Circular accelerators
- Acceleration and RF-technology
- Beam diagnostics
- Accelerator magnets
- Injection and extraction systems
- Synchrotron radiation

### Literature
- Recommended during the course

### Prerequisites / notice
- Prérequis: Notion de relativité restreinte et d'électrodynamique

### 151-2041-00L Introduction to Medical Radiation Physics (EPFL)
- W 4 credits 3G external organisers

**Abstract**
This course covers the physical principles underlying medical imaging using ionizing radiation (radiography, fluoroscopy, CT, SPECT, PET).

**Objective**
The focus is not only on risk and dose to the patient and staff, but also on an objective description of the image quality.

**Content**
- Physics of radiography: X-ray production, Radiation-patient interaction, Image detection and display
- Dose to the patient: External irradiation, Internal contamination, compartmental models
- Physics of computer tomography (CT)
- Risk and radiation: Rational risk and state of our knowledge, Psychological aspects, Ethics and communication
- Physics of single-photon emission computed tomography (SPECT)
- Physics of mammography
- Receiver operating characteristics (ROC) and hypothesis testing: Link between medical diagnostic and statistical hypothesis testing, Sensitivity, specificity, prevalence, predictive values
- Physics of radioscop
- Model observers in medical imaging: Human visual characteristics and their quantification, Bayesian cost and Ideal model observer, Anthropomorphic model observers, Detection experiments (rating, M-AFC, yes-no)
- Physics of positron emission tomography (PET)
- Physics of resonance magnetic imaging

### 151-2049-00L Energy Conversion and Renewable Energy (EPFL)
- W 4 credits 4G external organisers

**Abstract**
The goal of the lecture is to present the principles of the energy conversion for conventional and renewable energy resources and to explain the most important parameters that define the energy conversion efficiency, resources implications and economics of the energy conversion technologies.

**Objective**
By the end of the course, the student must be able to:
- Explain the efficiency and the main emission sources of energy conversion processes
- Quantify the efficiency and the main emission sources of energy conversion processes
- Model energy conversion systems and industrial processes
- Draw the energy balances of an energy conversion system
- Elaborate energy conversion scenarios
- Describe the principles and limitations of the main energy conversion technologies
- Compare energy conversion systems

**Content**
- Overview of energy stakes
- Thermodynamic principles relevant for energy conversion systems, review of thermodynamic power cycles, heat pumps and refrigeration cycles, co-generation
- Carbon capture and sequestration
- Renewable energy vectors, their physical principles and essential equations: Solar (photovoltaics and thermal - collectors/concentrators), geothermal, biomass (a.o. gasification, biogases, liquid biofuels), hydro, wind
- Fuel cells and hydrogen as energy vector
- Storage of energy: Batteries, compressed air, pumped hydro, thermal storage
- Integrated urban systems

**Lecture notes**
Slides, videos and other documents are available on moodle (http://moodle.epfl.ch)

**Prerequisites / notice**
Required courses: Physics I and Physics II

Important concepts to start the course: Conservation principles (energy, mass, momentum)

### 151-2051-00L Radiation Detection (EPFL)
- W 3 credits 3G external organisers

**Abstract**
No enrolment to this course at ETH Zurich. Book the corresponding module directly at EPFL.
Abstract

The course presents the detection of ionizing radiation in the keV and MeV energy ranges. It introduces the physical processes of radiation/matter interaction. It covers the several steps of detection, and the detectors, instrumentations and measurements methods commonly used in the nuclear field.

Objective

By the end of the course, the student must be able to:
- Explain interaction processes of ionising radiation and matter
- Describe the production of a detection signal and its processing
- Explain the operation of all types of commonly used detectors
- Assess / Evaluate the detection system and method required for a specific measurement

Content

- Interaction of radiation with matter at low energies: X-rays/gammas, charged particles and neutrons up to MeV range, ionisation, nuclear cross sections
- Characteristics and types of detectors: gas detectors, semiconductor detectors, scintillators and optical fibers, fission chambers, meshed and pixel detectors
- Signal processing and analysis: types of electronics, signal collection and amplification, particle discrimination, spatial and time resolution
- Nuclear instrumentation and measurements: principle of measurements, spectrometry, common detection instrumentations, applications in nuclear engineering and R&D.

Literature

Radiation detection and measurement, Glenn F. Knoll. Wiley 2010

151-2053-00L Experimental Methods in Physics (EPFL) W 3 credits 3G 3G 3G external organisers

Abstract

No enrolment to this course at ETH Zurich. Book the corresponding module directly at EPFL.

Objective

By the end of the course, the student must be able to:
- Integrate the notions of critical reading of articles
- Assess / Evaluate scientific articles, their quality and defaults
- Interpret knowledge of several specific experimental methods

Content

- Noise and interference: Their origins, their influence on experimental results, methods for noise and interference reduction

151-2055-00L Image Processing I (EPFL) W 3 credits 3G 3G 3G external organisers

Abstract

Introduction to the basic techniques of image processing. Introduction to the development of image-processing software and to prototyping in JAVA. Application to real-world examples in industrial vision and biomedical imaging.

Objective

By the end of the course, the student must be able to:
- Exploit the multidimensional Fourier transform
- Select appropriately Hilbert spaces and inner-products
- Optimize 2-D sampling to avoid aliasing
- Formalize convolution and optical systems
- Design digital filters in 2-D
- Analyze multidimensional linear shift-invariant systems
- Apply image-analysis techniques
- Elaborate morphological filters
- Construct image-processing software
- Interpret knowledge of several specific experimental methods
- Assess / Evaluate scientific articles, their quality and defaults
- Integrate the notions of critical reading of articles

Content

- Characterization of continuous images. Image classes. 2D Fourier transform. Shift-invariant systems.
- Introduction to image analysis and computer vision. Segmentation, edge detection, objet detection, image comparison.


Abstract

No enrolment to this course at ETH Zurich. Book the corresponding module directly at EPFL.

Objective

The goal of the lecture is to present and apply techniques for the modelling and the thermo-economic optimisation of industrial process and energy systems. The lecture covers the problem statement, the solving methods for the simulation and the single and multi-objective optimisation problems.

By the end of the course, the student must be able to:
- Master the concepts of thermodynamic efficiency, E6
- Establish the flow diagram of an industrial process and calculate the corresponding energy and mass balance, E22
- Analyse the energy and exergy efficiency of industrial energy systems, E23
- Model, design and optimize energy conversion systems and industrial processes, E24
- Establish the flow diagram of an industrial process and calculate the corresponding energy and mass balance, E20
- Explain and apply the concepts of thermodynamic efficiency, E6
- Analyze the energy and exergy efficiency of industrial energy systems, E21
- Model, design and optimize energy conversion systems and industrial processes, E22
By the end of the course, the student must be able to: Use applications codes.

- Manipulate the fundamental elements of the plasma fluid and kinetic theory
- Identify features of a PDE relevant for the selection and performance of a numerical algorithm.
- Assess / Evaluate numerical methods in light of the theoretical results.
- Implement numerical methods for saddle point problems
- Choose an appropriate method to solve a given differential problem
- Prove convergence of a discretisation scheme

Numerics for Fluids, Structures and Electromagnetics (EPFL)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at EPFL.

Objective
By the end of the course, the student must be able to:

- Concepts of Computer Aided Process System Engineering methods to tackle the problems of energy conversion systems modelling and optimisation. The students will acquire a methodology to state the problem, identify the solving procedure, solve the problem and analyse the results;
- Definition of the basic system modelling concepts: state variables, energy and mass balances, simulation parameters and equations, degree of freedom analysis, different types of specifications, inequalities, objective functions;
- Energy systems equipments models;
- System models: flowsheets, degrees of freedom, sequential or simultaneous solving approach, numerical methods and their implications;
- Measurement data reconciliation and parameter identification;
- Calculating systems performances: operating cost, efficiency, environmental impact, investments, thermo-economic and environomic performances;
- Stating and solving optimization problems: decision variables, objective functions and constraints, solving strategies, numerical methods and their implications.
- Realization of a case study.

Neutron and X-ray Scattering of Quantum Materials

This course will present an overview of the nuclear interactions for neutrons on nuclei below a few hundreds of MeV. The aspect of so-called "nuclear data" will be presented from the perspective of experiments, compilation, calculation, evaluation, processing and applications.

Neutron and X-ray scattering are some of the most powerful and versatile experimental methods to study the structure and dynamics of materials on the atomic scale. This course covers basic theory, instrumentation and scientific applications of these experimental methods.

By the end of the course, the student must be able to:

- Prove convergence of a discretisation scheme
- Implement numerical methods for saddle point problems
- Identify features of a PDE relevant for the selection and performance of a numerical algorithm.
- Assess / Evaluate numerical methods in light of the theoretical results.
- Choose an appropriate method to solve a given differential problem
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- Assess / Evaluate numerical methods in light of the theoretical results.
- Choose an appropriate method to solve a given differential problem
- Prove convergence of a discretisation scheme
By the end of the course, the student must be able to:
- Plan, predict and interpret neutron scattering experiments
- Read and evaluate articles containing neutron scattering results

Neutron scattering is one of the most powerful and versatile experimental methods to study the structure and dynamics of materials on the nanometer scale. Its application spans from crystaline matter to bio-materials and engineering, including fields like magnetism and superconductivity. Similar to the vast possibilities with X-rays at synchrotron facilities, neutron scattering is a so-called large scale technique with neutron facilities among other at PSI in Switzerland, ILL in Grenoble and a new joint European Spallation Source under construction in Sweden.

The course provides an introduction to the versatile experimental techniques of neutron scattering and covers the following aspects:

1. Theory of the neutron scattering cross section
2. Neutron sources and neutron instrumentation
3. Neutron imaging, neutron reflectivity and neutron small angle scattering
4. Neutron diffraction, crystal structures
5. Neutron scattering, phonons
6. Magnetic neutron scattering, magnetic structures
7. Inelastic magnetic neutron scattering, magnetic dynamics
8. Resonant Inelastic X-ray Scattering (RIXS) a complementary technique

The elective project is designed to train the students in the solution of specific engineering problems related to nuclear technology. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

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<td>151-0150-00L</td>
<td>Advanced Topics in Nuclear Reactor Materials</td>
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<td>4</td>
<td>3G</td>
<td>M. A. Pouchon, P. J.-P. Spätig, M. Streit</td>
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<td>151-2037-00L</td>
<td>Nuclear Computations Lab</td>
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<td>4</td>
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<td>A. Pautz, H. Ferroukhi, further lecturers</td>
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<td>151-2039-00L</td>
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Abstract
The course contains lectures and exercise sessions. Exercise sessions will contain deriving relevant formulas, Monte-Carlo simulation of neutron scattering experiments, and discussion of representative scientific articles using neutron scattering. We use partially flip-classroom format for interactive learning.

Objective
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</table>
Introduction to aspects of Nuclear Power Plant decommissioning including project planning and management, costs and financing,


Prerequisites: Recommended courses: 151-0156-00L Safety of Nuclear Power Plants plus either 151-0163-00L Nuclear Energy Conversion or 151-2045-00L Reactor Technology

Decommissioning of Nuclear Power Plants

Students registered at ETH Zurich have to enroll to this course at ETH. EPFL students can enroll to this course directly at EPFL.

Abstract
Introduction to aspects of Nuclear Power Plant decommissioning including project planning and management, costs and financing, radiological characterization, dismantling/decontamination technologies, safety aspects and radioactive waste management considerations.

Objective
Aim of this course is to provide the students with an overview of the multidisciplinary issues that have to be addressed for the successful decommissioning of NPPs. Students will get exposed to principles of project management, operations management, cost estimations, radiological characterization, technologies relevant to the safe dismantling of NPPs and best-practice in the context of radioactive waste management.

Content
Legal framework, project management and operations methods and tools, cost estimation approaches and methods, nuclear calculations and on-site radiological characterization and inventorying, state-of-the-art technologies for decontamination and dismantling, safety considerations, state-of-the-art practice for radioactive waste treatment, packaging and transport, interface with radioactive waste management and disposal. The course will additionally include student visits to relevant nuclear sites in Switzerland and Germany.

Lecture notes
Slides will be handed out.

Literature


Elective Project Nuclear Engineering

The subject of the Elective Project and the choice of the supervisor (ETH or EPFL professor) are to be approved in advance by the tutor.

Abstract
The elective project has the purpose to train the students in the solution of specific engineering problems related to nuclear technology. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

Objective
The elective project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's programme.

Biomedical Imaging

Introduction to diagnostic medical imaging based on electromagnetic and acoustic fields including X-ray planar and tomographic imaging, radio-tracer based nuclear imaging techniques, magnetic resonance imaging and ultrasound-based procedures.

Objective
Upon completion of the course students are able to:

- Explain the physical and mathematical foundations of diagnostic medical imaging systems
- Characterize system performance based on signal-to-noise ratio, contrast-to-noise ratio and transfer function
- Design a basic diagnostic imaging system chain including data acquisition and data reconstruction
- Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications

Content
- Introduction (intro, overview, history)
- Signal theory and processing (foundations, transforms, filtering, signal-to-noise ratio)
- X-rays (production, tissue interaction, contrast, modular transfer function)
- X-rays (resolution, detection, digital subtraction angiography, Radon transform)
- X-rays (filtered back-projection, spiral computed tomography, image quality, dose)
- Nuclear imaging (radioactive tracer, collimation, point spread function, SPEC/PE)
- Nuclear imaging (detection principles, image reconstruction, kinetic modelling)
- Magnetic Resonance (magnetic moment, spin transitions, excitation, relaxation, detection)
- Magnetic Resonance (plane wave encoding, Fourier reconstruction, pulse sequences)
- Magnetic Resonance (contrast mechanisms, gradient- and spin-echo, applications)
- Ultrasound (mechanical wave generation, propagation in tissue, reflection, transmission)
- Ultrasound (spatial and temporal resolution, phased arrays)
- Ultrasound (Doppler shift, implementations, applications)
- Summary, example exam questions

Lecture notes
Lecture notes and handouts

Literature
Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

Prerequisites
Analysis, Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming
The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and fostered

Type
assessed

Hours
30 credits

The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

Analytical Competencies

Decision-making
fostered

Media and Digital Technologies
fostered

Problem-solving
assessed

Social Competencies

Communication
assessed

Personal Competencies

Cooperation and Teamwork
assessed

Adaptability and Flexibility
fostered

Creative Thinking
assessed

Critical Thinking
assessed

Integrity and Work Ethics
fostered

Self-direction and Self-management
fostered

ECTS

8 credits

Lecturers
M. Stampanoni, F. Marone Welford

External Organisers

No registration required via myStudies.

Objective
Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

Content

Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

Lecture notes
Available online

Literature
Will be indicated during the lecture.

► Electives

Course from the catalogue of Master courses ETH Zurich and EPFL. At least 4 credit points must be collected from the offer of Science in Perspective (SiP) compulsory electives at ETH Zurich or Management of Technology and Entrepreneurship at EPFL.

► Industrial Internship

Number
151-1090-00L

Title
Industrial Internship

Type
O

ECTS
8 credits

Hours
17A

Lecturers
External Organisers

Objective
The main objective of the minimum twelve-week internship is to expose Master's students to the industrial work environment. The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

Abstract
Access to the company list and request for recognition under www.mavt.ethz.ch/praxis.

No registration required via myStudies.

Objective
The main objective of the minimum twelve-week internship is to expose Master's students to the industrial work environment. The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

► Semester Project

Number
151-1020-00L

Title
Semester Project Nuclear Engineering

Type
O

ECTS
8 credits

Hours
17A

Lecturers
Professors

Abstract
The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

Objective
The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's programme.

► Master's Thesis

Number
151-1009-00L

Title
Master's Thesis Nuclear Engineering

Type
O

ECTS
30 credits

Hours
64D

Lecturers
Supervisors

Abstract
Master's programs are concluded by the master's thesis. The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem. The subject of the master's thesis, as well as the project plan and roadmap, are proposed by the tutor and further elaborated with the student.

Objective
The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem.
### Nuclear Engineering Master - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
<th>W+</th>
<th>W</th>
<th>E-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<tr>
<td>O</td>
<td>Compulsory</td>
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</tbody>
</table>

| Key for Hours |
|---------------|----------------------------------|
| V             | lecture                          |
| G             | lecture with exercise            |
| U             | exercise                         |
| S             | seminar                          |
| K             | colloquium                       |
| P             | practical/laboratory course      |
| A             | independent project              |
| D             | diploma thesis                   |
| R             | revision course / private study  |

ECTS European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Pharmaceutical Sciences Master

Core Courses I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>535-0030-00L</td>
<td>Pharmaceutical Immunology II &amp; Therapeutic Proteins</td>
<td>O</td>
<td>3 credits</td>
<td>3G</td>
<td>C. Halin Winter, D. Neri</td>
</tr>
<tr>
<td></td>
<td>Prerequisites: Either 535-0830-00L Pharmaceutical Immunology I or 551-0317-00L Immunology I must have been taken.</td>
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<tr>
<td>Abstract</td>
<td>In this course, various topics related to the development, GMP production and application of therapeutic proteins will be discussed. Furthermore, students will expand their training in pharmaceutical immunology and will be introduced to the basic concepts of pharmaceutical product quality management.</td>
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<tr>
<td>Objective</td>
<td>Students know and understand:</td>
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<tr>
<td></td>
<td>- basic mechanisms and regulation of the immune response</td>
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<td></td>
<td>- the pathogenic mechanisms of the most important immune-mediated disorders</td>
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<td></td>
<td>- the concepts of vaccination and cancer immunotherapy</td>
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<td></td>
<td>- the most frequently used expression systems for the production of therapeutic proteins</td>
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<td></td>
<td>- the use of protein engineering tools for modifying different features of therapeutic proteins</td>
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<td></td>
<td>- the mechanism of action of selected therapeutic proteins and their application</td>
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<tr>
<td></td>
<td>- basic concepts in the GMP production of therapeutic proteins</td>
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<tr>
<td>Content</td>
<td>The course consists of two parts:</td>
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<td></td>
<td>In the first part, students will complete their training in Pharmaceutical Immunology. This part particularly focuses on the pathogenic mechanisms of immune-mediated diseases, vaccination and cancer immunotherapy. Deepened knowledge of immunology will be relevant for understanding the mechanism of action of many therapeutic proteins, as well as for understanding one major concern related to the use of protein-based drugs, namely, immunogenicity.</td>
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<td>The second part focuses on topics related to the development and application of therapeutic proteins, such as protein expression, protein engineering, reducing immunogenicity, and GMP production of therapeutic proteins. Furthermore, selected examples of approved therapeutic proteins will be discussed.</td>
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</tr>
<tr>
<td>Literature</td>
<td>Handouts to the lectures will be available for downloading under <a href="http://www.pharma.ethz.ch/scripts/index">http://www.pharma.ethz.ch/scripts/index</a></td>
<td></td>
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<tr>
<td>Literature</td>
<td>Janeway's ImmunoBiology, by Kenneth Murphy (9th or 10th Edition)</td>
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<tr>
<td>Literature</td>
<td>Lecture Handouts</td>
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<tr>
<td>Literature</td>
<td>Paper References provided in the Scripts</td>
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<tr>
<td>Literature</td>
<td>EMEA Dossier for Humira</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Either 535-0830-00L Pharmaceutical Immunology I or 551-0317-00L Immunology I</td>
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</table>

535-0041-00L Pharmaceutical and Toxicology III

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pharmacology and Toxicology III</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>U. Quitterer, M. Arand, Y. Yamauchi</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course is divided into three parts. The first part provides an overview of drugs used for the pharmacotherapy of infectious diseases, osteoporosis, autoimmune diseases and cancer. The second part gives an overview of the field of medical virology, and the third part is focused on pharmacogenomics of drug metabolism and basic concepts of toxicology.</td>
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<tr>
<td>Objective</td>
<td>The course advances basic knowledge in pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiological and clinical aspects of drug therapy in the fields of infectious diseases, osteoporosis, autoimmune diseases and cancer. The course also provides an overview of the fields of medical virology, toxicology, and pharmacogenomics with a special focus on the role of genetic polymorphisms in drug response and adverse effects.</td>
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<tr>
<td>Content</td>
<td>Topics include the pharmacology and pharmacotherapy of infectious diseases, osteoporosis, autoimmune diseases and cancer. Medical virology covers important viral infections and their pharmacotherapy with different classes of antiviral drugs. In the field of pharmacogenomics, the course is focused on examples of genetic variability of drug metabolism and drug responses, and the relevance of pharmacogenomics and toxicogenomics for clinical drug development. Finally, basic concepts of toxicology are introduced.</td>
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<tr>
<td>Lecture notes</td>
<td>A script is provided for each lecture. The scripts define important and exam-relevant contents of the lectures. Scripts do not replace the lectures.</td>
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<tr>
<td>Literature</td>
<td>Recommended reading:</td>
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<tr>
<td></td>
<td>The classic textbook in Pharmacology:</td>
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<td></td>
<td>Goodman and Gilman’s The Pharmacological Basis of Therapeutics</td>
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<td></td>
<td>Laurence Brunton, Björn C. Knollman. 14th edition (2022)</td>
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<td></td>
<td>ISBN-10: 1264258070</td>
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<td>or</td>
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</table>
This course will be a combination of formal lectures, group discussions and self-directed studies. Course material will be taught through Knowledge in the field of intellectual property, especially of patents and trademarks, with particular emphasis on pharmaceutics.

- Historical landmarks of drug safety
- Pharmacovigilance and causality assessment
- Drug safety in premarking clinical trials
- Descriptive, cohort and case-control drug safety study designs; Data analysis and control of confounding
- Pharmacoepidemiology and regulatory decision making in drug safety; Risk management plans (RMPIs)
- Medication errors, clinical pharmacology / clinical pharmacy
- Clinical Decision Support Systems, Interventional Pharmacoepidemiology
- Pharmacoepidemiological databases, 'Big Data'
- Interactive discussion of many real-life examples for each topic

Lecture notes
This course will be a combination of formal lectures, group discussions and self-directed studies. Course material will be taught through seminars, case studies in small groups.

Reading material and scripts will be provided for each week.

Literature
- Rothman: Introduction to Epidemiology
- Strom, Kimmel, Hennessy: Textbook of Pharmacoepidemiology
- Gigerenzer: Risk Savvy - How to Make Good Decisions

535-0505-00L  Pharmacoepidemiology and Drug Safety  O  3 credits  2G  A. Burden, S. Russmann

Abstract
Introduction to the principles, methods and applications of pharmacoepidemiology and drug safety. Drug safety in the pharmaceutical industry and regulatory authorities, but also for hospital and office pharmacists. Another focus is the evaluation and interpretation of pharmacoepidemiological drug safety studies in the medical literature and the evaluation of benefits vs. risks.

Objective
Objectives:
- To familiarize participants with the principle methods and applications of pharmacoepidemiology and drug safety that is relevant for industry, regulatory affairs, but also for clinical pharmacists in hospitals and office pharmacies.
- Perform independently a causality assessment of suspected adverse drug reactions in patients
- Study designs and biostatistics used for the quantitative evaluation of drug safety
- Setup of programs that can effectively reduce medication errors and improve drug safety in clinical practice, particularly in hospitals

Content
- Historical landmarks of drug safety
- Pharmacovigilance and causality assessment
- Drug safety in premarking clinical trials
- Descriptive, cohort and case-control drug safety study designs; Data analysis and control of confounding
- Pharmacoepidemiology and regulatory decision making in drug safety; Risk management plans (RMPIs)
- Medication errors, clinical pharmacology / clinical pharmacy
- Clinical Decision Support Systems, Interventional Pharmacoepidemiology
- Pharmacoepidemiological databases, 'Big Data'
- Interactive discussion of many real-life examples for each topic

Lecture notes
This course will be a combination of formal lectures, group discussions and self-directed studies. Course material will be taught through seminars, case studies in small groups.

Reading material and scripts will be provided for each week.

Literature
- Rothman: Introduction to Epidemiology
- Strom, Kimmel, Hennessy: Textbook of Pharmacoepidemiology
- Gigerenzer: Risk Savvy - How to Make Good Decisions

535-0546-00L  Patents  O  1 credit  1V  C. Ebner, A. Koepl

Abstract
Knowledge in the field of intellectual property, especially of patents and trademarks, with particular emphasis on pharmaceutics. Introduction into intellectual property; prosecution of patent applications; patent information; exploitation and enforcement of patents; peculiarities in pharmaceutics and medicine; social, political and ethical aspects; Trademarks.

Objective
Basic knowledge in the field of industrial property, especially of patents and trademarks, with particular emphasis on the chemical, pharmaceutical and biotech field.

Content
1. Introduction into industrial property (patents, trademarks, industrial designs);
2. Prosecution of patent applications (patentability);
3. Patent information (patent publications, databases, searches);
4. Exploitation and enforcement of patents (possibilities of exploitation, licenses, parallel imports, scope of protection, patent infringement);
5. Peculiarities in pharmaceutics and medicine (supplementary protection certificates, experimental use exemption, therapy and diagnosis, medical indication);
6. Social, political and ethical aspects (patents and prices for medicinal products, traditional knowledge and ethnomedicine, bioprospecting and biopiracy, human DNA inventions);
7. Trademarks, types of trademarks, grounds for refusal, peculiarities of pharma-trademarks.

Lecture notes
A script is provided in electronic form during the lecture.

Literature

Prerequisites / notice
None
### Competencies

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Social Competencies**

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Personal Competencies**

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

### Abstract

This course provides a broad overview of the concepts and processes employed in today’s drug discovery and development. It has an introductory character but will also provide more detailed insights employing real-life examples. The course combines lectures and interactive elements with active participation of the students.

### Objective

**Students**

- Understand the drug discovery process and can explain major approaches and relevant technical terms (for details see lecture notes).
- Understand and appreciate the content and timing of drug development process steps, development phases and decision criteria.
- Understand the concepts underlying drug product development through all the phases from preclinical and clinical development to regulatory submission, approval and market launch.
- Can differentiate between small molecule drug development and biological drug development.
- Understand the most important differences for drug development and approval between the EU and USA Pharma markets with regard to legal and regulatory requirements.

### Content

Course unit comprises weekly lectures covering the early phases of target and drug discovery (535-0901-01 S “From A to Z in Drug Discovery and Development”) with group work in the area of Drug Development (511-0000-00 G). The latter course lasts 2 full days (Days 1 and 2) and comprises both lectures and group work: inter alia an introduction to the entire suite of drug product development processes in the pharmaceutical industry, covering preclinical research and development, clinical development, regulatory processes and market launch.

R&D support processes such as project management, quality management, pharmacovigilance and pharmaco-economics will be covered as well as organizational and governance aspects of the pharmaceutical industry. In addition, important success factors for a later career in the pharmaceutical industry will be briefly discussed at the end of Day 2 of the course.

### Lecture notes

Will be published on "myStudis".

### Literature


Further readings will be listed in the lecture notes.

### Prerequisites / notice

This course provides the essential basic knowledge required for the industry-specific modules of the spring semester.

### Competencies

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Project Management

**Personal Competencies**

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection

### Electives I

**Number**

535-0011-00L

**Title**

Drug Seminar

**Type**

W

**ECTS**

5

**Hours**

9S

**Lecturers**


**Abstract**

The course provides a platform for the investigation, presentation and discussion of a topic with relevance to the field of pharmaceutical sciences. Students work in small groups on a chosen topic and present their work on a one day symposium.
Objective

The main objectives of this course are:
- students develop their scientific reflection (Critical Thinking) and working skills by working independently on a relevant pharmaceutical topic
- students gain in-depth knowledge of the topic investigated
- students train their scientific writing and presentation skills
- students train their ability to plan a project and work in a team

Content

The Course Drug Seminar takes place during the first 7 weeks of the 1. Master semester. It is a compulsory course of the MSc Pharmacy curriculum and an elective course in the MSc PharmSciences.

The course provides a platform for the investigation, presentation and discussion of a topic with relevance to the field of pharmaceutical sciences.

During the course, students work in small teams on a topic of their choice and elaborate an oral presentation. Each team is tutored by a lecturer of the Institute of Pharmaceutical Sciences. The work is mainly based on literature search/review, but may also involve conducting interviews or site visits, if appropriate. The final presentations of all groups will take place in the framework of a dedicated Symposium held in the middle of the semester.

Prerequisites / notice

Only for students of MSc Pharmacy and MSc Pharmaceutical Sciences.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td>Methods-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
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</table>

<table>
<thead>
<tr>
<th>511-1001-00L Biopharmacy (Crash Course)</th>
<th>E-</th>
<th>2 credits</th>
<th>1S</th>
<th>S.-D. Krämer</th>
</tr>
</thead>
</table>

Abstract

This course provides the basic concepts of biopharmacy (ADMET, absorption, distribution, metabolism, excretion, toxicity of drugs) and pharmacokinetics. After an introduction to the fundamental parameters and concepts, the participants will study independently and apply and consolidate their knowledge in tutorials.

Objective

- Knowledge of the ADMET processes and the respective pharmacokinetic parameters.
- Interpretation of pharmacokinetic parameters.
- Analysis of drug plasma concentration-time curves.
- Prediction of pharmacokinetic parameters based on in vitro assays and physicochemical drug properties.
- Knowledge of the effects of physiological factors on the pharmacokinetic parameters and on drug plasma and tissue concentrations.
- Design of dosage regimens, based on pharmacokinetic parameters.
- Prediction of drug-drug interaction potentials based on in vitro assays and pharmacokinetic parameters.

Content

- Introduction to biopharmacy (ADMET) and pharmacokinetics.
- Definition of the most important pharmacokinetic parameters and their calculation from plasma concentration-time curves.
- Introduction to compartment models, statistical models, physiological models.
- Pharmacokinetic profiling of drugs for therapy optimization and for the analysis of the interaction potential.
- Design of dosage regimens. In vitro assays to predict pharmacokinetic parameters.

Lecture notes

Slides, see documents repository.

Literature

DOI: 10.1002/9783527645763

Prerequisites / notice

Obligatory course if assigned by the Admission committee.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<tbody>
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<td>Methods-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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</table>

<table>
<thead>
<tr>
<th>511-1002-00L Pharmaceutical Analytics and Pharmacopoeia (Crash Course)</th>
<th>E-</th>
<th>2 credits</th>
<th>1S</th>
<th>C. Steuer</th>
</tr>
</thead>
</table>

Abstract

This course provides the basic concepts of pharmaceutical analytics in the context of pharmacopeial regulation. After an introduction to the fundamental techniques and concepts, the participants will study independently, apply and consolidate their knowledge in tutorials.

Objective

Students are able to:
- summarize the structure of the Ph. Eur.
- summarize the most important pharmacopeias and their communalities and differences
- discuss the structure of a monograph
- explain qualification of instruments and validation of methods
- explain and compare most important analytical techniques for pharmaceutical industry

Content

Students gain knowledge in pharmaceutical analytics to fulfill regulatory requirements in pharmaceutical industry based on the pharmacopeia in force. Focus is set on method validation, equipment qualification, identification, purity testing and content determination of active pharmaceutical ingredients and excipients.

Lecture notes

Slides, see documents repository

Literature

The course enables the student to understand and apply the general concepts of gene technology, including recombinant DNA technology and its application in genomics, transcriptomics and proteomics. Protein cloning, expression and modifications and bimolecular interactions will be discussed. The concept of display technology and its applications in the field of drug discovery will be presented.

The students remember and understand:

1. The tools of recombinant DNA technology
2. Next generation sequencing approaches and their relevance for -omics projects
3. Protein cloning, expression, modification/labelling and oligomerization
4. Thermodynamic and kinetic affinity constants in bimolecular reactions
5. Basic structure of the antibody molecule
6. Concepts of antibody phage technology and antibody engineering
7. Construction of antibody-, peptide- or small molecule libraries and affinity-based selection methodologies

### Content

**I) Genomics:**
- recombinant DNA technology
- methods to sequence genomes
- application to human biology

**Transcriptomics / Proteomics**

**II) Proteins:**
- protein cloning and expression
- homo- and heterodimerization
- chemical modifications and radioactive labelling
- detection of bimolecular interactions
- affinity constant and experimental measurement
- kinetic association and dissociation constants

**III) Display technology:**
- the antibody molecule, CDRs, basics of antibody engineering
- antibody phage display and selection methodologies
- construction of antibody libraries
- other display technologies (peptide display, DNA-encoded chemical libraries)

### Lecture notes

Slides and script used for the course and literature for reading and discussions will be made available online.

### Literature

Dedicated chapters of:
- other display technologies (peptide display, DNA-encoded chemical libraries)

Further references will be provided in the course.

### Prerequisites / notice

Admission to MSc in Pharmaceutical Sciences

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**535-0423-00L Drug Delivery and Drug Targeting**

**Objective**
The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.

**Content**
The students dispose of an overview on current principles and systems for the controlled delivery and targeting of drugs. The focus of the course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines. Various micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.

**Lecture notes**
Selected lecture notes, documents and supporting material will be directly provided or may be downloaded from the course website.

**Literature**


Further references will be provided in the course.

---

**535-0250-00L Biotransformation of Drugs and Xenobiotics**

**Objective**
The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.

**Content**
The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.

**Lecture notes**

Selected lecture notes, documents and supporting material will be directly provided or may be downloaded from the course website.

**Literature**


Further references will be provided in the course.
Abstract
Knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism.

Objective
Goals: knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism.

Content
Major reactions of biotransformation. Major enzymes and reaction partners involved in the biotransformation of drugs and xenobiotics. Toxic reactions of metabolites. Factors which affect the biotransformation.

Lecture notes
Biotransformation of drugs and xenobiotics

Literature

Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: fostered
- Method-specific Competencies
  - Analytical Competencies: fostered
  - Decision-making: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: fostered
  - Project Management: fostered
- Personal Competencies
  - Creative Thinking: assessed
  - Critical Thinking: fostered

535-0015-00L
History of Pharmacy
W 1 credit 1V S. Ruppen

Abstract
In the lecture, basic knowledge of the history of pharmacy is imparted, taking into account the various historical epochs.

Objective
After attending the lecture, the students are able to name significant events in the development of the pharmacy profession, pharmacy and medicines and to place them in a temporal context. They can list sources for working on questions from the history of pharmacy and evaluate their advantages and disadvantages. This enables them to confidently describe the importance of pharmacy as an independent, supporting pillar of the health system, the history of which has many interfaces with medicine, science, social and cultural history.

Content
The lecture conveys knowledge about the development of the pharmacist profession from ancient times to the present. Some pharmacists who made significant contributions to pharmacy are presented in more detail and their significance for today's pharmacy is discussed. The social position of pharmacists in society and the legal conditions in different epochs are also discussed. It explains what influence the pharmacists had on the development of the pharmaceuticals, but again the pharmaceuticals on the development of the pharmacists. For this purpose, it is shown how much the meaning, the nature, the type and the composition of pharmaceuticals and the knowledge about them changed over time.

Literature
Wird in der ersten Veranstaltung mitgeteilt.

Prerequisites / notice
An interest in the history of pharmacy, the pharmacy profession, and medicines is an asset.

Competencies
- Subject-specific Competencies
  - Concepts and Theories: fostered
  - Techniques and Technologies: fostered
- Method-specific Competencies
  - Analytical Competencies: fostered
  - Decision-making: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: fostered
  - Project Management: fostered
- Social Competencies
  - Sensitivity to Diversity: fostered
- Personal Competencies
  - Critical Thinking: fostered

535-0344-00L
From Ethnopharmacy to Molecular Pharmacognosy
W 1 credit 1V B. Frei Haller, A. Lardos

Abstract
Basic understanding and awareness of ethnopharmaceutical and ethnopharmacological issues and research. Knowledge of methods used in drug discovery from natural sources. Discussion of the issues around law and international treaties. Importance of ethnopharmaceutical knowledge for world health.

Objective
Basic understanding and awareness of ethnopharmaceutical and ethnopharmacological issues and research. Knowledge of methods used in drug discovery from natural sources. Discussion of the issues around law and international treaties. Importance of ethnopharmaceutical knowledge for world health.

Content

Lecture notes
Handouts will be provided.

Literature

Prerequisites / notice
Prerequisites: Basic lectures in biology or biochemistry and pharmaceutical biology have been attended; not suitable for first semester students.
Objective

Students gain basic knowledge in "pharmaceutical glycobiology". This implies knowing and understanding:

- major mechanisms underlying the roles of glycosylation for the biological/therapeutic actions of glycoproteins (glycosylation-function relationships) using prominent examples of glycoprotein drugs.
- the major types of protein-linked glycans and the biosynthetic pathways for their formation
- how glycoprotein drugs are produced (including the most important expression systems used), glycoengineered and analysed (quality control).

Students are able to apply this knowledge in solving simple problems in glycoprotein drug development (on paper).

Students gain the ability to reflect on roles of glycosylation in various biological contexts.

Content

Lecture plan:
1. Glycans - information carriers in biology and pharmacotherapy
2. Glucocerebrosidase and the biosynthesis of N-glycans
3. Improving the therapeutic profile of monoclonal antibodies by glycoengineering
4. Mucin-type O-glycans and sialylation as gCQA of glycoprotein hormone drugs
5. gCQA analysis of glycoprotein hormone drugs (sialylated glycoproteins)
6. EPO "the same but different"

Lecture notes

The slides used for the lectures will be provided online.

Literature

- recent publications as cited/proposed on the lecture slides

Prerequisites

Requirements: Basic knowledge in immunology, molecular biology, protein and carbohydrate chemistry, analytical techniques. Basic knowledge in pharmacology.

Objective

To critically appraise the ethical, societal, economical and political expectations in the development of new drugs.

Content

In December 2006, Pfizer stopped a large phase III study on the use of Torcetrapib for the prevention of atherosclerosis and cardiovascular disease. 800 million $ in development costs and 21 billion $ in stocks were annihilated overnight. The failure of Torcetrapib has pinpointed the limitations of an extremely reductionist view of atherosclerosis and it’s prevention by drug therapy. It has also highlighted what high economical and political expectations in new drugs shall be reflected and discussed.

These are the topics of the present course. Using three particularly informative examples of drug failures, the problems encountered and the concepts and informative value of preclinical and clinical studies will be analyzed and discussed. Furthermore, the ethical, societal, economical and political expectations in new drugs shall be reflected.

Lecture notes

Lecture slides and literature for reading and discussions will be available online.

Prerequisites

Requirements: basic knowledge in Medicinal Chemistry and Pharmacology. Ability to read and understand scientific publications written in English.
Deficiencies of particular vitamins result in specific diseases such as for example scurvy (vitamin C deficiency). Such disease patterns are usually easily recognized and facile to be treated. The clinical utility of supplementation concerns people with severe deficiencies and a risk of complications. Latent vitamin deficiencies might result in variable disorders and risks. As an example neurological disorders in elderly as a consequence of chronic lack of vitamin B12 should be mentioned. Subclinical deficiencies are often difficult to assess. However, these are exactly the cases where advice of a pharmacist is requested.

A large intake of vitamins by over-supplementation or food fortification might be dangerous (hypervitaminosis). This is in particular the case for fat-soluble vitamins or in the case of constant intake of high amounts of water-soluble vitamins over a long time period.

The lecture ‘Vitamins in Heath and Disease’ will give an overview over the history and applications of vitamins and their functions to preserve good health. The utility of vitamin supplementation during conditions of deficiencies, potential consequences of a latent deficiency as well as risks of over-supplementation will be discussed.
Compétences | Compétences spécifiques | Compétences méthodologiques | Compétences personnelles
--- | --- | --- | ---
Assisté | Concepts et Théories | Techniques et Technologies | Assisted
Assisté | Compétences analytiques | Médias et Technologies numériques | Assisted
Assisté | Compétences de résolution de problèmes | Assisted
Assisté | Adaptabilité et Flexibilité | Assisted
Assisté | Pensez et Réflexion | Assisted
Assisté | Socialisés | Assisted
Assisté | Communication | Assisted
Assisté | Cooperation and Teamwork | Assisted
Assisté | Sensibilité à la Diversité | Assisted
Assisté | Adaptabilité et Flexibilité | Assisted
Assisté | Creative Thinking | Assisted
Assisté | Critical Thinking | Assisted
Assisté | Ethique et Éthique du Travail | Assisted
Assisté | Sensibilité et Self-reflection | Assisted
Assisté | Self-direction et Self-management | Assisted

535-0024-00L | Méthodes de la substance | 1 crédit | 1V | G. Schneider

*Note: The course does not take place this semester.*

Abstract
The lecture is organized as a two-week block during the practical course "Computer-Assisted Drug Design" (535-0023-00 P), totalling 10 two-hour lectures. It provides an introduction to advanced drug design techniques and approaches emphasizing computer-assisted molecular design.

Objective
Participants will learn about computational algorithms and advanced experimental approaches to drug discovery and design, including selected actual topics and practical applications. The contents of the lecture will allow for a deeper understanding of modern computer-assisted drug design methods and how they are linked to experimental applications. The main focus is on computational medicinal chemistry, so that participants will be able to use relevant computer-based methods in their own research projects.

Littérature

Prérequis / Notice
The lecture is mandatory for all participants of the course "Computer-Assisted Drug Design" (535-0023-00 P).

535-0023-00L | Design du Medica | 4 crédits | 6P | G. Schneider

*Note: The course does not take place this semester.*

Abstract
The practical course is open for master and graduate students to get an introduction into hands-on computer-assisted drug design. The class includes an introduction to computer-based screening of a virtual compound library, subsequent synthesis of candidate ligands, and biochemically testing for activity on pharmacologically important drug targets.

Objective
Participants become familiar with state-of-the-art methodologies in a real-life computer-aided medicinal chemistry project. Participants work as small teams, perform literature research and discuss recent research findings. A seminar talk is to be given presenting the molecular design strategy chosen and the results obtained during the course.

Content
The course offers the possibility for people with and without computational and or laboratory background to get an introduction into computer-assisted drug design, as well as practical training in a modern chemical laboratory. Using various software suites, the participants will computationally create and screen a virtual compound library for potential active small molecules. The process will involve an introduction to screening a virtual compound library, synthesizing candidate inhibitors, and biophysical testing against a pharmacologically important drug target.

Lecture notes
Detailed information will be handed out during the course.

Literature
Textbook:

Prérequis / Notice
The number of participants is limited.

Kick-off meeting and confirmation of registration (Vorbesprechung und Platzvergabe): During the last lecture of the class "Computer-Assisted Drug Design" (535-0023-00).

*Note: Ideally, students interested in the course participated and successfully passed the lecture "Computer-Assisted Drug Design" (535-0023-00).*

► Research Project

<table>
<thead>
<tr>
<th>Numéro</th>
<th>Titre</th>
<th>Type</th>
<th>ECTS</th>
<th>Heures</th>
<th>Praticiens</th>
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</thead>
<tbody>
<tr>
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<td>Méthodes pharmaceutiques pratiques</td>
<td>O</td>
<td>8 crédits</td>
<td>17A</td>
<td>Praticiens</td>
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</tbody>
</table>

Abstract
Practical Methods in Pharmaceutical Sciences familiarise students with scientific procedures and operational methodologies through supervised participation in current research work.

Objective
Students get acquainted with scientific working methods and deepen their knowledge in a particular research area.

Compétences

<table>
<thead>
<tr>
<th>Compétences spécifiques</th>
<th>Concepts et Théories</th>
<th>Techniques et Technologies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Problem-solving</th>
<th>Project Management</th>
<th>Communication</th>
<th>Cooperation and Teamwork</th>
<th>Sensitivity to Diversity</th>
<th>Adaptabilité et Flexibilité</th>
<th>Creative Thinking</th>
<th>Critical Thinking</th>
<th>Integrity and Work Ethics</th>
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<th>Self-direction and Self-management</th>
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► Electives II

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<td>Praticiens</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 1962 of 2653
Abstract
Research project familiarises students with scientific procedures and operational methodologies through supervised participation in current research work. The research group is chosen by the student.

Objective
Students get acquainted with scientific working methods and deepen their knowledge in a particular research area.

Prerequisites / notice
Prerequisite: Practical Methods in Pharmaceutical Sciences passed

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
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<td>Techniques and Technologies</td>
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<tr>
<td>Method-specific Competencies</td>
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<td>Problem-solving</td>
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<td>Self-direction and Self-management</td>
<td>fostered</td>
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511-0005-00L Internship ■ W 10 credits 31A Lecturers
Abstract
The internship takes place outside universities, the main locations being: pharmaceutical industry, consultancy, health and regulatory authorities and hospitals. Students experience the professional handling of questions in the field of pharmaceutical sciences through their own practical activities.

Objective
In an internship the students experience the professional handling of questions in the field of pharmaceutical sciences through their own practical activities and be able to implement the knowledge gained, by
- analysing problems in their complexity and developing solutions in a conceptual way,
- experiencing the aspects of an everyday working environment,
- acquiring key skills,
- establishing contacts for prospective careers.

Content
Work experience outside of university, duration of at least 12 weeks.

An Internship agreement is set up between the student, the company and a member of the teaching staff of the Institute of Pharmaceutical Sciences.

At the end of the internship, the student draws up a formal report.

511-0006-00L Consolidation Work ■ W 7 credits 14A Lecturers
Abstract
The Consolidation Work consists of a literature work and provides an opportunity for the students to deeply investigate and consolidate their knowledge in a scientific or technical field of relevance to pharmaceutical sciences / the pharmaceutical industry.

Objective
- students develop their scientific reflection ("Critical Thinking") and independent working skills on a topic relevant to pharmaceutical sciences / the pharmaceutical industry
- students gain in-depth knowledge of the topic investigated
- students train their scientific writing skills

Content
The Consolidation Work consists of a literature work and provides an opportunity for the students to deeply investigate and consolidate their knowledge in a scientific or technical field of relevance to pharmaceutical sciences / the pharmaceutical industry. Students work alone on a topic of their choice over a time period of maximally 12 weeks and elaborate a written review article. Over this time, the student is loosely supervised by a lecturer of the Master Study Program.

Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
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<td>O</td>
<td>30</td>
<td>40D</td>
<td>Lecturers</td>
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</table>

Abstract
In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is usually carried out in a subject area of Pharmaceutical Sciences as chosen by the student.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tr>
<td></td>
<td>Techniques and Technologies</td>
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</tbody>
</table>

Science in Perspective

see Science in Perspective: Language Courses ETH/UZH
**Course Units for Additional Admission Requirements**

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<tr>
<td>535-0421-AAL</td>
<td>Galenical Pharmacy I+II</td>
<td>E-</td>
<td>4 credits</td>
<td>7R</td>
<td>J.-C. Leroux</td>
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</tbody>
</table>

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**

Principles and technologies for the manufacturing of dosage forms and drug delivery systems. Knowledge of pharmaceutical excipients, materials, containers, liquid, solid and semi-solid dosage forms, their production, function, quality and application.

**Objective**

Knowledge of the most important pharmaceutical excipients, materials, containers, liquid, solid and semi-solid dosage forms, of their production, function, quality, stability and application. Comprehension of the molecular interactions in solid state, solution and colloidal systems.

**Content**


**Literature**


**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: assessed
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed

**Personal Competencies**
- Negotiation: fostered
- Adaptability and Flexibility: assessed
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

<table>
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<tr>
<th>Number</th>
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<th>ECTS</th>
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<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-0521-AAL</td>
<td>Pharmacology and Toxicology I+II</td>
<td>E-</td>
<td>5 credits</td>
<td>7R</td>
<td>U. Quitterer</td>
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</table>

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**

This course is a condition for admission to the Pharmaceutical Sciences Master. By self-directed learning, students acquire knowledge about basic principles in pharmacology and toxicology, mechanisms of drug action and clinical uses of important classes of drugs.

**Objective**

After the successful completion of this course, students have gained knowledge about basic principles in pharmacology and toxicology, mechanisms of drug action and clinical uses of important classes of drugs.

**Content**

Contents of this course are defined by the textbook "Basic and Clinical Pharmacology" by Bertram Katzung. The following sections are exam-relevant.

**Lecture notes**

Course contents are defined by the textbook "Basic and Clinical Pharmacology" by Bertram Katzung and Anthony Trevor. Exam-relevant sections of this book are listed above in the contents section.

**Literature**

Basic and Clinical Pharmacology

Bertram Katzung, Todd W. Vanderah

15th edition (Dec. 2020)

McGraw-Hill Education

ISBN-10: 126045231X

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction into the histology and anatomy of the human body, including the musculoskeletal, cardio-respiratory, digestive, endocrine, urinary, reproductive systems, as well as the nervous system and sensory organs.

Objective
Students acquire basic knowledge of the micro- and macro structure of the organ systems in the human body. They understand basic concepts of the relationship between structure and function, and - based on examples - of the relationship between structural changes and disease.

376-0173-AAL  Physiology I+II  E- 5 credits  11R  C. Spengler
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Principles of human physiology and clinical pathophysiology.

Objective
Understand the basic principles of human physiology and mechanisms of related clinical pathophysiology.

406-0603-AAL  Stochastics (Probability and Statistics)  E- 4 credits  9R  M. Kalisch
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

Objective
The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

Content
From "Statistics for research" (online)  
Ch 1: The Role of Statistics  
Ch 2: Populations, Samples, and Probability Distributions  
Ch 3: Binomial Distributions  
Ch 4: Sampling Distribution of Averages  
Ch 5: Normal Distributions  
Ch 6: Student's t Distribution  
Ch 9: Distributions of Two Variables  

From "Introductory Statistics with R (online)"  
Ch 1: Basics  
Ch 2: The R Environment  
Ch 3: Probability and distributions  
Ch 4: Descriptive statistics and tables  
Ch 5: One- and two-sample tests  
Ch 6: Regression and correlation  

Literature
* "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435  
From within the ETH, this book is freely available online under: http://onlinelibrary.wiley.com/book/10.1002/0471477435

From within the ETH, this book is freely available online under: http://www.springerlink.com/content/m1757b/

Competencies

<table>
<thead>
<tr>
<th>Subfield</th>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject-specific Competencies</td>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Method-specific Competencies</td>
<td></td>
<td>Analytical Competencies</td>
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<td>Media and Digital Technologies</td>
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<td>assessed</td>
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<tr>
<td>Personal Competencies</td>
<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
</tr>
</tbody>
</table>

Pharmaceutical Sciences Master - Key for Type

W+  Eligible for credits and recommended
W  Eligible for credits
E-  Recommended, not eligible for credits

Z  Courses outside the curriculum
Dr  Suitable for doctorate
O  Compulsory

Key for Hours

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS  European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
Pharmaceutical Sciences Bachelor

First Year Compulsory Subjects

First Year Examinations

First Year Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-1001-01L</td>
<td>General Chemistry (for Biol./Pharm.Sc.)</td>
<td>O</td>
<td>4 credits</td>
<td>4V+2U</td>
<td>J. Cvengros</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The lecture deals with a number of basic chemistry concepts. These include (amongst others) chemical reactions, energy transfer during chemical reactions, properties of ionic and covalent bonds, Lewis structures, properties of solutions, kinetics, thermodynamics, acid-base equilibria, electrochemistry and properties of metal complexes.</td>
<td></td>
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<tr>
<td><strong>Objective</strong></td>
<td>The course is designed to provide an understanding of the basic principles and concepts of general and inorganic chemistry.</td>
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<tr>
<td><strong>Competencies</strong></td>
<td>Subject-specific Competencies: Concepts and Theories</td>
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<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Social Competencies: Communication</td>
<td>fostered</td>
<td></td>
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<tr>
<td></td>
<td>Personal Competencies: Adaptability and Flexibility</td>
<td>fostered</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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</tbody>
</table>

**529-1011-00L** | Organic Chemistry I (for Biol./Pharm.Sc./HST) | O    | 4 credits | 4G | C. Thilgen |
| **Abstract** | Fundamentals of Organic Chemistry: molecular structure. Bonding and functional groups; nomenclature; resonance and aromaticity; stereochemistry; conformation; bond strength; organic acids and bases; basic reaction thermodynamics and kinetics; reactive intermediates: carbanions, carbenium ions and radicals. |      |      |       |           |
| **Objective** | Understanding the basic concepts and definitions of organic chemistry. Knowledge of the functional groups and classes of compounds that are important in biological systems. Foundations for the understanding of the relationship between structure and reactivity. |      |      |       |           |
| **Lecture notes** | Lecture notes are available (pdf file). Exercises, answer keys and other handouts can be downloaded from the Moodle course "Organic Chemistry I" of the current semester (https://moodle-app2.let.ethz.ch). |      |      |       |           |
| **Prerequisites / notice** | The course consists of lectures (36 hours) and problem-solving lessons (20 hours, groups of ca. 25 people). In addition, online exercises are available in the e-learning environment Moodle (Course OC I). |      |      |       |           |
| **Competencies** | Subject-specific Competencies: Concepts and Theories | assessed |      |       |           |
| | Analytical Competencies | assessed |      |       |           |
| | Communication | fostered |      |       |           |
| | Personal Competencies: Critical Thinking | fostered |      |       |           |
| | Sensitivity to Diversity | fostered |      |       |           |
| | Self-awareness and Self-reflection | fostered |      |       |           |
| | Self-direction and Self-management | fostered |      |       |           |

**551-0125-00L** | Fundamentals of Biology I: From Molecules to the Biochemistry of Cells | O    | 6 credits | 5G | J. Vorholt-Zambelli, N. Ban, R. Glockshuber, K. Locher, J. Piel |
| **Abstract** | The lecture provides an introduction to the basics of biochemistry and molecular biology as well as evolutionary principles. The focus is on bacteria and archaea under consideration of universal concepts. |      |      |       |           |
| **Objective** | Introduction to biochemistry, molecular biology and evolutionary principles |      |      |       |           |
The lecture introduces biology as an interdisciplinary science. Links to physics and chemistry will manifest as biological processes that operate within the laws of thermodynamics and are rooted in elements, molecules and chemical reactions. The transition from geochemistry to biochemistry is discussed and considered in relation to the origin of life. Evolutionary principles are introduced and resulting processes are used as a guiding principle. Unifying concepts in biology are presented, including the structure and function of cellular macromolecules and the ways in which hereditary information is encoded, decoded and replicated. Central principles of universal energy conversion are looked at, starting from redox processes and focusing on bacteria and archaea. Finally, biological processes are put into an ecosystems perspective.

The lecture is divided into different sections:
1. Geochemical perspectives on Earth and introduction to evolution
2. Building blocks of life
3. Macromolecules: Proteins
4. Membranes and transport across the plasma membrane
5. Universal mechanisms of inheritance, transcription and translation
6. Reaction Kinetics, binding equilibria and enzymatic catalysis
7. Essentials of Catabolism
8. Essentials of Anabolism
9. Metabolism and biogeochemical cycling of elements

Lecture notes
The newly conceived lecture is supported by scripts.

Literature

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
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<tbody>
<tr>
<td>Techniques and Technologies</td>
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<table>
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<tr>
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<tr>
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<table>
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<tr>
<th>Personal Competencies</th>
<th>Critical Thinking</th>
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</thead>
<tbody>
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<td>Self-awareness and Self-reflection</td>
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<td>fostered</td>
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First Year Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
First identification with Pharmaceutical Sciences; motivation for profiling in the Natural Sciences, which are focused on within the first two years as a preparation for the specialized studies; sensitization for the duties and the responsibilities of a person with a federal diploma in Pharmacy; information about job opportunities.

Objective
First identification with Pharmaceutical Sciences; motivation for profiling in the Natural Sciences as a preparation for the specialized studies; sensitization for the duties and the responsibilities of a person with a federal diploma in Pharmacy; information about job opportunities.

Content
Introduction to Pharmaceutical Sciences by selected milestones of research and development. Overview on research activities at the Institute of Pharmaceutical Sciences that is focussed on drug delivery and development (from concepts to prototypes). Sensitization for communication skills and information management. Demonstration of job opportunities in community pharmacies, in the hospital, in industry, and in the public sector by experts in the different fields.

Lecture notes
Handouts for individual lectures.

Prerequisites / notice
Interactive teaching

401-0291-00L Mathematics I

Abstract
Mathematics I/II is an introduction to one- and multidimensional calculus and linear algebra emphasizing on applications.

Objective
Students understand mathematics as a language for modeling and as a tool for solving practical problems in natural sciences. Students can analyze models, describe solutions qualitatively or calculate them explicitly if need be. They can solve examples as well as their practical applications manually and using computer algebra systems.
## Eindimensionale diskrete Entwicklungen ##
- linear, exponentiell, begrenzt, logistisch
- Fixpunkte, diskrete Veränderungsrate
- Folgen und Grenzwerte

## Funktionen in einer Variablen ##
- Reproduktion, Fixpunkte
- Periodizität
- Stetigkeit

## Differentialrechnung (I) ##
- Veränderungsrate/-geschwindigkeit
- Differentialquotient und Ableitungsfunktion
- Anwendungen der Ableitungsfunktion

## Integralsrechnung (I) ##
- Stammfunktionen
- Integrationstechniken

## Gewöhnliche Differentialgleichungen (I) ##
- Qualitative Beschreibung an Beispielen: Beschränkt, Logistisch, Gompertz
- Stationäre Lösungen
- Lineare DGL 1. Ordnung
- Trennung der Variablen

## Lineare Algebra ##
- Erste Arithmetische Aspekte
- Matrizenrechnung
- Eigenwerte / -vektoren
- Quadratische LGS und Determinante

### Lecture notes ###
In Ergänzung zu den Vorlesungskapiteln der Lehrveranstaltungen fassen wir wichtige Sachverhalte, Formeln und weitere Ausführungen jeweils in einem Vademecum zusammen.

Dabei gilt:
* Die Skripte ersetzen nicht die Vorlesung und/oder die Übungen!
* Ohne den Besuch der Lehrveranstaltungen verlieren die Ausführungen ihren Mehrwert.
* Details entwickeln wir in den Vorlesungen und den Übungen, um die hier bestehenden Lücken zu schliessen.
* Prüfungsrelevant ist, was wir in der Vorlesung und in den Übungen behandeln.

### Literature ###
Siehe auch Lernmaterial > Literatur

**Th. Wihler**
Mathematik für Naturwissenschaften, 2 Bände: Einführung in die Analysis, Einführung in die lineare Algebra; Haupt-Verlag Bern, UTB.

**H. H. Storrer**

**Ch. Blatter**
Lineare Algebra; VDF und als Skript in der PolyBox

**A. Caspar, N. Hungerbühler**

### Prerequisites / notice ###
+ Die Übungsauflagen (Handaufgaben, Khan-Aufgaben, Multiple-Choice) sind ein wichtiger Bestandteil der Lehrveranstaltung.
+ Es wird erwartet, dass Sie mindestens 9 von 13 der wöchentlichen Serien bearbeiten und zur Korrektur einreichen.
+ Der Prüfungsstoff ist eine Auswahl von Themen aus Vorlesung und Übungen. Für eine erfolgreiche Prüfung ist die konzentrierte Bearbeitung der Aufgaben unerlässlich.

### Competencies ###
#### Subject-specific Competencies ####
- Concepts and Theories
- Techniques and Technologies

#### Method-specific Competencies ####
- Analytical Competencies
- Decision-making
- Problem-solving

#### Social Competencies ####
- Communication
- Cooperation and Teamwork

#### Personal Competencies ####
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-direction and Self-management

### Abstract ###
Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics and elements of quantum mechanics
Objective

Students know and understand the basic ideas of the scientific description of nature. They understand the fundamental concepts and laws of mechanics and they are able to apply them in practical problems. They know the concepts of quantization and quantum numbers.

Content

1. Description of Motion
2. The laws of Newton
3. Work and energy
4. Collision problems
5. Wave properties of particles
6. The atomic structure of matter

Lecture notes

T. Ihn: Physics for Students in Biology and Pharmaceutical Sciences (unpublished lecture notes)

Literature

The lecture contains elements of:


Competencies

Subject-specific Competencies
Concepts and Theories
Analytical Competencies
Decision-making
Analytical Competencies
Analytical Competencies
Problem-solving
Cooperation and Teamwork
Sensitivity to Diversity
Critical Thinking
Self-awareness and Self-reflection
Self-direction and Self-management

Method-specific Competencies
Analytical Competencies
Analytical Competencies
Analytical Competencies
Analytical Competencies
Problem-solving

Social Competencies
Cooperation and Teamwork
Sensitivity to Diversity

Personal Competencies
Critical Thinking
Self-awareness and Self-reflection
Self-direction and Self-management

Additional First Year Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>535-1001-00L</td>
<td>Laboratory Course General Chemistry (for Biology and Pharmacy)</td>
<td>O</td>
<td>6 credits</td>
<td>8P</td>
<td>S. Gruber, J. Hall</td>
</tr>
</tbody>
</table>

Abstract

Introduction to the practical work in a chemistry laboratory. The most important manipulations and techniques are treated, as well as the most fundamental chemical reaction types.

Objective

- Knowledge of the basic chemical laboratory methods
- Basic knowledge of the scientific approach in experimenting
- Observation and interpretation of chemical processes
- Keeping of a reliable laboratory journal

Content

- Simple chemical working techniques/methods
- Separation techniques
- Physical measurements: mass, volume, pH
- Ionic solids (salts)
- Acid/base chemistry, buffers
- Redox reactions
- Metal complexes
- Titration methods and quantitative spectrometry
- Introduction to qualitative analysis

Lecture notes

Course manual in German (is handed out to the students at the begin of the lessons)

Language: German, English upon request

Literature


is a suitable textbook.

Prerequisites / notice

This practical course causes costs for materials and chemicals. The costs are charged to the students at the end of semester.

By enrolling in this lab course, students confirm that they will thoroughly study and follow all safety information and instructions and that they have an accident insurance valid for Switzerland for the entire duration of the semester.

Competencies

Subject-specific Competencies
Concepts and Theories
Analytical Competencies
Decision-making
Analytical Competencies
Analytical Competencies
Problem-solving
Communication
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Self-awareness and Self-reflection
Self-direction and Self-management

Method-specific Competencies
Analytical Competencies
Analytical Competencies
Analytical Competencies
Analytical Competencies
Problem-solving

Social Competencies
Cooperation and Teamwork
Sensitivity to Diversity

Personal Competencies
Critical Thinking
Self-awareness and Self-reflection
Self-direction and Self-management

Second Year Courses

Core Courses

<table>
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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>252-0852-00L</td>
<td>Foundations of Computer Science</td>
<td>O</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>M. Dahinden, L. E. Fässler</td>
</tr>
</tbody>
</table>

Abstract

This course provides selected computer science concepts for interdisciplinary projects.

The following topics are covered: introduction to programming, sequence analysis, modeling and simulations, introduction matrices, managing data with with relational databases.
Students learn to...

- encode a problem into a program, test the program, and correct errors.
- understand and improve existing code.
- deal with the complexity of real data.
- store data in a suitable data structure.
- query databases and understand and evaluate the corresponding database model.
- implement models from the natural sciences as a simulation.
- run random experiments and interpret the results.
- explain and apply standard algorithms and evaluate their efficiency.

**Content**

1. Variables, data types
2. Control structures, logic
3. Sequential data types, search- and sort algorithms, sequence analysis
4. Functions, modules , simulation and animation
5. Manage data with a relational database
6. Matrices, random experiments, cellular automata

**Lecture notes**
All materials for the lecture are available at www.gdi.ethz.ch

**Literature**

This course is based on application-oriented learning. The students spend most of their time working through projects with data from
natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials
available.

**Competencies**

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<tr>
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<td>Social Competencies</td>
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<td></td>
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<td></td>
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</table>

**Statistics II**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credits</th>
<th>Format</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0643-13L</td>
<td>3 credits</td>
<td>O</td>
<td>J. Dambon</td>
</tr>
</tbody>
</table>

**Abstract**
Vertiefung von Statistikmethoden. Nach dem detaillierten Fundament aus Statistik I liegt nun der Fokus auf konzeptioneller Breite und
konkreter Problemlösungsfähigkeit mit der Statistiksoftware R.

**Objective**
Sie verstehen die Konzepte von Methoden wie lineare Regression (mit Faktoren, Interaktion, Modellwahl), ANOVA
(1-weg, 2-weg), Chi-Quadrat-Test, Fisher-Test, GLMs, Mixed Models, Clustering, PCA und können diese mit der Statistiksoftware R in der
Praxis umsetzen. Zudem kennen Sie die Grundprinzipien von gutem experimentellem Design und können bestehende Studien kritisch
hinterfragen.

**Fundamentals of Biology III: Multicellularity**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credits</th>
<th>Format</th>
<th>Instructor</th>
</tr>
</thead>
</table>

**Abstract**
The lecture conveys the fundamental concepts underlying multicellularity with an emphasis on the molecular basis of multicellular biological
systems and their functional integration into coherent wholes. The structural and functional specialization in multicellular organisms will be
discussed by highlighting common and specific functions in fungi, plants, and animals (including humans).

**Objective**
1. Students can describe advantages and challenges associated with being multicellular and outline independent solutions that organisms
have developed to cope with the challenges of complex multicellularity.
2. Students can explain how the internal and external structures of fungi, plants and animals function to support survival, growth, behavior,
and reproduction.
3. Students can explain the basic pathways and mechanisms of cellular communication regulating cellular behavior (cell adhesion,
metabolism, proliferation, reproduction, development).

**Content**
The lecture introduces the structural and functional specialization in fungi, plants and animals, including humans. After providing an
overview on the diversity of eukaryotic organisms, the lecture will discuss how fungi, plants, animals and humans have evolved structures
and strategies to cope with the challenges of multicellularity. The molecular basis underlying communication, coordination and
differentiation will be conveyed and complemented by key aspects of reproduction, metabolism development, and regeneration. Topics
include form and function of fungi and plants, human anatomy and physiology, metabolism, cell signaling, adhesion, stem cells,
regeneration, reproduction, and development.

**Literature**
Campbell "Biology", 11th Edition

**Prerequisites / notice**
Some lecture are held in English.
Human Physiology I

5 credits
4V
W. Langhans, M. Willecke, to be announced

Abstract
Der Schwerpunkt dieses Kurses liegt auf dem Verständnis der physiologischen Mechanismen des menschlichen Körpers. Im Mittelpunkt steht dabei die gesunde Mensch, ergänzt um Beispiele für klinisch wichtige Funktionsstörungen/ Krankheiten. Im Sinne einer integrativen Betrachtungsweise wird bezüglich Funktion jeweils der Bogen von den molekularen Mechanismen bis zum komplexen Zusammenspiel der Organe im Gesamtorganismus gespannt. Die Anatomie wird dort speziell besprochen, wo sie für das Verständnis der Funktion notwendig oder hilfreich ist.

Objective

Content
Humanphysiologie I (HS)

- «Kern-Konzepte» in der Physiologie
  1. Struktur und Funktion
  2. Energietransfer, -speicherung und -nutzung
  3. Informationsfluss, -speicherung und -nutzung
  4. Homöostase
  5. Evolution
- Allgemeine Endokrinologie und endokrines System
- Allgemeine Neurophysiologie und Neuroanatomie
- Die chemischen Sinne, Geschmack und Geruch
- Ernährung und Verdauung
- Leber und Stoffwechsel
- Energiehomöostase
- Flüssigkeitshomöostase und Niere
- Reproduktion, Entwicklung und Altern

Humanphysiologie II (FS)

- Sinnesphysiologie
- Muskelpathologie
- Neuronale Kontrolle von Haltung und Bewegung
- Höhere zentralnervöse Hirnfunktionen
- Atmung und Lunge
- Herz und Kreislauf
- Blut
- Immunologie
- Thermoregulation/Fieber
- Stress

Lecture notes
Online-Material wird im Laufe des Kurses zur Verfügung gestellt.

Literature
Wird im Kurs bekannt gegeben.

Competencies
| Subject-specific Competencies | Concepts and Theories | assessed |
| Method-specific Competencies | Analytical Competencies | fostered |

Pharmaceutical Analytics I

3 credits
O
3G
C. Steuer

Abstract
This course provides the basic concepts of pharmaceutical analytics in the context of pharmacopeial regulation by Ph. Eur und Ph. Helv.

Objective
Summarize the structure of the Ph. Eur.
Summarize the most important pharmacopeias and their commonalities and differences (USP, JP, Ph.Eur., Ph. Helv.)
Discuss the structure of a monograph
Explain qualification of instruments and validation of methods
Explain and compare most important analytical techniques for pharmacies and pharmaceutical industry

Content
Knowledge in pharmaceutical analytics to fulfill regulatory requirements in pharmaceutical industry based on the pharmacopeia in force.
Focus is set on method validation, equipment qualification, identification of functional groups and content determination of active pharmaceutical ingredients and excipients.

Lecture notes
The slides of the lectures will be provided.

Literature
Instrumentelle Analytik; G. Rücker, M. Neugebauer, G.G. Willems; Deutscher Apotheker Verlag, Stuttgart
Arzneistoffanalyse; H. J. Roth, K. Eger, R. Troschütz; Deutscher Apotheker Verlag, Stuttgart
Introduction to Pharmaceutical Chemical Analysis; S.H. Hansen, S. Pedersen-Bjergaard, K. Rasmussen; Wiley & Sons

Prerequisites / notice
SR 2013: 6 credits Analytik/Pharmaceutical Analytics or 36 credits of compulsory lectures 2nd year
SR 2020: 7 credits Pharmazeutische Analytik I und II or 36 credits of compulsory lectures 2nd year

Competencies
| Subject-specific Competencies | Concepts and Theories | assessed |
| Method-specific Competencies | Analytical Competencies | assessed |
| Decision-making | assessed |

Laboratory Courses

Practical Course Organic Chemistry (for Students of Biology and Pharmaceutical Sciences)

8 credits
O
12P
C. Thilgen

Latest online enrolment is 10 days before the beginning of the semester.

Abstract
Analytical part: basic operations for the separation of mixtures of organic compounds (recrystallization, distillation, extraction, chromatography)
Synthetic part (main part): at least 8 synthetic steps (one- or two-step syntheses).

Objective
Learn the basic techniques for the preparation and purification of organic compounds.
Learn to take accurate notes of the experiments and to write reports.
Deepen the understanding of reaction mechanisms.
Analytical part: basic operations for the separation of mixtures of organic compounds (recrystallization, distillation, extraction, chromatography).

Synthetic part (main part): at least 8 synthesis steps (one- to two-step preparations) from the following classes of reactions: 1. nucleophilic substitution at C(sp3), 2. elimination or electrophilic addition to a C=C bond, 3. electrophilic aromatic substitution, 4. reduction of an aldehyde/ketone, 5. Grignard reaction, 6. heterocyclization with imine/enamine formation, 7. synthesis of a carboxylic acid derivative by acyl group transfer, 8. aldol, Claisen, Mannich, Michael reaction or Robinson annelation.

Introduction to database searches (Reaxys, SciFinder).

Lecture notes
Written documents are distributed via Moodle course.

Literature
1) P. Wörfel, M. Bitzer, U. Claus, H. Felber, M. Hübel, B. Vollenweider, Laborpraxis (Bd. 1: Einführung, allgemeine Methoden; Bd. 2: Messmethoden; Bd. 3: Trennungsmethoden; Bd. 4: Analytische Methoden); Birkhäuser Verlag; Basel; 1990.

Prerequisites / notice
The basic reactions of Organic Chemistry and their mechanisms should be known and the corresponding exam have been passed (cf. course 529-1012-00L Organic Chemistry II for Students of Biology, Pharmaceutical Sciences, and Health Sci. and Tech.).

The prerequisite for participation is passing the ETH security exam.

By enrolling in this lab course, students confirm that they have thoroughly studied all safety information and will follow all instructions.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Method-specific Competencies
Analytical Competencies
Media and Digital Technologies
Social Competencies
Communication
Cooperation and Teamwork
Self-presentation and Social Influence
Sensitivy to Diversity
Negotiation
Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Third Year Courses
Core Courses

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<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<tr>
<td>535-0230-00L</td>
<td>Medicinal Chemistry I</td>
<td>O</td>
<td>2 credits</td>
<td>2V</td>
<td>J. Hall</td>
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</table>

Abstract
The lectures give an overview of selected drugs and the molecular mechanisms underlying their therapeutic effects in disease. The historical and modern-day methods by which these drugs were discovered and developed are described. Structure-function relationships and the biophysical rules underlying ligand-target interactions will be discussed and illustrated with examples.

Objective
Basic understanding of therapeutic agents with respect to molecular, pharmacological and pharmaceutical properties.

Content
Molecular mechanisms of action of drugs. Structure function and biophysical basis of ligand-target interactions

Lecture notes
Will be provided in parts before each individual lecture.

Literature

Prerequisites / notice
Requirements: Knowledge of physical and organic chemistry, biochemistry and biology.

For Pharmacy and non-Pharmacy students, Medicinal Chemistry I and II are examined in a SINGLE examination (Jahresprüfung).

Competencies
Subject-specific Competencies
Concepts and Theories
Method-specific Competencies
Project Management
Social Competencies
Leadership and Responsibility
Personal Competencies
Self-awareness and Self-reflection

535-0421-00L | Galenical Pharmacy I | O    | 2 credits | 2G   | J.-C. Leroux, E. Giger

Abstract
Principles and technologies for the manufacturing of dosage forms and drug delivery systems. Knowledge of pharm. excipients, materials, containers, liquid and semi-solid dosage forms, their production, function, quality and application. Comprehension of molecular interactions in solution and colloidal systems. Comprehension of interfacial phenomena and stabilization measures in dosage forms.

Objective
Knowledge of the most important pharmaceutical excipients, materials, containers, liquid and semi-solid dosage forms, of their production, function, quality, stability and application. Comprehension of the molecular interactions in solution and colloidal systems. Comprehension of interfacial phenomena and stabilization measures in dispense dosage forms.

Content
Introduction and overview of important fundamentals, principles and technologies for the development and manufacturing of dosage forms and drug delivery systems. Overview of the most important pharmaceutical excipients and polymers, their structure, properties and processing; importance of materials properties for containers. Pharmaceutical solvents, fundamentals of solubility and solubilization of drugs. Water treatment processes, sterilization techniques and quality requirements of pharmaceutical water. Parenteral dosage forms and liquid ophthalmics. Surfactants, micelle formation and colloidal systems. Liquid suspensions and emulsions. Stabilization measures in dosage forms.

Literature
The lecture is centered around the discussion of medicinal plants and herbal medicines and their common medical applications. The main areas addressed in the lecture are (a) the structure and biosynthesis of plant constituents (i.e. plant-derived natural products) and (b) the pharmacological effects and therapeutic applications of biogenic drugs of plant origin (herbal medicines based on plant extracts as well as isolated natural products). The basic pathways for the biosynthesis of the most important classes of plant-derived natural products are discussed in detail. Likewise, the molecular basis of the pharmacological effects of medicinal plant extracts (and derived herbal medicines) and their individual constituent components (isolated natural products) is broadly addressed. As part of this discussion the availability of clinical data (or lack thereof) to support specific clinical applications of herbal medicines will be repeatedly highlighted. Potential risks associated with the use of herbal medicines are discussed for selected cases.

The lecture is structured according to the major classes of natural products prevalent in medicinal plants and herbal medicines: Carbohydrates, lipids, terpenes, phenolic compounds, alkaloids, essential oils. The lecture Pharmacology and Toxicology I (535-0521-00L) must be attended in parallel to or prior to this course.

Requirements: Lecture courses in basic organic chemistry, biochemistry, and biology

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535-0333-00L  Pharmaceutical Biology  O  3 credits  2V  B. Pfeiffer, A. E. Fraley

Abstract
The structure and biosynthesis of plant constituents and the pharmacological effects and therapeutic applications of biogenic drugs of plant origin (extract-based herbal medicines: isolated natural products) are discussed. Areas of focus are (a) major biosynthetic pathways for plant-derived natural products, (b) pharmacological effects of herbal extracts, and (c) molecular mechanisms of action.

Objective
The understanding of the biosynthesis of plant-derived natural products. Acquisition of fundamental knowledge on the medical applications of important herbal medicines and of isolated natural products (general disease areas, molecular constituents of medicinal plants and herbal medicines in general, molecular constituents responsible for pharmacological activity, possible mechanisms of action, available clinical data to support medical use).

Content
The lecture is centered around the discussion of medicinal plants and herbal medicines and their common medical applications. The main areas addressed in the lecture are (a) the structure and biosynthesis of plant constituents (i.e. plant-derived natural products) and (b) the pharmacological effects and therapeutic applications of biogenic drugs of plant origin (herbal medicines based on plant extracts as well as isolated natural products). The basic pathways for the biosynthesis of the most important classes of plant-derived natural products are discussed in detail. Likewise, the molecular basis of the pharmacological effects of medicinal plant extracts (and derived herbal medicines) and their individual constituent components (isolated natural products) is broadly addressed. As part of this discussion the availability of clinical data (or lack thereof) to support specific clinical applications of herbal medicines will be repeatedly highlighted. Potential risks associated with the use of herbal medicines are discussed for selected cases.

The lecture is structured according to the major classes of natural products prevalent in medicinal plants and herbal medicines: Carbohydrates, lipids, terpenes, phenolic compounds, alkaloids, essential oils.

Lecture notes
Is provided in parts before each lecture (electronically as pdf) and also available on the Ilias platform via My Studies.

Literature
- There is no English translation of the above textbook (or any reasonably equivalent text). Students intending to take the exam for the course and are not sufficiently proficient in German should contact the lecturer before the start of the course.

535-0525-00L  Pharmaceutical Cases  O  1 credit  1G  D. Stämpfli, S. Erni, E. Kut Bacs, P. Obrist

Abstract
The course places the basic pharmaceutical knowledge acquired to date, particularly in pharmacology, in an applied therapeutic context and encourages interdisciplinary thinking in pharmacy. Weekly practical sessions present and discuss common pharmaceutical case studies that may arise in a pharmacist's daily work.

Objective
Students
• are able to independently analyse, present, explain, and discuss simple case studies from pharmacy practice based on their basic knowledge of pharmacy, particularly pharmacology.
• deepen their knowledge of therapeutic classes, drugs, and treatment guidelines.
• are able to analyse the pharmacological profiles of selected drugs in a therapeutic context (e.g., with regard to adverse drug reactions and interactions).
• are able to compare different drugs and derive therapy-relevant characteristics.

Content
Pharmaceutical case studies from different therapeutic fields comprehend following subject areas:
• Indication
• Dosage Form
• Adverse Drug Reactions
• Interactions
• Contraindications

Lecture notes
Is made available via Moodle.

Prerequisites / notice
As stated in the cases.

The course takes place weekly. For each lesson, group work is prepared and submitted in advance, presented by one group at a time, and discussed in plenary.
Gene Technology  
O  2 credits  2G  J. Scheurmann, N. Grob

Abstract
The course gives a description and summary of the field of gene technology and its pharmaceutical applications. The course focuses on important methods and technologies and their application for genomic, transcriptomic and proteomic analyses in human biology.

Objective
The course gives an overview of current state-of-the-art and advancement in the fields of gene technology. Herein, the course focuses on genomic, transcriptomic and proteomic analysis and their uses in drug discovery and biomedical applications. The course is structured into lectures and practical examples drawn from the research field. Upon completion, the students are familiar and know current state-of-the-art of methods and applications, but are also able to classify, contrast and apply different strategies and methods within the field of gene technology. The course is suited for advanced undergraduate and early graduate students in pharmaceutical sciences or related fields.

Content
I) Genomics and transcriptomics

Methods and Techniques:
• Recombinant DNA technology
• Next generation sequencing methods, sequencing of genomes
• CRISPR technology

Application to human biology:
• Functional genomics/transcriptomics
• Principles of cancer, genetic diseases
• Therapies: cell-based therapies/gene therapies/DNA and RNA vaccination

II) Proteomics

Methods and Techniques:
• Protein cloning and expression
• The antibody molecule
• Measurement and determination of biomolecular interactions
• Protein characterization and engineering
• Modifications and radioactive labelling

Application to human biology:
• Protein therapeutics
• Proteomic approaches for identification of novel disease-related targets and biomarkers

III) Drug discovery: Protein-based libraries

• Immune repertoire mining
• Display and selection technologies
  1. antibody phage display
  2. other polypeptide display technologies
  3. small-molecules display: DNA-encoded chemical libraries

Lecture notes
The lecture series follows the above-described content, and the students are provided with the lecture slides and additional notes. The additional notes are needed for the in-depth study of the individual topics, and to set the frame and content of the in-class group work of the chosen examples.

Pharmaceutical Immunology I
O  2 credits  2G  C. Halin Winter

Abstract
Get Students familiar with basic Immunological concepts of pharmaceutical relevance.

Objective
Get Students familiar with basic Immunological concepts of pharmaceutical relevance.

Content
Janeway's Immunobiology, by Kenneth Murphy et al. (9th or 10th Edition; W.W. Norton & Company).

Literature
Janeway's Immunobiology, by Kenneth Murphy et al. (9th or 10th Edition; W.W. Norton & Company)

Paperback [www.garlandscience.com]

Clinical Microbiology
O  1 credit  1V  K. Lucke

Abstract
Thorough knowledge of major pathogens involved in infectious diseases; principles of laboratory diagnosis of pathogenic bacteria and fungi.

Objective
Thorough knowledge of all major pathogens involved in infectious diseases; principles of laboratory diagnosis of pathogenic bacteria and fungi.
Basics and principles of clinical microbiology:
- host-pathogen interaction
- symptoms and diagnosis of major bacterial pathogens
- therapeutic regimens commonly used against bacterial disease
- major aspects of medical mycology, virology and parasitology
- epidemiology

Literature
- Madigan M.T. et al., Brock Mikrobiologie, Pearson, 15. aktualisierte Auflage 2020
- Kayser F.H. et al., Medizinische Mikrobiologie, Thieme, 14. überarbeitete Auflage 2022

Prerequisites / notice
Basic knowledge of biochemistry, general microbiology, immunology

Competencies

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<tr>
<td>Radiopharmaceutical Chemistry</td>
<td>2 credits 2V R. Schibli, L. Mu</td>
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</tbody>
</table>

Abstract
- Molecular imaging in drug development
- Radiopharmaceutical syntheses
- Knowledge of the physical principles of radioactivity
- Structure and function of radiopharmaceuticals
- Examples of application in diagnosis and therapy in humans
- Targeted radionuclide therapy

Objective
- The students know and are able to describe the different imaging procedures in medicine, especially PET and SPET.
- At the end of the lecture, the students are able to explain and describe the physical basics in connection with radioactivity and the different types of radioactive radiation that are relevant in radiopharmacy and nuclear medicine.
- The students know how radionuclides can be produced and extracted.
- The students can describe the structure and function of radiopharmaceuticals and are able to develop strategies for the design of new radiopharmaceuticals.
- The students know selected examples of clinically relevant radiopharmaceuticals and can explain the structure and mechanism of action.
- The students can discuss and apply the principles of internal dosimetry of systemically applied radiopharmaceuticals using selected examples.

Content
Introduction to molecular imaging, radioactive decay, radiation and radionuclides relevant in nuclear medicine. Radionuclide generators Radiopharmaceutical synthesis strategies Heart, brain and tumour diagnostics with radiopharmaceuticals Kinetic modelling with radiopharmaceuticals Tumour therapy with radiopharmaceuticals Dosimetry of radiopharmaceuticals Practical aspect of nuclear medicine and radiopharmacy

Literature
Book Title: Fundamentals of Nuclear Pharmacy Authors Gopal B. Saha DOI https://doi.org/10.1007/978-3-319-57580-3.


Book Title Radiopharmaceutical Chemistry Editors Jason S. Lewis Albert D. Windhorst, Brian M. Zeglis DOI https://doi.org/10.1007/978-3-319-98947-1.

Access via ETH Library

Prerequisites / notice
Prerequisites: basic knowledge in physics and chemistry

Competencies

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Method-specific Competencies

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<td>Problem-solving</td>
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Project Management | fostered |

Social Competencies

| Communication | fostered |
| Cooperation and Teamwork | fostered |
| Customer Orientation | fostered |
| Leadership and Responsibility | fostered |

Self-presentation and Social Influence | fostered |

Sensitivity to Diversity | fostered |

Negotiation | fostered |

Personal Competencies

| Adaptability and Flexibility | fostered |
| Creative Thinking | assessed |
| Critical Thinking | assessed |

Integrity and Work Ethics | fostered |

Self-awareness and Self-reflection | fostered |

Self-direction and Self-management | fostered |

Pharmacology and Toxicology I

Abstract
This two-semester lecture course provides a detailed understanding of the fundamentals of drug action and the therapeutic use of important classes of drugs. The lectures are intended for students of pharmaceutical sciences.

Objective
The lectures provide a comprehensive survey of pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiological and clinical aspects.

Content
Topics include disease-relevant macroscopic, microscopic, pathobiocenical and functional disturbances of specific organs and organ systems. The lectures integrate disease pathology with mechanisms of drug action, usage, metabolism, pharmacokinetics, side effects, toxicity, contraindications and dosage of relevant drugs. Basic principles of clinical pharmacology and pharamcotherapy will be covered.
Lecture notes
A script is provided for each lecture. Scripts define important course contents but do not replace the lectures.

Literature
Recommended reading:
Urban & Fischer (Elsevier)
ISBN: 978-3-437-42622-3

The classic textbook in Pharmacology:
Goodman and Gilman’s The Pharmacological Basis of Therapeutics
Laurence Brunton, Bjorn Knollman.
14th edition (2022)
ISBN-10: 1264258070

Prerequisites / notice
Voraussetzungen: Abschluss Grundstudium

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management fostered
Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility assessed
Self-presentation and Social Influence fostered
Sensitivity to Diversity assessed
Negotiation fostered
Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Laboratory Courses

<table>
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<tr>
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<tr>
<td>535-0239-00L</td>
<td>Practical Course in Medicinal Chemistry</td>
<td>O</td>
<td>3 credits</td>
<td>7P</td>
<td>J. Hall, C. Halin Winter, J. Scheuermann</td>
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</table>

Abstract
The course comprises experiments relating to concepts of medicinal chemistry including statistical processing, fitting of experimental data, computer modeling of protein structures, experimental measurement of affinity constants and kinetic dissociation constants for protein ligands. The chemical stability of a drug will be studied. Basic gene cloning and protein expression will be introduced.

Objective
Knowledge of experimental methods in drug discovery and development

Content
Characterisation of the biophysical and biological properties of drugs.

Lecture notes
Scripts

Literature
- Original literature

Prerequisites / notice
Laboratory course in Pharmaceutical Analytics;
Lecture Medicinal Chemistry I in the same semester or earlier.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management fostered
Social Competencies
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility assessed
Self-presentation and Social Influence fostered
Sensitivity to Diversity assessed
Negotiation fostered
Personal Competencies
Integrity and Work Ethics assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

535-0166-00L | Medical Microbiology Practical Course | O    | 1 credit | 1G    | A. Lehner

Abstract
Basic Training in Practical Medical Microbiology.

Objective
Supplement to the parallel lecture in Medical Microbiology. Analysis of simulated clinical specimens using classical methods of Medical Microbiology (microscopy, culture etc.). Main aims are the detection and identification of bacterial, mycobacterial and mycological pathogens as well as microbial susceptibility testing.

Content
Safe lab-technical handling is imperative, because pathogens of risk groups 1 and 2 are cultured. Therefore aseptic techniques need to be learned together with the basics in sterilization, disinfection and preservation.

Basics of Bio-Safety.
Simulated patient specimens representing ca. 50 realistically constructed cases are analysed. The students work in groups and gain insight into the procedures in a routine clinical microbiological laboratory. Using a scriptum, they learn how to identify pathogens and test them for antimicrobial susceptibility. As single groups can work only on a fraction of the cases, results and observations are shared by short presentations through all groups.

Lecture notes
The scriptum (in German) will be distributed at the beginning of the course. It contains all protocols necessary for the practical work

Literature
Prerequisites / Requirements:
Registration for the course until 15 October;
Attendance of the lecture Medicinal Microbiology in the same semester or earlier;
Basic skills in careful laboratory work.

By enrolling in this lab course, students confirm to thoroughly study all safety information and follow instructions.

535-0219-00L Laboratory Course in Pharmaceutical Analytics  O  4 credits  7P  C. Steuer

Abstract
Solving analytical problems; Development and interpretation of analytical methods.

Objective
Solving analytical problems; Development and interpretation of analytical methods.

Content
Solving analytical problems. Development and interpretation of analytical methods.

Literature
Skript Pharmazeutische Analytik Praktikum

Prerequisites / Requirements:
SR 2020: 7 KP Pharmazeutische Analytik 1 and Pharmazeutische Analytik 2 or 36 KP of compulsory lectures 2nd year

By enrolling in this lab course, students confirm to thoroughly study all safety information and follow instructions.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving
Project Management

Social Competencies
Cooperation and Teamwork

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics

E Electives

Number Title Type ECTS Hours Lecturers
535-0250-00L Biotransformation of Drugs and Xenobiotics W 1 credit 1V S.-D. Krämer

Abstract
Knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intragroup factors influencing metabolism.

Objective
Major reactions of biotransformation. Major enzymes and reaction partners involved in the biotransformation of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intragroup factors influencing metabolism.

Content
Major reactions of biotransformation. Major enzymes and reaction partners involved in the biotransformation of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intragroup factors influencing metabolism.

Lecture notes
Biotransformation of drugs and xenobiotics

Literature

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving
Project Management

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking

535-0344-00L From Ethnopharmacy to Molecular Pharmacognosy W 1 credit 1V B. Frei Haller, A. Lardos

Abstract
Basic understanding and awareness of ethnopharmaceutical and ethnopharmacological issues and research. Knowledge of methods used in drug discovery from natural sources. Discussion of the issues around law and international treaties. Importance of ethnopharmaceutical knowledge for world health.

Objective
Basic understanding and awareness of ethnopharmaceutical and ethnopharmacological issues and research. Knowledge of methods used in drug discovery from natural sources. Discussion of the issues around law and international treaties. Importance of ethnopharmaceutical knowledge for world health.

Content

Lecture notes
Handouts will be provided.

Literature

Prerequisites / Requirements:
Basic lectures in biology or biochemistry and pharmaceutical biology have been attended; not suitable for first semester students.
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**535-0015-00L History of Pharmacy**

**Abstract**

In the lecture, basic knowledge of the history of pharmacy is imparted, taking into account the various historical epochs.

**Objective**

After attending the lecture, the students are able to name significant events in the development of the pharmacy profession, pharmacy and medicines and to place them in a temporal context. They can list sources for working on questions from the history of pharmacy and evaluate their advantages and disadvantages. This enables them to confidently describe the importance of pharmacy as an independent, supporting pillar of the health system, the history of which has many interfaces with medicine, science, social and cultural history.

**Content**

The lecture conveys knowledge about the development of the pharmacist profession from ancient times to the present. Some pharmacists who made significant contributions to pharmacy are presented in more detail and their significance for today's pharmacy is discussed. The social position of pharmacists in society and the legal conditions in different epochs are also discussed. It explains what influence the pharmacists had on the development of the pharmaceuticals, but again the pharmaceuticals on the development of the pharmacists. For this purpose, it is shown how much the meaning, the nature, the type and the composition of pharmaceuticals and the knowledge about them changed over time.

**Literature**

Wird in der ersten Veranstaltung mitgeteilt.

**Prerequisites / notice**

An interest in the history of pharmacy, the pharmacy profession, and medicines is an asset.

**Competencies**

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**535-0060-00L Evidence Based Phytotherapy**

**Abstract**

Based on epidemiology, economic importance and evidence-based medicine, basic principles of rational phytotherapy will be discussed: a) identification of drug candidates, b) registration requirements, c) criteria to assess efficacy, d) biomarkers and pharmacokinetics, e) safety and f) principles of extract generation. Important prototypes will be discussed.

**Objective**

Students should learn about the importance of rational (= evidence-based) pharmacotherapy with herbal extracts and know which factors influence the quality of such medicinal products. The following topics are covered:

- How are interesting development candidates identified. What are the strategies?
- What are the regulatory requirements (traditional use, well-established use, new herbal entities)?
- Determination of efficacy from (animal/human studies, biomarkers)
- Quality of clinical studies
- Pharmacokinetics of phytopharmaceuticals
- Safety (toxicity, adverse effects, interactions)
- Pharmaceutical quality
- Varietal purity (wild collections, cultivation)
- Influence of genetic variability on extract quality
- Ensuring consistent quality
- Which extraction methods?

The topics are explained and critically discussed using various phytopharmaceuticals as examples (see programme below).

**Content**

Effektive Zeiten 15.45 - 16.30; 16.45-17.30)

**Lecture notes**

The scripts will be sent to the participants via email before the respective lectures.

**Competencies**

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**535-0021-00L Vitamins in Health and Disease**

**Abstract**

Vitamins are essential organic compounds that cannot be synthesized by an organism and hence, they have to be acquired from the diet. This lecture will give an overview about the application of vitamins in health and disease.

**Objective**

The aim of this lecture is a critical examination of the students with the topic of "Vitamins in Health and Disease". The students will get an overview of vitamins, of their medical applications and the role of the pharmacist with "over-the-counter" products.
Deficiencies of particular vitamins result in specific diseases such as for example scurvy (vitamin C deficiency). Such disease patterns are usually easily recognized and facile to be treated. The clinical utility of supplementation concerns people with severe deficiencies and a risk of complications. Latent vitamin deficiencies might result in variable disorders and risks. As an example neurological disorders in elderly as a consequence of chronic lack of vitamin B12 should be mentioned. Subclinical deficiencies are often difficult to assess. However, these are exactly the cases where advice of a pharmacist is requested.

A large intake of vitamins by over-supplementation or food fortification might be dangerous (hypervitaminosis). This is in particular the case for fat-soluble vitamins or in the case of constant intake of high amounts of water-soluble vitamins over a long time period. The lecture ‘Vitamins in Health and Disease’ will give an overview over the history and applications of vitamins and their functions to preserve good health. The utility of vitamin supplementation during conditions of deficiencies, potential consequences of a latent deficiency as well as risks of over-supplementation will be discussed.

In December 2006, Pfizer stopped a large phase III study on the use of Torcetrapib for the prevention of atherosclerosis and cardiovascular disease. 800 million $ in development costs and 21 billion $ in stocks were annihilated overnight. The failure of Torcetrapib has pinpointed the limitations of an extremely reductionist view of atherosclerosis and it’s prevention by drug therapy. It has also highlighted what high expectations we have in a safe and wide applicability of drugs and of their economical success.

To critically appraise the ethical, societal, economical and political expectations in the development of new drugs.

Using selected examples of prominent glycoprotein drugs, the course aims at providing insight into glycosylation-activity relationships and into biotechnological production and analytics.

Students gain basic knowledge in "pharmaceutical glycobiology". This implies knowing and understanding:
- major mechanisms underlying the roles of glycosylation for the biological/therapeutic actions of glycoproteins (glycosylation-function relationships) using prominent examples of glycoprotein drugs.
- the major types of protein-linked glycans and the biosynthetic pathways for their formation
- how glycoproteins are produced (including the most important expression systems used), glycoengineered and analysed (quality control).

Students are able to apply this knowledge in solving simple problems in glycoprotein drug development (on paper). Students gain the ability to reflect on roles of glycosylation in various biological contexts.

The slides used for the lectures will be provided online

- recent publications as cited/proposed on the lecture slides

Requirements: Basic knowledge in immunology, molecular biology, protein and carbohydrate chemistry, analytical techniques. Basic knowledge in pharmacology.

To develop a critical understanding of the relevance and limitations of the current approaches to explaining and anticipating drug effects.

To critically appraise the ethical, societal, economical and political expectations in the development of new drugs.

In December 2006, Pfizer stopped a large phase III study on the use of Torcetrapib for the prevention of atherosclerosis and cardiovascular disease. 800 million $ in development costs and 21 billion $ in stocks were annihilated overnight. The failure of Torcetrapib has pinpointed the limitations of an extremely reductionist view of atherosclerosis and it’s prevention by drug therapy. It has also highlighted what high expectations we have in a safe and wide applicability of drugs and of their economical success.

Torcetrapib is not a single case. In the last 10 years, on average one drug per year was withdrawn from the market due to lack of efficacy, unexpected side effects or toxicity. This clearly shows that the common investigations and the modern understanding of drug actions are often not sufficient to predict the effects a drug will have in large patient populations. These are the topics of the present lecture. Using three particularly informative examples of drug failures, the problems encountered and the concepts and informative value of preclinical and clinical studies will be analyzed and discussed. Furthermore, the ethical, societal, economical and political expectations in new drugs shall be reflected.

Lecture slides and literature for reading and discussions will be available online.

Requirements: basic knowledge in medicinal Chemistry and Pharmacology. Ability to read and understand scientific publications written in English.

The concepts include molecular representations and similarity, ligand-based virtual screening (similarity search, QSAR, etc.) and structure-based virtual screening (docking, physics-based models).
### Literature

**Recommended textbooks:**

### Competencies

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### 535-0423-00L Drug Delivery and Drug Targeting

**Abstract**
The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.

**Objective**
The students dispose of an overview on current principles and systems for the controlled delivery and targeting of drugs. The focus of the course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines.

**Content**
The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and transnasal drug delivery and 3D printing of drug delivery systems.

**Lecture notes**
Selected lecture notes, documents and supporting material will be directly provided or may be downloaded from the course website.

**Literature**


Further references will be provided in the course.

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### 376-0021-00L Materials and Mechanics in Medicine

**Abstract**
Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

**Objective**
Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering, Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

**Content**
Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

**Lecture notes**
course website on Moodle

**Literature**

### 376-1305-00L Development of the Nervous System (University of Zurich)

**Abstract**
The lecture will cover molecular and cellular processes underlying the development of the nervous system (neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation). The importance of these processes in the context of developmental diseases is discussed.

**Objective**
Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering, Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

**Content**
Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

**Lecture notes**
course website on Moodle

**Literature**

**Mind the enrolment deadlines at UZH:**

**Development of the Nervous System (University of Zurich)**

**No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.**

**UZH Module Code:** BIO344
The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.

Objective
- On successful completion of the module the student should be able to
  - relate structure and function of the nervous system to its development
  - apply principles of molecular, cellular, and developmental biology to the development of the nervous system
  - identify key steps in development underlying neurological syndromes and diseases
- Key skills
  - On successful completion of the module the student should be able to
    - interpret and critically evaluate original research reports
    - apply knowledge and relate experimental approaches from molecular, cellular and developmental biology to the developing nervous system.

Content
The course covers the physiology of nerve cells, from the single cell through the neuronal network to the systemic level. The focus is on molecular and cellular mechanisms – synaptic transmission, signal transduction, gene expression, synaptic plasticity.

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on OLAT.

Prerequisites
BIO142 Developmental Biology, BIO143 Neurobiology

376-1305-00L Molecular Neurophysiology: From Molecules to Systems
- Information for UZH students: Enrolment to this course unit only possible at ETH. Please mind the ETH enrolment deadlines for UZH students: https://ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html

Abstract
The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.

Objective
Based on an understanding of molecular and cellular mechanisms, the aim is to provide a deepened insight into neurophysiological processes underlying complex brain functions – learning/memory, sleep, sensory.

Content
First, basic molecular and cellular mechanisms in nerve cells (excitability, neurotransmission, signal transduction, gene expression, synaptic plasticity) are introduced. Afterwards, their significance for selected neurophysiological processes (learning/memory, sleep, sensory) will be illuminated.

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on Moodle.

Prerequisites
No prerequisites.

376-1714-00L Biocompatible Materials
- Subject-specific Competencies
  - Concepts and Theories
  - Analytical Competencies
- Method-specific Competencies

Abstract
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

Objective
The course covers the following topics:
1. Introduction to molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Content
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated.

Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Literature

(available online via ETH library)

Prerequisites
No prerequisites.

551-0313-00L Microbiology (Part I)
- Abstract
  - Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.
- Objective
  - This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.
- Content
  - Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.
- Lecture notes
  - Updated handouts will be provided during the class.
- Literature
  - Current literature references will be provided during the lectures.
- Prerequisites / notice
  - English
  - The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

551-0319-00L Cellular Biochemistry (Part I)
- Abstract
  - Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.
- Objective
  - This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.
- Content
  - Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.
- Lecture notes
  - Updated handouts will be provided during the class.
- Literature
  - Current literature references will be provided during the lectures.
- Prerequisites / notice
  - English
  - The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.
**Abstract**

Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

**Objective**

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

**Content**

Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

**Lecture notes**

Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

**Literature**

Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

**Prerequisites / notice**

To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

**Competencies**

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**752-1003-00L Food Chemistry II**

**Abstract**

Descriptive chemistry of food constituents (focus on structure-function relationships).

Reactions which affect the colour, flavour, texture, and the nutritional value of food raw materials and food products during processing, storage and preparation in a positive or in a negative way (lipid oxidation, Maillard reaction, enzymatic browning).

**Objective**

- Be able to draw chemical structures of the main ingredients, recognize functional groups in the structures and explain their properties.
- Understand foods as complex systems and be able to make connections between chemical structures, chemical reactions and their influence on quality.
- Recognize chemical reactions of lipid oxidation, Maillard reaction and enzymatic reactions and be able to formulate them themselves.

**Content**

Descriptive chemistry of food constituents (focus on structure-function relationships).

Reactions which affect the colour, flavour, texture, and the nutritional value of food raw materials and food products during processing, storage and preparation in a positive or in a negative way (lipid oxidation, Maillard reaction, enzymatic browning).

Links to food analysis, food processing, and nutrition.

Topics:
- Lipid oxidation, Maillard reaction, structural proteins/enzymes
- Food as complex systems
- Chemical reactions and reaction mechanisms
- Selected (possibly changing) food chemistry topics (e.g. sweeteners, polysaccharides, from olive to margarine, etc.)

The lectures Food Chemistry I and Food Chemistry II constitute a unit.

**Lecture notes**

The lectures are supplemented with handouts.

**Literature**


**Competencies**

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**752-4005-00L Food Microbiology I**

**Abstract**

This lecture is the first part of a one-year course. It offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts and molds present in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.

**Objective**

The lecture offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts, molds and protozoa in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms. The focus of this first part of the two part lecture (Food Micro II is offered in the FS) will be on the organisms, but also on the factors which determine spoilage and foodborne disease.
Biomechanics of Sports Injuries and Rehabilitation

**Abstract**
This lecture introduces the basic principles of injury mechanics and rehabilitation focussing on sports injuries.

**Objective**
Within the scope of this lecture you will learn the basic principles of trauma biomechanics. Based on examples from sports, you will get to know different mechanisms that can possibly result in injury. Investigating the background and cause of injury should allow you to assess the injury risk for sports activities. Furthermore you should be able to develop measures to prevent such injury.

**Content**
This lecture deals with the basic principles of injury mechanics and rehabilitation. Mechanisms that can result in injury are presented. Furthermore possibilities to prevent injuries are discussed. Thereby the lecture focuses on sports injuries.

**Lecture notes**
Handouts will be made available.

**Literature**

A course work is required. The mark of this course work contributes to the final credits for this lecture. Details will be given during the first lecture.

Molecular Biology of Foodborne Pathogens

**Abstract**
The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

**Objective**
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

**Content**
Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

**Lecture notes**
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

**Prerequisites / notice**
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break!
The module Epidemiology and Prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health. Students will also become aware of how epidemiological facts are used in prevention, practice and politics.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: fostered
  - Problem-solving: assessed

- **Social Competencies**
  - Communication: fostered

- **Personal Competencies**
  - Creative Thinking: fostered
  - Critical Thinking: fostered

**Objective**

To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic disease, as well as the progression of complications of the chronic diseases.

**Content**

The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Lecture notes**

There is no script. Powerpoint presentations will be made available on-line to students.

**Literature**

To be provided by the individual lecturers, at their discretion.

**Prerequisites / notice**

No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

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**752-6105-00L**  
**Nutrition and Chronic Disease**  
**W**  
**3 credits**  
**2V**  
**F. von Meyenn, M. Andersson**

**Abstract**

To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Objective**

To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Content**

- To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed

**Objective**

To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic disease, as well as the progression of complications of the chronic diseases.

**Content**

The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Lecture notes**

There is no script. Powerpoint presentations will be made available on-line to students.

**Literature**

To be provided by the individual lecturers, at their discretion.

**Prerequisites / notice**

No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

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**752-5001-00L**  
**Food Biotechnology**  
**W**  
**3 credits**  
**2V**  
**N. Bokulich, A. Greppi, B. Pugin**

**Abstract**

Biotechnology is the use of living organisms (or their products) to produce valuable substances or to perform specific services. In this course, you will learn about diverse applications of biotechnology in food and ingredient production, with a focus on microbial biotechnologies.

**Objective**

In this course you will explore the roles and potential of biotechnology in food production past, present, and future, with a focus on microbial biotechnologies. At the end of this course, you will be able to identify the microorganisms and biotechnologies currently implemented in food and food ingredient production and independently evaluate the potential of biotechnological solutions to current and future food challenges.

**Content**

The course will cover diverse topics in modern food biotechnology, including:
- * food fermentation (arguably the world’s oldest biotechnology)
- * the taxonomy and metabolism of microorganisms used in food production
- * microbial and fermentation kinetics
- * bioreactors for food and ingredient production
- * biopreservation
- * molecular diagnostics
- * safety and regulation of biotechnological ingredients in food production.

At the end of this course, you will be able to identify beneficial/detrimental bacteria associated with food products, execute basic bioinformatic analysis (DNA-based) to identify them, explain the main production (upstream) and purification (downstream) processes of food-relevant microorganisms and ingredients, calculate microbial kinetic parameters, connect key metabolic features with specific application in the food industry (e.g. biopreservation), and understand the general legislation (EU/CH) regarding the use of microorganisms in food.

**Literature**

A list of references will be given at the beginning of the course for the different topics presented during the course.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed

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**Compensatory Courses**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>535-0344-00L</td>
<td>From Ethnopharmacy to Molecular Pharmacognosy</td>
<td>W</td>
<td>1 credit</td>
<td>1V</td>
<td>B. Frei Haller, A. Lardos</td>
</tr>
</tbody>
</table>
The topics are explained and critically discussed using various phytopharmaceuticals as examples (see programme below).
The scripts will be sent to the participants via email before the respective lectures.

### Competencies

<table>
<thead>
<tr>
<th>Type of Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Personal Competencies</th>
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<tr>
<td>Concepts and Theories</td>
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<tr>
<td>Techniques and Technologies</td>
<td>Assessed</td>
<td></td>
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<tr>
<td>Analytical Competencies</td>
<td>Fostered</td>
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<td>Fostered</td>
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<tr>
<td>Decision-making</td>
<td>Fostered</td>
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<tr>
<td>Critical Thinking</td>
<td>Fostered</td>
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<td>Fostered</td>
</tr>
</tbody>
</table>

### Literature

- **Vitamins in Health and Disease**
  - W. Müller
  - 1 credit
  - 1V

### Prerequisites / notice

- Requirements: Basic knowledge in biochemistry and pharmacology. Ability to read and understand scientific publications in English.
- Book recommendation: reference books:
  - Handbuch Nährstoffe, Burgerstein, Trias Verlag ISBN 978-3-8304-6071-8
  - Arzneimittel und Mikronährstoffe - Medikationsorientierte Supplementierung; WVG, ISBN 978-3-8047-2779-3

### Prerequisites / notice

- Requirements: Basic knowledge in biochemistry and pharmacology. Ability to read and understand scientific publications in English.
- Book recommendation: reference books:
  - Handbuch Nährstoffe, Burgerstein, Trias Verlag ISBN 978-3-8304-6071-8
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  - Arzneimittel und Mikronährstoffe - Medikationsorientierte Supplementierung; WVG, ISBN 978-3-8047-2779-3
In December 2006, Pfizer stopped a large phase III study on the use of Torcetrapib for the prevention of atherosclerosis and cardiovascular disease. 800 million $ in development costs and 21 billion $ in stocks were annihilated overnight. The failure of Torcetrapib has pinpointed the limitations of an extremely reductionist view of atherosclerosis and it’s prevention by drug therapy. It has also highlighted what high expectations we have in a safe and wide applicability of drugs and of their economical success.

Torcetrapib is not a single case. In the last 10 years, on average one drug per year was withdrawn from the market due to lack of efficacy, unexpected side effects or toxicity. This clearly shows that the common investigations and the modern understanding of drug actions are often not sufficient to predict the effects a drug will have in large patient populations.

These are the topics of the present course. Using three particularly informative examples of drug failures, the problems encountered and the concepts and informative value of preclinical and clinical studies will be analyzed and discussed. Furthermore, the ethical, societal, economical and political expectations in new drugs shall be reflected.

Further references will be provided in the course.

The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.

These are the topics of the present course. Using three particularly informative examples of drug failures, the problems encountered and the concepts and informative value of preclinical and clinical studies will be analyzed and discussed. Furthermore, the ethical, societal, economical and political expectations in new drugs shall be reflected.

The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.

The students dispose of an overview on current principles and systems for the controlled delivery and targeting of drugs. This focus of the course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines. The course covers the following topics: drug targeting and delivery principles, macro/molecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.

The concepts and informative value of preclinical and clinical studies will be analyzed and discussed. Furthermore, the ethical, societal, economical and political expectations in new drugs shall be reflected.

The students will learn how molecules can be represented in computers and how molecular similarity is calculated. They will learn the concepts of ligand-based and structure-based virtual screening to identify potential drug candidates, and understand possibilities and limitations of computer-assisted drug design in pharmaceutical chemistry. As a result, they are prepared for professional assessment of computer-assisted drug design studies in medicinal chemistry projects.

The lecture series provides an introduction to computer applications in medicinal chemistry. The topics cover molecular representations and similarity, ligand-based virtual screening, and structure-based virtual screening. All theoretical concepts and algorithms presented are illustrated by practical applications and case studies.

The concepts and informative value of preclinical and clinical studies will be analyzed and discussed. Furthermore, the ethical, societal, economical and political expectations in new drugs shall be reflected.

The topics include molecular representations and similarity, ligand-based virtual screening (similarity search, QSAR, etc.) and structure-based virtual screening (docking, physics-based models).
Subject-specific Competencies
On successful completion of the module the student should be able to:
- Relate structure and function of the nervous system to its development - apply principles of molecular, cellular, and developmental biology to the development of the nervous system - identify key steps in development underlying neurological syndromes and diseases

Key skills
On successful completion of the module the student should be able to:
- Interpret and critically evaluate original research reports - apply knowledge and relate experimental approaches from molecular, cellular and developmental biology to the developing nervous system.

Content
The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.

Lecture notes
Must be downloaded from OLAT: https://www.olat.uzh.ch/olat/dmz/
as BIO344

Literature
- BIO142 Developmental Biology
- BIO143 Neurobiology

Prerequisites / notice
Enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

Literature
Recommended textbooks:

Comptetencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed
Method-specific Competencies
- Analytical Competencies assessed
- Media and Digital Technologies assessed
- Problem-solving assessed

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered

376-0021-00L Materials and Mechanics in Medicine
W 4 credits 3G M. Zenobi-Wong, J. G. Snedeker

Abstract
Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Objective
Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Content
Biocompatible Materials, Tissue Engineering, Tissue Biomechanics, Implants.

Lecture notes
course website on Moodle

Literature
Academic Press

376-1305-00L Development of the Nervous System (University of Zurich)
W 3 credits 2V University lecturers

Abstract
The lecture will cover molecular and cellular processes underlying the development of the nervous system (neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation). The importance of these processes in the context of developmental diseases is discussed.

Objective
On successful completion of the module the student should be able to:
- Relate structure and function of the nervous system to its development - apply principles of molecular, cellular, and developmental biology to the development of the nervous system - identify key steps in development underlying neurological syndromes and diseases

Key skills
On successful completion of the module the student should be able to:
- Interpret and critically evaluate original research reports - apply knowledge and relate experimental approaches from molecular, cellular and developmental biology to the developing nervous system.

Content
The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.

Lecture notes
Must be downloaded from OLAT: https://www.olat.uzh.ch/olat/dmz/
as BIO344

Literature
- BIO142 Developmental Biology
- BIO143 Neurobiology

376-1305-00L Molecular Neurophysiology: From Molecules to Systems
W 3 credits 2V G. Schratt, R. Fiore, W. von der Behrens, J. Winterer

Abstract
Information for UZH students: Enrolment to this course unit only possible at ETH. Please mind the ETH enrolment deadlines for UZH students: https://ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

Objective
Based on an understanding of molecular and cellular mechanisms, the aim is to provide a deepened insight into neurophysiological processes underlying complex brain functions – learning/memory, sleep, sensory.

Content
First, basic molecular and cellular mechanisms in nerve cells (excitability, neurotransmission, signal transduction, gene expression, synaptic plasticity) are introduced. Afterwards, their significance for selected neurophysiological processes (learning/memory, sleep, sensory) will be illuminated.

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on Moodle.

376-1714-00L Biocompatible Materials
W 4 credits 3V K. Maniera, M. Rottmar, M. Zenobi-Wong
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Handouts and references therin.

551-0313-00L Microbiology (Part I) W 3 credits 2V W.-D. Hardt, L. Eberl, B. Nguyen, J. Piel, M. Pilhofer, A. Vagstad

Abstract
This concept class will be providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis. The full-year course (551-0319-00 & 551-0320-00) forms the basis for this advanced lecture.

Objective
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Lecture notes
Updated handouts will be provided during the class.

Content
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Literature

551-0319-00L Cellular Biochemistry (Part I) W 3 credits 2V U. Kutay, F. Allain, T. Kleele, I. Zemp

Abstract
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

Content
The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Lecture notes
Handouts and references therin.

Literature
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed
assessed

752-1003-00L Food Chemistry II W 3 credits 2V L. Nyström, S. Boulou, M. Erzinger

Abstract
Descriptive chemistry of food constituents (focus on structure-function relationships).

Objective
Recognize chemical reactions of lipid oxidation, Maillard reaction and enzymatic reactions and be able to formulate them themselves.

Content
Descriptive chemistry of food constituents (focus on structure-function relationships).

Topics:
- Lipid oxidation, Maillard reaction, structural proteins/enzymes
- Food as complex systems
- Chemical reactions and reaction mechanisms
- Selected (possibly changing) food chemistry topics (e.g. sweeteners, polysaccharides, from olive to margarine, etc.)

The lectures Food Chemistry I and Food Chemistry II constitute a unit.

Lecture notes
The lectures are supplemented with handouts.
### Literature


### Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
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<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>Problem-solving</td>
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</tbody>
</table>

### Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

### Method-specific Competencies

- Analytical Competencies
- Problem-solving

### Social Competencies

- Communication

### Food Microbiology I

**752-4005-00L**

**W 3 credits 2V M. Loessner, A. Harms**

**Abstract**

This lecture is the first part of a one-year course. It offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts and molds present in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.

**Objective**

The lecture offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts, molds and protozoa in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms. The focus of this first part of the two part lecture (Food Micro II is offered in the FS) will be on the organisms, but also on the factors which determine spoilage and foodborne disease.

**Content**

1. History of Food Microbiology
   - 1.1. Short synopsis of foodborne microorganisms
   - 1.2. Spoilage of Foods
   - 1.3. Foodborne Disease
   - 1.4. Food Preservation
   - 1.5. VIP’s of Food Microbiology
2. Overview of Microorganisms in Foods
   - 2.1 Origin of foodborne Microorganisms
   - 2.2. Bacteria
   - 2.3. Yeasts
   - 2.4. Molds
   - 3. Microbial Spoilage of Foods
   - 3.1. Intrinsic and Extrinsic Parameters
   - 3.2. Meats, Seafoods, Eggs
   - 3.3. Milk and Milk Products
   - 3.4. Vegetable and Fruit Products
   - 3.5. Miscellaneous (baked goods, nuts, spices, ready-to-eat products)
   - 3.6. Drinks and Canned Foods
   - 4. Foodborne Disease
   - 4.1. Significance and Transmission of Foodborne pathogens
   - 4.2. Staphylococcus aureus
   - 4.3. Gram-positive Sporeformers (Bacillus & Clostridium)
   - 4.4. Listeria monocytogenes
   - 4.5. Salmonella, Shigella, Escherichia coli
   - 4.6. Vibrio, Yersinia, Campylobacter
   - 4.7. Brucella, Mycobacterium
   - 4.8. Parasites
   - 4.9. Viruses and Bacteriophages
   - 4.10. Mycotoxins
   - 4.11. Bioactive Amines
   - 4.12. Miscellaneous (Antibiotic-resistant Bacteria, Biofilms)

**Lecture notes**

Electronic copies of the presentation slides (PDF) and additional material will be made available for download.

**Literature**

Recommendations will be given in the first lecture.

### Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

- Fostered
- Assessed

### Biomechanics of Sports Injuries and Rehabilitation

**376-2017-00L**

**W 3 credits 2V K.-U. Schmitt, J. Goldhahn**

**Abstract**

This lectures introduces the basic principles of injury mechanics and rehabilitation focussing on sports injuries.

**Objective**

Within the scope of this lecture you will learn the basic principles of trauma biomechanics. Based on examples from sports, you will get to know different mechanisms that can possibly result in injury. Investigating the background and cause of injury should allow you to assess the injury risk for sports activities. Furthermore you should be able to develop measures to prevent such injury.

**Content**

This lecture deals with the basic principles of injury mechanics and rehabilitation. Mechanisms that can result in injury are presented. Furthermore possibilities to prevent injuries are discussed. Thereby the lecture focuses on sports injuries.

**Lecture notes**

Handouts will be made available.

**Literature**


### Prerequisites / notice

A course work is required. The mark of this course work contributes to the final credits for this lecture. Details will be given during the first lecture.

### Molecular Biology of Foodborne Pathogens

**752-4009-00L**

**W 3 credits 2V M. Loessner, A. Harms**

**Competencies**

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Problem-solving
- Communication

- Assessed
- Fostered
Abstract
The course offers detailed information on selected foodborne pathogens and toxin-producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Objective
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content
Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Literature
Recommendations will be given in the first lecture

Prerequisites / notice
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break!

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed

Social Competencies
- Communication: fostered

Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: fostered

752-5101-00L Nutrition and Chronic Disease

Abstract
To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Objective
To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic disease, as well as the progression of complications of the chronic diseases.

Content
The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Lecture notes
There is no script. Powerpoint presentations will be made available on-line to students.

Literature
To be provided by the individual lecturers, at their discretion.

Prerequisites / notice
No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

752-5105-00L Epidemiology and Prevention

Abstract
The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development of prevention and treatment interventions and to improved population health. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

Objective
The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

Content
The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

752-5501-00L Food Biotechnology

Abstract
Biotechnology is the use of living organisms (or their products) to produce valuable substances or to perform specific services. In this course, you will learn about diverse applications of biotechnology in food and ingredient production, with a focus on microbial biotechnologies.

Objective
In this course you will explore the roles and potential of biotechnology in food production past, present, and future, with a focus on microbial biotechnologies. At the end of this course, you will be able to identify the microorganisms and biotechnologies currently implemented in food and food ingredient production and independently evaluate the potential of biotechnological solutions to current and future food challenges.

Content
The course will cover diverse topics in modern food biotechnology, including:
* food fermentation (arguably the world’s oldest biotechnology)
* the taxonomy and metabolism of microorganisms used in food production
* microbial and fermentation kinetics
* bioreactors for food and ingredient production
* biopreservation
* molecular diagnostics
* safety and regulation of biotechnological ingredients in food production.

At the end of this course, you will be able to identify beneficial/detrimental bacteria associated with food products. In particular, you will be able to comment on the use of biotechnology in food processing and production processes.

Literature
A list of references will be given at the beginning of the course for the different topics presented during the course.
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<tr>
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<td>Media and Digital Technologies</td>
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<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
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**Science in Perspective**

*see Science in Perspective: Language Courses ETH/UZH*

*see Science in Perspective: Type A: Enhancement of Reflection Capability*

**Recommended Science in Perspective (Type B) for D-CHAB**

### Pharmaceutical Sciences Bachelor - Key for Type

<table>
<thead>
<tr>
<th>W+</th>
<th>W</th>
<th>E-</th>
<th>Z</th>
<th>Dr</th>
<th>O</th>
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<tbody>
<tr>
<td>Eligible for credits and recommended</td>
<td>Eligible for credits</td>
<td>Recommended, not eligible for credits</td>
<td>Courses outside the curriculum</td>
<td>Suitable for doctorate</td>
<td>Compulsory</td>
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### Key for Hours

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<th>V</th>
<th>G</th>
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<th>S</th>
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<tbody>
<tr>
<td>lecture</td>
<td>lecture with exercise</td>
<td>exercise</td>
<td>seminar</td>
<td>colloquium</td>
<td>practical/laboratory course</td>
<td>independent project</td>
<td>diploma thesis</td>
<td>revision course / private study</td>
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</table>

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Pharmacy Master

### Core Courses I

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</table>

**Abstract**
The course provides a platform for the investigation, presentation and discussion of a topic with relevance to the field of pharmaceutical sciences. Students work in small groups on a chosen topic and present their work on a one day symposium.

**Objective**
The main objectives of this course are:
- students develop their scientific reflection (Critical Thinking) and working skills by working independently on a relevant pharmaceutical topic
- students gain in-depth knowledge of the topic investigated
- students train their scientific writing and presentation skills
- students train their ability to plan a project and work in a team

**Content**
The Course Drug Seminar takes place during the first 7 weeks of the 1. Master semester. It is a compulsory course of the MSc Pharmacy curriculum and an elective course in the MSc PharmSciences.

During the course, students work in small teams on a topic of their choice and elaborate an oral presentation. Each team is tutored by a lecturer of the Institute of Pharmaceutical Sciences. The work is mainly based on literature search/review, but may also involve conducting interviews or site visits, if appropriate. The final presentations of all groups will take place in the framework of a dedicated Symposium held in the middle of the semester.

**Prerequisites / notice**
Only for students of MSc Pharmacy and MSc Pharmaceutical Sciences.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Competencies</th>
<th>Assessed</th>
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<tbody>
<tr>
<td>Subject-specific</td>
<td>Concepts and Theories</td>
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<td>Method-specific</td>
<td>Techniques and Technologies</td>
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<td>Social Competencies</td>
<td>Analytical Competencies</td>
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<td>Project Management</td>
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<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Personal Competencies</td>
<td>Adaptablety and Flexibility</td>
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<td>Critical Thinking</td>
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<td>Self-direction and Self-management</td>
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### Pharmacology and Toxicology III

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>535-0041-00L</td>
<td>Pharmacology and Toxicology III</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>U. Quitterer, M. Arand, Y. Yamauchi</td>
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</table>

**Abstract**
The course is divided into three parts. The first part provides an overview of drugs used for the pharmacotherapy of infectious diseases, osteoporosis, autoimmune diseases and cancer. The second part gives an overview of the field of medical virology, and the third part is focused on pharmacogenomics of drug metabolism and basic concepts of toxicology.

**Objective**
The course advances basic knowledge in pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiological and clinical aspects of drug therapy in the fields of infectious diseases, osteoporosis, autoimmune diseases and cancer. The course also provides an overview of the fields of medical virology, toxicology, and pharmacogenomics with a special focus on the role of genetic polymorphisms in drug response and adverse effects.

**Content**
Topics include the pharmacology and pharmacotherapy of infectious diseases, osteoporosis, autoimmune diseases and cancer. Medical virology covers important viral infections and their pharmacotherapy with different classes of antiviral drugs. In the field of pharmacogenomics, the course is focused on examples of genetic variability of drug metabolism and drug responses, and the relevance of pharmacogenomics and toxicogenomics for clinical drug development. Finally, basic concepts of toxicology are introduced.

**Lecture notes**
A script is provided for each lecture. The scripts define important and exam-relevant contents of the lectures. Scripts do not replace the lectures.

**Literature**
Recommended reading:
- The classic textbook in Pharmacology:
  Goodman and Gilman’s The Pharmacological Basis of Therapeutics
  Laurence Brunton, Bjorn C. Knollman.
  14th edition (2022)
  ISBN-10: 1264258070

or
- Klaus Aktories, Veit Flockerzi, Ulrich Förstermann, Franz Hofmann.
  Allgemeine und spezielle Pharmakologie und Toxikologie.
  13th edition (2022)
  Urban & Fischer (Elsevier)
Pharmacoepidemiology and Drug Safety

Introduction to the principles, methods and applications of pharmacoepidemiology and drug safety. Drug safety in the pharmaceutical industry and regulatory authorities, but also for hospital and office pharmacists. Another focus is the evaluation and interpretation of pharmacoepidemiological drug safety studies in the medical literature and the evaluation of benefits vs. risks.

Objectives:
- To familiarize participants with the principle methods and applications of pharmacoepidemiology and drug safety that is relevant for industry, regulatory affairs, but also for clinical pharmacists in hospitals and office pharmacies.
- Perform independently a causality assessment of suspected adverse drug reactions in patients
- Study designs and biostatistics used for the quantitative evaluation of drug safety
- Setup of programs that can effectively reduce medication errors and improve drug safety in clinical practice, particularly in hospitals

Content:
- Historical landmarks of drug safety
- Pharmacovigilance and causality assessment
- Drug safety in premarketing clinical trials
- Descriptive, cohort and case-control drug safety study designs; Data analysis and control of confounding
- Pharmacoepidemiology and regulatory decision making in drug safety; Risk management plans (RMPs)
- Medication errors, clinical pharmacology / clinical pharmacy
- Clinical Decision Support Systems, Interventional Pharmacoepidemiology
- Pharmacoepidemiological databases, 'Big Data'
- Interactive discussion of many real-life examples for each topic

Lecture notes:
This course will be a combination of formal lectures, group discussions and self-directed studies. Course material will be taught through seminars, case studies in small groups.
Reading material and scripts will be provided for each week.

Literature:
- Rothman: Introduction to Epidemiology
- Strom, Kimmel, Hennessy: Textbook of Pharmacoepidemiology
- Gigerenzer: Risk Savvy - How to Make Good Decisions

Pharmaceutical Immunology II & Therapeutic Proteins

In this course, various topics related to the development, GMP production and application of therapeutic proteins will be discussed. Furthermore, students will expand their training in pharmaceutical immunology and will be introduced to the basic concepts of pharmaceutical product quality management.

Objective:
- Students know and understand:
  - basic mechanisms and regulation of the immune response
  - the pathogenic mechanisms of the most important immune-mediated disorders
  - the concepts of vaccination and cancer immunotherapy
  - the most frequently used expression systems for the production of therapeutic proteins
  - the use of protein engineering tools for modifying different features of therapeutic proteins
  - the mechanism of action of selected therapeutic proteins and their application
  - basic concepts in the GMP production of therapeutic proteins

Content:
The course consists of two parts:
In the first part, students will complete their training in Pharmaceutical Immunology. This part particularly focuses on the pathogenic mechanisms of immune-mediated diseases, vaccination and cancer immunotherapy. Deepened knowledge of immunology will be relevant for understanding the mechanism of action of many therapeutic proteins, as well as for understanding one major concern related to the use of protein-based drugs, namely, immunogenicity.

The second part focuses on topics related to the development and application of therapeutic proteins, such as protein expression, protein engineering, reducing immunogenicity, and GMP production of therapeutic proteins. Furthermore, selected examples of approved therapeutic proteins will be discussed.

Lecture notes:
Handouts to the lectures will be available for downloading under http://www.pharma.ethz.ch/scripts/index

Literature:
- Janeway's Immunobiology, by Kenneth Murphy (9th or 10th Edition)
- Lecture Handouts
- Paper References provided in the Scripts
- EMEA Dossier for Humira

Prerequisites / notice:
Prerequisites: Either 535-0830-00L Pharmaceutical Immunology I or 551-0317-00L Immunology I
Competencies

- Subject-specific Competencies: Concepts and Theories
  - assessed
- Method-specific Competencies: Analytical Competencies
  - assessed
- Social Competencies: Communication
  - fostered
- Personal Competencies: Critical Thinking
  - fostered

535-0137-00L Clinical Chemistry II

- 1 credit
- M. Hersberger

Abstract
Detailed knowledge on particular aspects of clinical chemistry and medical laboratory diagnostics concerning quality control, point-of-care analytics, analytics of kidney stones, tumor markers, diagnosis of HIV and hepatitis, pharmacogenetics, thyroid function, bone metabolism and laboratory diagnosis of hypertension.

Objective
Detailed knowledge on the implementation and interpretation of clinical laboratory diagnostic tests. Competence to interpret selected tests.

Content
Internal and external quality control, point-of-care analytics, analytics of kidney stones, use of tumor marker determinations, diagnosis of HIV and hepatitis, pharmacogenetics, thyroid function, bone metabolism and laboratory diagnosis of hypertension.

Lecture notes
Documentation will be available before the lectures electronically.

Literature
- Jürgen Hallbach, Klinische Chemie und Hämatologie für den Einstieg, Thieme Verlag
- Harald Renz, Praktische Labordiagnostik, de Gruyter Verlag
- Walter Guder, Das Laborbuch für Klinik und Praxis, Elsevier Verlag
- Lothar Thomas, Labor und Diagnose, TH Books
- William Marshall, Clinical Chemistry, Mosby Ltd.
- Alan H.B. Wu, Tietz, Clinical Guide to Laboratory Tests, Saunders

Prerequisites / notice
Requirement: basic knowledge in clinical chemistry and laboratory diagnostics

Core Courses (Clinical Subjects)

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</table>

Abstract
This course provides basic clinical and pharmaceutical knowledge and skills for triage, diagnostics and therapy support of the most common diseases.

Objective
- know and understand the pathomechanisms and clinical lead and warning symptoms (red flags) of the most common diseases in the fields listed below.
- can use this knowledge to triage patients: i.e. analyse simple symptoms and diseases, make a tentative diagnosis and recommend suitable medication or further examinations or measures.
- know the therapeutic guidelines, classes of active ingredients and selected, practice-relevant drugs (including indications and the most frequent and important adverse drug reactions, interactions and contraindications).

Content
- "Pharmaceutical Care" und "Health Care"
- Häufigste Erkrankungen und Therapien der
  - Allergologie
  - Angiologie und Hämatologie
  - Dermatologie
  - Endokrinologie und Diabetologie
  - Gastroenterologie
  - Infektiologie
  - Kardiologie
  - Neurologie
  - Ophthalmologie
  - Otorhinolaryngologie
  - Pneumologie
  - Psychiatrie
  - Rheumatologie
  - Urologie

Lecture notes
Provided via moodle.

Literature
As stated in the lecture notes.

Prerequisites / notice
Please note that the assessment of this course must be passed (not compensable).

The performance assessment of the course takes place in two written on campus online partial examinations. The overall grade results from the average of the grades of both partial examinations. If the overall grade is unsatisfactory, both partial examinations must be repeated.

The courses Pharmacology and Toxicology I and II and Pathobiology provide indispensable basics which students must master at the beginning of the semester in order to successfully complete the course.

Pharmacology and Toxicology III must be visited at the same time.

Competencies

- Subject-specific Competencies: Concepts and Theories
  - assessed
- Method-specific Competencies: Analytical Competencies
  - assessed
- Social Competencies: Communication
  - fostered
- Personal Competencies: Critical Thinking
  - fostered

Biotransformation of drugs and xenobiotics

The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.

Literature


The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This

Further references will be provided in the course.

### Electives

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>535-0423-00L</td>
<td>Drug Delivery and Drug Targeting</td>
<td>W</td>
<td>2 credits</td>
<td>1.5V</td>
<td>J.-C. Leroux</td>
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<td>Abstract</td>
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<td></td>
<td>The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.</td>
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<td>The students dispose of an overview on current principles and systems for the controlled delivery and targeting of drugs. The focus of the course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines.</td>
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<td></td>
<td>Content</td>
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<td>The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.</td>
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<td>Lecture notes</td>
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<td>Selected lecture notes, documents and supporting material will be directly provided or may be downloaded from the course website.</td>
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<td></td>
<td>Literature</td>
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Further references will be provided in the course.

### Biotransformation of Drugs and Xenobiotics

535-0250-00L

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td></td>
<td>Biotransformation of Drugs and Xenobiotics</td>
<td>W</td>
<td>1 credit</td>
<td>1V</td>
<td>S.-D. Krämer</td>
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<tr>
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<td>Abstract</td>
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<td>Knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism.</td>
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<td>Objective</td>
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<td>Goals: knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism.</td>
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<td>Content</td>
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<td></td>
<td>Major reactions of biotransformation. Major enzymes and reaction partners involved in the biotransformation of drugs and xenobiotics. Toxic reactions of metabolites. Factors which affect the biotransformation.</td>
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<td>Lecture notes</td>
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<td></td>
<td>Biotransformation of drugs and xenobiotics</td>
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<td></td>
<td>Literature</td>
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Further references will be provided in the course.

### Patents

535-0546-00L

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td></td>
<td>Patents</td>
<td>W</td>
<td>1 credit</td>
<td>1V</td>
<td>C. Ebner, A. Koepf</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>Knowledge in the field of intellectual property, especially of patents and trademarks, with particular emphasis on pharmaceutics. Introduction into intellectual property; prosecution of patent applications; patent information, exploitation and enforcement of patents; peculiarities in pharmaceutics and medicine; social, political and ethical aspects; Trademarks.</td>
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<td>Basic knowledge in the field of industrial property, especially of patents and trademarks, with particular emphasis on the chemical, pharmaceutical and biotech field.</td>
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<td></td>
<td>1. Introduction into industrial property (patents, trademarks, industrial designs);</td>
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<td></td>
<td>2. Prosecution of patent applications (patentability);</td>
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<td>3. Patent information (patent publications, databases, searches);</td>
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<td>4. Exploitation and enforcement of patents (possibilities of exploitation, licenses, parallel imports, scope of protection, patent infringement);</td>
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<td>5. Peculiarities in pharmaceutics and medicine (supplementary protection certificates, experimental use exemption, therapy and diagnosis, medical indication);</td>
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<td>6. Social, political and ethical aspects (patents and prices for medicinal products, traditional knowledge and ethnomedicine, bioprospecting and biopiracy, human DNA inventions);</td>
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<td>7. Trademarks, types of trademarks, grounds for refusal, peculiarities of pharma-trademarks.</td>
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<td>Lecture notes</td>
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<td></td>
<td>A script is provided in electronic form during the lecture.</td>
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fostered

Basic understanding and awareness of ethnopharmaceutical and ethnopharmacological issues and research. Knowledge of methods used in drug discovery from natural sources. Discussion of the issues around law and international treaties. Importance of ethnopharmaceutical knowledge for world health.


Handouts will be provided.


Prerequisites / notice

Prerequisites: Basic lectures in biology or biochemistry and pharmaceutical biology have been attended; not suitable for first semester students.
The aim of this lecture is a critical examination of the students with the topic of "Vitamins in Health and Disease". The students will get an overview of vitamins, of their medical applications and the role of the pharmacist with "over-the-counter" products.
Content

Deficiencies of particular vitamins result in specific diseases such as for example scurvy (vitamin C deficiency). Such disease patterns are usually easily recognized and facile to be treated. The clinical utility of supplementation concerns people with severe deficiencies and a risk of complications. Latent vitamin deficiencies might result in variable disorders and risks. As an example neurological disorders in elderly as a consequence of chronic lack of vitamin B12 should be mentioned. Subclinical deficiencies are often difficult to assess. However, these are exactly the cases where advice of a pharmacist is requested.

A large intake of vitamins by over-supplementation or food fortification might be dangerous (hypervitaminosis). This is in particular the case for fat-soluble vitamins or in the case of constant intake of high amounts of water-soluble vitamins over a long time period.

The lecture ‘Vitamins in Health and Disease’ will give an overview over the history and applications of vitamins and their functions to preserve good health. The utility of vitamin supplementation during conditions of deficiencies, potential consequences of a latent deficiency as well as risks of over-supplementation will be discussed.

Lecture notes

Hand-outs will be distributed during the lecture (partly in English, partly in German).

Literature

Handout recommendation: reference books:
- Handbuch Nährstoffe, Burgerstein, Trias Verlag ISBN 978-3-8304-6071-8

Prerequisites / notice

Requirements: Basic knowledge in biochemistry and pharmacology. Ability to read and understand scientific publications in English.

535-0360-00L Evidence Based Phyotherapy

Abstract

Based on epidemiology, economic importance and evidence-based medicine, basic principles of rational phytotherapy will be discussed: a) Identification of drug candidates, b) registration requirements, c) criteria to assess efficacy, d) biomarkers and pharmacokinetics, e) safety and f) principles of extract preparation. Important prototypes will be discussed

Objective

Content and aim of the lecture:
Students should learn about the importance of rational (= evidence-based) pharmacotherapy with herbal extracts and know which factors influence the quality of such medicinal products.

The following topics are covered:
- How are interesting development candidates identified? What are the strategies?
- What are the regulatory requirements (traditional use, well-established use, new herbal entities)?
- Determination of efficacy from (animal/human studies, biomarkers)
- Quality of clinical studies
- Pharmacokinetics of phytopharmaceuticals
- Safety (toxicity, adverse effects, interactions)
- Pharmaceutical quality
- Varietal purity (wild collections, cultivation)
- Influence of genetic variability on extract quality
- Ensuring consistent quality
- Which extraction methods?

The topics are explained and critically discussed using various phytopharmaceuticals as examples (see programme below).

Lecture notes

Effektive Zeiten 15.45 - 16.30; 16.45-17.30

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Critical Thinking

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking

535-0022-00L Computer-Assisted Drug Design

Abstract

The lecture series provides an introduction to computer applications in medicinal chemistry. The topics cover molecular representations and similarity, ligand-based virtual screening, and structure-based virtual screening. All theoretical concepts and algorithms presented are illustrated by practical applications and case studies

Objective

The students will learn how molecules can be represented in computers and how molecular similarity is calculated. They will learn the concepts of ligand-based and structure-based virtual screening to identify potential drug candidates, and understand possibilities and limitations of computer-assisted drug design in pharmaceutical chemistry. As a result, they are prepared for professional assessment of computer-assisted drug design studies in medicinal chemistry projects.

Content

The topics include molecular representations and similarity, ligand-based virtual screening, and structure-based virtual screening (similarity search, QSAR, etc.) and structure-based virtual screening (docking, physics-based models).

Lecture notes

Script will be available.

535-0024-00L Methods in Drug Design

Abstract

The lecture is organized as a two-week block during the practical course "Computer-Assisted Drug Design" (535-0023-00P), totalling 10 two-hour lectures. It provides an introduction to advanced drug design techniques and approaches emphasizing computer-assisted molecular design.

Does not take place this semester.

Complementary to the practical course "Computer-Assisted Drug Design (Practical Course)" 535-0023-00L.

Compulsory for the students of the practical course, open for other interested students.

Literature

Recommended textbooks:

Performance

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Media and Digital Technologies
- Problem-solving

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
Objective
Participants will learn about computational algorithms and advanced experimental approaches to drug discovery and design, including selected actual topics and practical applications. The contents of the lecture will allow for a deeper understanding of modern computer-assisted drug design methods and how they are linked to experimental applications. The main focus is on computational medicinal chemistry, so that participants will be able to use relevant computer-based methods in own research projects.

Literature

Prerequisites / notice
The lecture is mandatory for all participants of the course "Computer-Assisted Drug Design" (535-0023-00 P).

535-0023-00L Computer-Assisted Drug Design (Practical Course) W 4 credits 6P G. Schneider

Abstract
The practical course is open for master and graduate students to get an introduction into hands-on computer-assisted drug design. The class includes an introduction to computer-based screening of a virtual compound library, subsequent synthesis of candidate ligands, and biochemically testing for activity on pharmacologically important drug targets.

Objective
Participants become familiar with state-of-the-art methodologies in a real-life computer-aided medicinal chemistry project. Participants work as small teams, perform literature research and discuss recent research findings. A seminar talk is to be given presenting the molecular design strategy chosen and the results obtained during the course.

Content
The course offers the possibility for people with and without computational and or laboratory background to get an introduction into computer-assisted drug design, as well as practical training in a modern chemical laboratory. Using various software suites, the participants will computationally create and screen a virtual compound library for potential active small molecules. The process will involve an introduction to screening a virtual compound library, synthesizing candidate inhibitors, and biophysical testing against a pharmacologically important drug target.

Lecture notes
Detailed information will be handed out during the course.

Literature
Textbook:

Prerequisites / notice
The class is organized as a two-week block course.
The number of participants is limited.

Kick-off meeting and confirmation of registration (Vorbesprechung und Platzvergabe): During the last lecture of the class "Computer-Assisted Drug Design" (535-0022-00)

Ideally, students interested in the course participated and successfully passed the lecture "Computer-Assisted Drug Design" (535-0022-00).

Practical Pharmacy I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
This course provides basic knowledge relevant to pharmacy and its application in nephrology, phytotherapy, complementary medicine, wound care and pharmaceutical care.

Objective
Students know and understand the therapeutic concepts of the mentioned topics and their application in practice.

(for detailed learning objectives see the guidelines)

Content
- complementary medicine
- phytotherapy
- wound care
- pharmaceutical care 2
- nephrology

Lecture notes
Provided via myStudies.

Literature
As specified in the lecture notes

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Sensitivity to Diversity

Personal Competencies
- Critical Thinking
- Self-awareness and Self-reflection


Abstract
This course provides basic clinical and pharmaceutical knowledge and its application for triage, diagnostics and therapy support for the most common diseases in geriatrics, women's health, oncology, paediatrics and neurology (epilepsy). In addition, the role of nutrition in special life situations and in selected health disorders is taught.
Objective

- know and understand the pathomechanisms and the clinical lead and warning symptoms (red flags) of the most common diseases in the fields listed.
- can triage patients by applying this knowledge: i.e. analyse simple symptoms and disease patterns, make a tentative diagnosis and recommend suitable medication or further examinations or measures.
- know the therapeutic guidelines, drug classes and selected, practice-relevant drugs (including indications and the most frequent and important dosages, adverse drug reactions, interactions and contraindications).

(for detailed learning objectives, see the guideline)

Content

- nutrition
- geriatrics
- neurology (epilepsy)
- oncology
- paediatrics
- women's health

Lecture notes

Provided via myStudies.

Literature

As specified in the lecture notes

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Social Competencies

Communication assessed
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Sensitivity to Diversity fostered

Personal Competencies

Critical Thinking fostered
Self-awareness and Self-reflection fostered

Practical Pharmacy II

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-5502-00L</td>
<td>Pharmaceutical Manufacturing in Small Quantities (Compounding)</td>
<td>O</td>
<td>3 credits</td>
<td>5G</td>
<td>P. G. Tiefenböck, A. Romagna</td>
</tr>
</tbody>
</table>

Abstract

Pharmaceutical Manufacturing relevant for the community pharmacy considering the “GMP-Regeln in kleinen Mengen” of the Pharmacopoeia: The preparation of extemporaneous products covering the most common forms under consideration of their Risks and Quality Assurance.

Objective

The students are able to produce pharmaceutical relevant drug Systems without further assistance, lege artis, applying the right techniques and material. The production and packaging has to follow GMP rules and tailored for the patients need. The quality control and correct documentation have to be followed. The students know the most relevant specifications, concentration and dosing ranges of common APIs and excipients. The students are familiar with the relevant literature (Pharmaceutical and legal basis) regarding the Pharmaceutical manufacturing relevant for the community pharmacies.

Content

Vermittlung der wichtigsten Kenntnisse, Arbeitsschritte und -techniken im Bereich der Arzneimittelherstellung in kleinen Mengen (Formula) mit Fokus auf der Herstellung, Qualitätssicherung und Risikobeurteilung einschliesslich der patientenspezifischen Abgabepraxis.

In den Praktika: Anhand praxis-relevanter Beispiele wird die Aufgabenplanung, die Fertigung einschliesslich die korrekte Verwendung der Gerätschaften, die Inprozesskontrolle, die Verpackung und die Qualitätssicherung diverser Rezepte und Arzneiformen geübt. Unter Einbezug risikoadaptierter Massnahmen erfolgt die Qualitätssicherung, -kontrolle und Einhaltung von Hygienierichtlinien gemäss den geltenden Arzneibüchern. Die Studierenden vertiefen damit ihre GMP-relevanten Kenntnisse und Fertigkeiten.

Prerequisites / notice

Safety concept: https://chab.ethz.ch/studium/bachelor1.html

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Social Competencies

Communication assessed
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Sensitivity to Diversity fostered

Personal Competencies

Adaptability and Flexibility assessed
Creative Thinking fostered
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management assessed

535-5503-00L | Institutional Pharmacy Does not take place this semester. | O | 2 credits | 3G | P. Wiedemeier, M. Lutters, E. Martinelli, I. S. Vogel Kahmann |

Abstract

Organisation of institutional environments (emergency hospitals), with special focus on the medication process and institutional pharmaceutical care (continuum of care).

Objective

Students understand the concept of continuum of care and its practical implementation. They know the medication process within an institutional environment. They are able to find the necessary information and deal with problems in connection with pharmaceuticals, to evaluate them and to communicate and documentate their findings adequately. They know how a hospital is organised (procedures, possible problems), responsibilities of the different members of the staff and, most importantly, what the function of a hospital pharmacy is.
Content

Principals of the organisation of institutional environments (emergency hospitals), with special focus on medication processes and institutional pharmaceutical care (circulation of medication, continuum of care). Hygiene regulations, medical products, applications, drug formularies, patient files, SOAP notes, kardex study. Participation at interdisciplinary visits, internal trainings and doctors' reports as well as visitation of the emergency room. Drug interaction, generic substitution, quality management and pharmacovigilance.

535-5524-00L Clinical Trainings

<table>
<thead>
<tr>
<th>O</th>
<th>2 credits</th>
<th>3G</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Gutzelt, D. Stämpfli, P. Wiedemeier</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abstract

Basic training on and around patients with practical confrontation. The path of acute patients from patient presentation, through triage and diagnostics to therapy.

Objective

Students will be able to understand the medical-clinical way of thinking for the diagnosis and treatment of acute patients. They complete the change of perspective from the molecular mechanism of action of drugs to the treatment of patients in all its complexity. Using real patient examples, students acquire exemplary knowledge in diagnostics and triage as well as therapy selection and therapy support. They consolidate their understanding of the importance of pharmaceutical care before and after hospitalization.

Content


535-5526-00L Injection Techniques and Vaccinations

<table>
<thead>
<tr>
<th>O</th>
<th>2 credits</th>
<th>3G</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. S. Vogel Kahmann, C. Halin Winter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abstract

Die Studierenden erlernen die praktische Durchführung von subkutanen (s.c.) und intramuskulären (i.m.) Injektionen. Sie wissen, wie in Notfallsituationen vorzugehen ist.

Objective

Die Studierenden erwerben das theoretische Wissen und die praktischen Fähigkeiten, welche für die s.c. und i.m. Verabreichung von Medikamenten erforderlich sind. Sie sind fähig, Risikopatienten zu identifizieren und sind geschult, bei Notfällen (z.B. Anaphylaxie) korrekt zu handeln.

Content

Die Lernziele und Inhalte entsprechen dem Fähigkeitsprogramm FPH Impfen und Blutentnahme von PharmaSuisse (ausser venöse Blutentnahmen)

1. - BLS-AED-SRC Komplettkurs (siehe https://www.srg.ch)
2. - Vorgehen bei Notfällen (z.B. Herzinfarkt, Schlagenfall, Anaphylaxie u.a.) in der Apotheke
3. - Vorgehen bei der Versorgung akuter Wunden
4. - Injektionstechniken: Materialkunde, Hygienevorschriften und Desinfektion, Kommunikation mit Patienten, Vor- und Nachbereitung einer Injektion, praktische Durchführung von subkutanen Injektionen und intramuskulären Injektionen
5. - Theorie und praktische Aspekte bei der Durchführung von subkutanen Blutentnahmen
6. - Impfungen (z.B. Lenste von Impfauweisen, Erstellen eines individuellen Impfschemas, Impfdebatte)
7. - Schutzkonzept: https://chab.ethz.ch/studium/bachelor1.html

Lecture notes

Wird auf mystudies veröffentlicht.

Literature

Wird im Skript angegeben.

Prerequisites / notice


- BLS-I/R/SRC-Komplettkurs
- Vorgehen bei Notfällen (z.B. Herzinfarkt, Schlaganfall, Anaphylaxie u.a.) in der Apotheke
- Vorgehen bei der Versorgung akuter Wunden
- Injektionstechniken: Materialkunde, Hygienevorschriften und Desinfektion, Kommunikation mit Patienten, Vor- und Nachbereitung einer Injektion, praktische Durchführung von subkutanen Injektionen und intramuskulären Injektionen
- Theorie und praktische Aspekte bei der Durchführung von subkutanen Blutentnahmen
- Impfungen (z.B. Lesen von Impfauweisen, Erstellen eines individuellen Impfschemas, Impfdebatte)

Compensatory Courses

The elective courses can be used as compensatory courses.

Science in Perspective

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-CHAB

Master’s Thesis

<table>
<thead>
<tr>
<th>535-0660-00L Master’s Thesis</th>
<th>O</th>
<th>30 credits</th>
<th>40D</th>
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</thead>
<tbody>
<tr>
<td>Lecturers</td>
<td></td>
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</tbody>
</table>

Only students who fulfill the following criteria are allowed
to begin with their master thesis:
  a. successful completion of the bachelor programme;
  b. fulfilling of any additional requirements necessary to
     gain admission to the master programme.

Abstract
During the Master’s thesis students prove their ability to independent, structured scientific work. The Master’s thesis is usually carried out in
a subject area of Pharmaceutical Sciences as chosen by the student.

Objective
In the Master Thesis students prove their ability to independent, structured and scientific working.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Methods and Technologies</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Techniques and Technologies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analytical Competencies</td>
<td></td>
<td>assessed</td>
</tr>
<tr>
<td>Decision-making</td>
<td></td>
<td>assessed</td>
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<tr>
<td>Problem-solving</td>
<td></td>
<td>assessed</td>
</tr>
<tr>
<td>Project Management</td>
<td></td>
<td>assessed</td>
</tr>
<tr>
<td>Communication</td>
<td></td>
<td>assessed</td>
</tr>
<tr>
<td>Cooperation and Teamwork</td>
<td></td>
<td>assessed</td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td></td>
<td>fostered</td>
</tr>
<tr>
<td>Adaptability and Flexibility</td>
<td></td>
<td>fostered</td>
</tr>
<tr>
<td>Creative Thinking</td>
<td></td>
<td>assessed</td>
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<tr>
<td>Critical Thinking</td>
<td></td>
<td>assessed</td>
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<tr>
<td>Integrity and Work Ethics</td>
<td></td>
<td>assessed</td>
</tr>
<tr>
<td>Self-awareness and Self-reflection</td>
<td></td>
<td>fostered</td>
</tr>
<tr>
<td>Self-direction and Self-management</td>
<td></td>
<td>assessed</td>
</tr>
</tbody>
</table>

Course Units for Additional Admission Requirements
The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-0135-AAL</td>
<td>Clinical Chemistry I</td>
<td>E-</td>
<td>1 credit</td>
<td>2R</td>
<td>M. Hersberger</td>
</tr>
<tr>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
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<tr>
<td>Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.</td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Introduction into fundamentals of laboratory diagnostics and overview of the laboratory parameters concerning inflammation, lipid metabolism, myocardial infarction, diabetes, kidney function, urinary diagnostics, liver function, blood coagulation, blood count, therapeutic drug monitoring and drugs of abuse screening.</td>
<td></td>
<td></td>
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<tr>
<td>Objective</td>
<td>Overview of the possibilities and limitations in clinical laboratory diagnostics. Indications and methods of everyday parameters are known.</td>
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</tr>
<tr>
<td>Content</td>
<td>Introduction into medical laboratory diagnostics: immunochemical methods, diagnostics of inflammation, acute myocardial infarction, lipid metabolism, diabetes, kidney function and urinary diagnostics, blood coagulation, blood count, therapeutic drug monitoring, drugs of abuse screening, common diagnostics of liver diseases, point-of-care diagnostics.</td>
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</tr>
<tr>
<td>535-0440-AAL</td>
<td>Quality Management in Pharmaceutical Business</td>
<td>E-</td>
<td>1 credit</td>
<td>2R</td>
<td>A. Sterchi</td>
</tr>
<tr>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
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<tr>
<td>Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>The students know the relevance and the role of quality assurance measures to assure quality, efficacy and safety of drugs. The students know the most important Swiss regulations, including the associated European regulations, which are relevant from a quality assurance point of view and they are able to interpret the content of this regulations.</td>
<td></td>
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<tr>
<td>406-0603-AAL</td>
<td>Stochastics (Probability and Statistics)</td>
<td>E-</td>
<td>4 credits</td>
<td>9R</td>
<td>M. Kalisch</td>
</tr>
<tr>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
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</tr>
<tr>
<td>Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.</td>
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<tr>
<td>Objective</td>
<td>The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language &quot;R&quot;.</td>
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</tr>
<tr>
<td>Content</td>
<td>From &quot;Statistics for research&quot; (online)</td>
<td></td>
<td></td>
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<tr>
<td>Ch 1: The Role of Statistics</td>
<td></td>
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<tr>
<td>Ch 2: Populations, Samples, and Probability Distributions</td>
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<tr>
<td>Ch 3: Binomial Distributions</td>
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<tr>
<td>Ch 6: Sampling Distribution of Averages</td>
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<tr>
<td>Ch 7: Normal Distributions</td>
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<tr>
<td>Ch 8: Student's t Distribution</td>
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<tr>
<td>Ch 9: Distributions of Two Variables</td>
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</tr>
<tr>
<td>From &quot;Introductory Statistics with R (online)&quot;</td>
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</tr>
<tr>
<td>Ch 1: Basics</td>
<td></td>
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<tr>
<td>Ch 2: The R Environment</td>
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<tr>
<td>Ch 3: Probability and distributions</td>
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<tr>
<td>Ch 4: Descriptive statistics and tables</td>
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<tr>
<td>Ch 5: One- and two-sample tests</td>
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<tr>
<td>Ch 6: Regression and correlation</td>
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</tr>
</tbody>
</table>
Literature
- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
From within the ETH, this book is freely available online under:
From within the ETH, this book is freely available online under:
http://www.springerlink.com/content/m17578/

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
<td></td>
</tr>
</tbody>
</table>

Pharmacy Master - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td></td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Recommend, not eligible for credits</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr Suitable for doctorate</td>
</tr>
</tbody>
</table>

Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Generally Accessible Seminars and Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0101-00L</td>
<td>The Zurich Physics Colloquium</td>
<td>E-</td>
<td>0 credits</td>
<td>1K</td>
<td>S. Huber, A. Refregier, University lecturers</td>
</tr>
</tbody>
</table>

**Abstract**
Research colloquium

**Objective**
The goal of this event is to bring you closer to current day research in all fields of physics. In each semester we have a set of distinguished speakers covering the full range of topics in physics. As a participating student should learn how to follow a research talk. In particular, you should be able to extract key points from a colloquium where you don't necessarily understand every detail that is presented.

### Physics (General Courses) - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

### Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Physics Bachelor

#### First Year

<table>
<thead>
<tr>
<th>First Year Compulsory Courses</th>
</tr>
</thead>
</table>

#### Minor Courses

<table>
<thead>
<tr>
<th>Science in Perspective</th>
</tr>
</thead>
</table>

#### First Year Compulsory Courses

##### First Year Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-1261-07L</td>
<td>Analysis I: One Variable</td>
<td>O</td>
<td>10 credits</td>
<td>6V+3U</td>
<td>L. Kobel-Keller</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to the differential and integral calculus in one real variable: fundamentals of mathematical thinking, numbers, sequences, basic point set topology, continuity, differentiable functions, ordinary differential equations, Riemann integration.

**Objective**
The ability to work with the basics of calculus in a mathematically rigorous way.

**Literature**
- H. Amann, J. Escher: Analysis I
  - [link](https://link.springer.com/book/10.1007/978-3-7643-7756-4)
- J. Appell: Analysis in Beispielen und Gegenbeispielen
  - [link](https://link.springer.com/book/10.1007/978-3-540-88903-8)
- R. Courant: Vorlesungen über Differential- und Integralrechnung
  - [link](https://link.springer.com/book/10.1007/978-3-662-61988-5)
- O. Forster: Analysis 1
  - [link](https://link.springer.com/book/10.1007/978-3-658-00317-3)
- H. Heuser: Lehrbuch der Analysis
  - [link](https://link.springer.com/book/10.1007/978-3-322-96828-9)
- K. Königsberger: Analysis 1
  - [link](https://link.springer.com/book/10.1007/978-3-642-18490-1)
- W. Walter: Analysis 1
  - [link](https://link.springer.com/book/10.1007/978-3-540-35078-0)
- V. Zorich: Mathematical Analysis I (englisch)
  - [link](https://link.springer.com/book/10.1007/978-3-662-48792-1)
- A. Beutelspacher: "Das ist o.B.d.A. trivial"
  - [link](https://link.springer.com/book/10.1007/978-3-8348-9599-8)
- H. Schichl, R. Steinbauer: Einführung in das mathematische Arbeiten
  - [link](https://link.springer.com/book/10.1007/978-3-642-28646-9)

| 402-1701-00L | Physics I | O | 7 credits | 4V+2U | K. Ensslin |

**Abstract**
This course gives a first introduction to Physics with an emphasis on classical mechanics.

**Objective**
Acquire knowledge of the basic principles regarding the physics of classical mechanics. Skills in solving physics problems.

**Literature**
- Bjarne Stroustrup: Einführung in die Programmierung mit C++, Pearson Studium, 2010
- Andrew Koenig and Barbara E. Moo: Accelerated C++, Addison-Wesley, 2000

**Competencies**

### Subject-specific Competencies
- Concepts and Theories
  - assessed
- Techniques and Technologies
  - assessed

###Method-specific Competencies
- Analytical Competencies
  - assessed
- Decision-making
  - fostered
- Media and Digital Technologies
  - assessed
- Problem-solving
  - assessed

### Social Competencies
- Communication
  - fostered
- Cooperation and Teamwork
  - fostered

### Personal Competencies
- Creative Thinking
  - fostered
- Critical Thinking
  - fostered

##### First Year Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-1151-00L</td>
<td>Linear Algebra I</td>
<td>O</td>
<td>7 credits</td>
<td>4V+2U</td>
<td>S. Zerbes</td>
</tr>
</tbody>
</table>

**Abstract**
**Second and Third Year Compulsory Courses**

### Examination Blocks

#### Examination Block I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-2303-00L</td>
<td>Complex Analysis</td>
<td>O</td>
<td>6 credits</td>
<td>3V+2U</td>
<td>Ö. Imamoglu</td>
</tr>
<tr>
<td>Abstract</td>
<td>Complex functions of one variable, Cauchy-Riemann equations, Cauchy theorem and integral formula, singularities, residue theorem, index of closed curves, analytic continuation, special functions, conformal mappings, Riemann mapping theorem.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Working knowledge of functions of one complex variables; in particular applications of the residue theorem.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Literature | B. Palka: "An introduction to complex function theory."


Th. Gamelin: Complex Analysis. Springer 2001


D. Salamon: "Funktionentheorie". Birkhauser, 2011. (In German)

L. Ahlfors: "Complex analysis. An introduction to the theory of analytic functions of one complex variable."

K.Jaenich: Funktionentheorie. Springer Verlag

R.Remmert: Funktionentheorie I. Springer Verlag

E.Hille: Analytic Function Theory. AMS Chelsea Publications

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-2203-01L</td>
<td>Classical Mechanics</td>
<td>O</td>
<td>7 credits</td>
<td>4V+2U</td>
<td>M. Gaberdiel</td>
</tr>
<tr>
<td>Abstract</td>
<td>A conceptual introduction to theoretical physics: Newtonian mechanics, central force problem, oscillations, Lagrangian mechanics, symmetries and conservation laws, Hamiltonian mechanics, canonical transformations, Hamilton-Jacobi equation, spinning top, relativistic space-time structure.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Fundamental understanding of the description of Mechanics in the Lagrangian and Hamiltonian formulation. Detailed understanding of important applications, in particular, the Kepler problem, the physics of rigid bodies (spinning top) and of oscillatory systems.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Competencies</td>
<td>Subject-specific Competencies Concepts and Theories assessed</td>
<td></td>
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</tr>
<tr>
<td>Method-specific Competencies Analytical Competencies assessed</td>
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</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-2883-00L</td>
<td>Physics III</td>
<td>O</td>
<td>7 credits</td>
<td>4V+2U</td>
<td>S. Johnson</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introductory course on quantum and atomic physics including optics and statistical physics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>A basic introduction to quantum and atomic physics, including basics of optics and equilibrium statistical physics. The course will focus on the relation of these topics to experimental methods and observations.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>Einführung in die Quantenphysik: Planck'sche Strahlung (Wärmestrahlung), Photonen, Photoelektrischer Effekt, Thomson und Rutherford Streuung, Compton Streuung, Bohrsche Atommodell, de-Broglies Materiewellen.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Optik-Wellenoptik; Linsen, Abbildungssysteme, Brechung und Fermatsches Prinzip, Beugung, Interferenz, Fabry-Perot, Interferometer, Spektrometer.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endomorphismen und Eigenwerte</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Determinanten</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systeme von linearen Gleichungen und Matrizen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vektoren und lineare Abbildungen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Quantenmechanik: Dualismus Teilchen-Welle, Wellenfunktionen, Operatoren, Schrödinger-Gleichung, Potentialstufe und Potentialkasten, harmonischer Oszillator


Statistische Physik: Wahrscheinlichkeitsverteilungen, Ideales Gas, AQupartitionsgesetz, Zustandsdichte, Maxwell-Boltzmann-Verteilung, Fermi-Dirac-Statistik für Fermionen, Bose-Einstein-Statistik für Bosonen, Elektronengas, Herleitung Planck'sche Strahlungsgesetz (Photonen GAS)
Literature
M. Alonso, E. J. Finn
Quantenphysik und Statistische Physik
R. Oldenbourg Verlag, München
5. Auflage
ISBN 978-3-486-71340-4

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Personal Competencies
Creative Thinking fostered
Critical Thinking fostered

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>>> Examination Block IIa

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-2333-00L</td>
<td>Mathematical Methods of Physics I</td>
<td>O</td>
<td>6</td>
<td>3V+2U</td>
<td>P. Hintz</td>
</tr>
</tbody>
</table>

Abstract

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>>> Examination Block IIb

Offered in the Spring Semester

>>> Other Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0205-00L</td>
<td>Quantum Mechanics I</td>
<td>O</td>
<td>8</td>
<td>3V+2U</td>
<td>M. Krstic Marinkovic</td>
</tr>
</tbody>
</table>

Abstract

Objective
Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems.

Content
The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradoxon and Bell's inequality); Perturbation theory.

Lecture notes
Auf Moodle

Literature
G. Baym, Lectures on Quantum Mechanics
E. Merzbacher, Quantum Mechanics
L.I. Schiff, Quantum Mechanics
R. Feynman and A.R. Hibbs, Quantum Mechanics and Path Integrals
J.J. Sakurai: Modern Quantum Mechanics
A. Messiah: Quantum Mechanics I
S. Weinberg: Lectures on Quantum Mechanics

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

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Other Compulsory Courses ONLY for Programme Regulations 2016

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0205-10L</td>
<td>Quantum Mechanics I</td>
<td>O</td>
<td>10</td>
<td>3V+2U</td>
<td>M. Krstic Marinkovic</td>
</tr>
</tbody>
</table>

Abstract

Objective
Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems.

Autumn Semester 2024
The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradoxon and Bell's inequality); Perturbation theory.

Lecture notes
Auf Moodle

Literature
G. Baym, Lectures on Quantum Mechanics
E. Merzbacher, Quantum Mechanics
L.I. Schiff, Quantum Mechanics and Path Integrals
J.J. Sakurai: Modern Quantum Mechanics
A. Messiah: Quantum Mechanics I
S. Weinberg: Lectures on Quantum Mechanics

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management
Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation
Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Core Courses in Experimental Physics

402-0263-00L
Astrophysics I
- Physics BSc students with programme regulations 2016 need to register for "402-0263-10L Astrophysics".
- 8 credits
- 3V+2U
- A. Refregier

Abstract
This introductory course will develop basic concepts in astrophysics as applied to the understanding of the physics of planets, stars, galaxies, and the Universe.

Objective
The course provides an overview of fundamental concepts and physical processes in astrophysics with the dual goals of: i) illustrating physical principles through a variety of astrophysical applications; and ii) providing an overview of research topics in astrophysics.

Literature
Astrophysics for physicists, Arnab Ray Choudhuri

402-0255-00L
Introduction to Solid State Physics
- Physics BSc students with programme regulations 2016 need to register for "402-0255-10L Einführung in die Festkörperphysik".
- 8 credits
- 3V+2U
- A. Zheludev

Abstract
The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, electronic properties of insulators, metals, semiconductors, transport properties, and magnetism.

Objective
Introduction to Solid State Physics.

Content
The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, electronic properties of insulators, metals (classical and quantum mechanical description of electronic states, thermal and transport properties of metals); semiconductors (bandstructure and n/p-type doping); magnetism.

Lecture notes
The script will be available online.

Literature
C. Kittel, Festkörperphysik
Ashcroft & Mermin, Festkörperphysik

Prerequisites / notice
Voraussetzungen: Physik I, II, III wünschenswert

Personal Competencies
- Self-awareness and Self-reflection
- Self-direction and Self-management

Courses in Experimental Physics ONLY for Programme Regulations 2016

402-0263-10L
Astrophysics I
- Only for Physics BSc, Programme Regulations 2016.
- 10 credits
- 3V+2U
- A. Refregier
### Electives

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0347-00L</td>
<td>Applications of Physics in Medicine - An Introduction to Medical Physics</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>A. J. Lomax, F. Albertini-Cirelli, J. Hrbáček, D. Meer, S. Safai, U. Schneider, Y. Zhang</td>
</tr>
<tr>
<td>402-0883-63L</td>
<td>Symmetries in Physics</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>G. M. Graf</td>
</tr>
<tr>
<td>402-0247-00L</td>
<td>Electronics for Physicists I (Analogue)</td>
<td>W</td>
<td>4</td>
<td>2V+2P</td>
<td>G. Bison, W. Erdmann</td>
</tr>
</tbody>
</table>

### Prerequisites / notice
- An interest in medical applications of physics.

### Abstract
- Medical physics is a fascinating scientific discipline, providing many professional opportunities to apply physics to the care of patients, either in the clinic or in industry. It is also an area allowing for exciting, interesting and fulfilling areas of research. It is the aim of this course to give bachelor physics students an insight into the wide spectrum of medical applications of physics.

### Objective
- To provide physics students with an insight into the many and varied applications of physics in medicine. At the end of the course, students will be aware of the major topics in medical physics and its role in hospitals, industry and research.

### Content
- The course consists of 13 double lectures (2x45 mins), with an additional 1 hour tutorial associated with each lecture and is aimed at bachelor physics students in their last year of studies. Topics covered are:
  - History and background to medical physics
  - Physics background to medical applications and measurement techniques
  - The physics of medical imaging
  - The physics of radiotherapy
  - Computer and image assisted medical interventions
  - Medical physics in the clinic, industry and research.

### Competencies
- Subject-specific Competencies
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Problem-solving
- Personal Competencies
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics

### Notice
- Voraussetzungen: Physik I, II, III wünschenswert
Subject-specific Competencies fostered

Creative Thinking
Problem-solving

Lecture Series: Space Research and Exploration

Creative Thinking

Energy and Sustainability in the 21st Century (Part I)

fostered

Part I of this course covers the energy-related topics in this two-semester course. The importance of energy to life and our modern culture is explored and placed in the perspective of the ongoing energy transition in the context of necessary and urgent decarbonization efforts. How much energy do we need and how can it be provided in a way that enables a sustainable existence?

How much energy do we need and how can it be provided in a way that enables a sustainable existence?

Personal Competencies

Cooperation and Teamwork
Critical Thinking

Prerequisites / notice

no prior knowledge in electronics is required

402-0368-07L Lecture Series: Space Research and Exploration W 1 credit 2V S. P. Quanz

Abstract

Lecture Series about selected topics of space research and exploration consisting of individual talks given by different leading experts from academia and industry.

Objective

Attending students will
- experience the interdisciplinarity of space research and exploration spanning physics, engineering, geosciences, biology and more
- get familiar with the Swiss space research and industry landscape
- enhance their communication skills by broadening their research horizon
- have the opportunity for direct learning by posing questions to experts

Content

The field of space research and exploration is intrinsically interdisciplinary. Cutting edge space activities are dominated by an interplay between the scientifically desirable and the technologically possible. The ‘Lecture Series: Space Research and Exploration’ aims to shed light on key questions engaged by leading scientists and engineers today. It consists of weekly lectures, given by different speakers with vast experience in their respective field (e.g., Human Spaceflight, System Engineering of Spacecraft, Space Life Sciences, Space-based astrophysics). Subsequent to the talk, the student will have the opportunity to deepen their understanding by asking questions to the presenter in a moderated Q&A.

Confirmed speakers will be announced by the start of the semester (see lecture from last year for previous speakers).

Competencies

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Problem-solving

Social Competencies

Cooperation and Teamwork

Personal Competencies

Creative Thinking

402-0737-00L Energy and Sustainability in the 21st Century (Part I) W 6 credits 2V+1U P. Morf

Abstract

Part I of this course covers the energy-related topics in this two-semester course. The importance of energy to life and our modern culture is explored and placed in the perspective of the ongoing energy transition in the context of necessary and urgent decarbonization efforts. How much energy do we need and how can it be provided in a way that enables a sustainable existence?

Content

1. Introduction to Energy – what is it all about?
2. Energy and making use of it – a short history of energy use and an overview on energy technologies
3. Coal, oil and natural gas – fossil fuels
4. Renewables I: Biomass, Hydropower, and Wind Energy – from traditional use to the modern concepts
5. Renewables II: Geothermal, Tidal power and Solar Technologies – new renewables to lead the change
6. Nuclear power, radioactivity and ultimate storage – the quest for a safe technology
7. Breeding and Nuclear Fusion – can it work at all?
8. Energy Storage – the need to increase capacity and for new technologies
9. Climate Change and Decarbonisation of the Energy Mix – how much time do we have?
11. Energy Systems – how everything can play together
12. Life Cycle Assessment of Energy Technologies – problems and possibilities
13. Economics of Energy, Learning Curves, Technology Assessments and Innovation
14. The Actual Energy Transition and Decarbonisation – How is your 2040, 2050?

Literature

The Physics of Energy, R.L. Jaffe, W. Taylor, 2018
Clean Disruption of Energy and Transportation, T. Seba 2014
Energy and Civilization: A History, V. Smil, 2018
Renewable Energy – Without the Hot Air, D.J.C. Mackay 2009

Prerequisites / notice

Basics of Physics applied to Energy and Energy Technology. Investigation on current problems (and possible solutions) related to the energy system and the environmental interactions.

Training of scientific and multi-disciplinary methods, approaches and their limits in the exercises and discussions.
### Introduction to Computational Physics

**402-0809-00L**

**Objective**
- Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

**Content**
- Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

**Lecture notes**
- Lecture notes and slides are available online and will be distributed if desired.

**Literature**
- Literature recommendations and references are included in the lecture notes.

**Prerequisites / notice**
- Lecture and exercise lessons in English, exams in German or in English

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### Sustainable Energy Systems

**151-0109-00L**

**Abstract**
- The course introduces the fundamentals of energy system modeling for the analysis and the optimization of the energy system design and operations.

**Objective**
- At the end of this course, students will be able to:
  - define and quantify the key performance indicators of sustainable energy systems;
  - select and apply appropriate models for conversion, storage and transport of energy;
  - develop mathematical models for the analysis, design and operations of multi-energy systems and solve them with appropriate mathematical tools;
  - select and apply methodologies for the uncertainty analysis on energy systems models;
  - apply the acquired knowledge to tackle the challenges of the energy transition.

**Content**
- The global energy transition: Key performance indicators of sustainable energy systems; Optimization models; Heat integration and heat exchanger networks; Life-cycle assessment; Models for conversion, storage and transport technologies; Multi-energy systems; Design, operations and analysis of energy systems; Uncertainties in energy system modeling.

**Lecture notes**
- Lecture slides and supplementary documentation will be available online. Reference to appropriate book chapters and scientific papers will be provided.

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### Applied Glaciology

**101-0289-00L**

**Abstract**
- The course transmits fundamental knowledge for treating applied glaciological problems. Topics include climate-glacier interactions, glacier ice flow, glacier hydrology, ice avalanches, and lake ice.

**Objective**
- The objectives of the courses are to:
  - learn about fundamental glaciological processes, including glacier mass balance, ice dynamics, and glacier-related hazards;
  - apply the above knowledge to some case studies inspired by contract-works performed at ETH's Glaciology section;
  - generate the own computer code to solve the above case studies, and interpret the results;
  - understand, both in class and in the field, the practical relevance of glaciology, with a focus on the Swiss applications.
Content

The course will develop along the following outline:
- How glaciology became a scientific discipline
- Glaciology and hydropower
- Glacier mechanics and ice flow
- Gravitational glacier instabilities
- Glacier hydrology and glacier lake outbursts
- Lake ice and ice bearing capacity
- Field excursion to Jungfraujoch
- Discussion of the exercises performed during the semester

Lecture notes

Digital lecture handouts will be distributed prior to each class.

Literature

Links to relevant literature will be provided during the classes.

Prerequisites / notice

Completed BSc studies. Basic knowledge in computer scripting in any language (e.g. Python, R, Julia, Matlab, IDL, ...) will be advantageous for solving the exercises. The exercises will be performed in groups. A minimal level of fitness is required for the field excursion.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Literature

S. M. Sze: Semiconductor Devices, Physics and Technology
- Hong Xiao: Introduction to Semiconductor Manufacturing Technology
- W. Menz, J. Mohr, O. Paul: Microsystem Technology

151-0621-00L Signals and Systems

Abstract

Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to signals and produce other signals. In this course, we explore how signals can be represented and manipulated, and their effects on systems. We further explore how we can discover basic system properties by exciting a system with various types of signals.

Objective

Master the basics of signals and systems. Apply this knowledge to problems in the homework assignments and programming exercise.

Content


Lecture notes

Lecture notes available on course website. Knowledge of Control Systems I is helpful but not required.

Prerequisites / notice

Students from a diverse set of science and engineering backgrounds.

151-0913-00L Introduction to Photonics

Abstract

Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.
I- BASICS OF WAVE THEORY
1) General concepts
2) Differential wave equation
3) Wavefront
4) Plane waves and Fourier decomposition of optical fields
5) Spherical waves and Huygens-Fresnel principle

II- ELECTROMAGNETIC WAVES
1) Maxwell equations
2) Wave equation for EM waves
3) Dielectric permittivity
4) Refractive index
5) Nonlinear optics
6) Polarisation and polarisation control

III- PROPAGATION OF LIGHT
1) Waves at an interface
2) The Fresnel coefficients
3) Total internal reflection
4) Evanescent waves
5) Dispersion diagram

IV- INTERFERENCES
1) General considerations
2) Temporal and spatial coherence
3) The Young double slit experiment
4) Diffraction gratings
5) The Michelson interferometer
6) Multi-wave interference
7) Antireflecting coating and interference filters
8) Optical holography

V- LIGHT MANIPULATION
1) Optical waveguides
2) Photonic crystals
3) Metamaterials and metasurfaces
4) Optical cavities

VI- OPTICAL FORCES AND OPTICAL TWEEZERS
1) History of optical forces
2) Theory of optical trapping
3) Atom cooling
4) Optomechanics
5) Applications of optical tweezers

VII- INTRODUCTION TO OPTICAL MICROSCOPY
1) Basic concepts
2) Direct and Fourier imaging
3) Image formation
4) Fluorescence microscopy
5) Scattering-based microscopy
6) Digital holography
7) Computational imaging

Lecture notes
Class notes and handouts
Optics (Hecht) - Pearson

Literature
Prerequisites / notice
Physics

Competencies
Subject-specific Competencies
Concepts and Theories
assessed
Techniques and Technologies
assessed
Method-specific Competencies
Analytical Competencies
assessed
Problem-solving
assessed
Personal Competencies
Creative Thinking
assessed
Critical Thinking
assessed

252-0061-00L Systems Programming and Computer Architecture W 7 credits 4V+2U A. Klimovic, T. Roscoe

Abstract
Introduction to systems programming. C and assembly language, floating point arithmetic, basic translation of C into assembler, compiler optimizations, manual optimizations. How hardware features like superscalar architecture, exceptions and interrupts, caches, virtual memory, multicores processors, devices, and memory systems function and affect correctness, performance, and optimization.

Objective
The course objectives are for students to:
1. Develop a deep understanding of, and intuition about, the execution of all the layers (compiler, runtime, OS, etc.) between programs in high-level languages and the underlying hardware: the impact of compiler decisions, the role of the operating system, the effects of hardware on code performance and scalability, etc.
2. Be able to write correct, efficient programs on modern hardware, not only in C but high-level languages as well.
3. Understand Systems Programming as a complement to other disciplines within Computer Science and other forms of software development.

This course does not cover how to design or build a processor or computer.
This course provides an overview of "computers" as a platform for the execution of (compiled) computer programs. This course provides a programmer's view of how computer systems execute programs, store information, and communicate. The course introduces the major computer architecture structures that have direct influence on the execution of programs (processors with registers, caches, other levels of the memory hierarchy, supervisor/kernel mode, and I/O structures) and covers implementation and representation issues only to the extent that they are necessary to understand the structure and operation of a computer system.

The course attempts to expose students to the practical issues that affect performance, portability, security, robustness, and extensibility. This course provides a foundation for subsequent courses on operating systems, networks, compilers and many other courses that require an understanding of the system-level issues. Topics covered include: machine-level code and its generation by optimizing compilers, address translation, input and output, trap/event handlers, performance evaluation and optimization (with a focus on the practical aspects of data collection and analysis).

Lecture notes
- C programming
- Integers
- Pointers and dynamic memory allocation
- Basic computer architecture
- Compiling C control flow and data structures
- Code vulnerabilities
- Implementing memory allocation
- Linking
- Floating point
- Optimizing compilers
- Architecture and optimization
- Caches
- Exceptions
- Virtual memory
- Multicore
- Devices

Literature
The course is based in part on "Computer Systems: A Programmer's Perspective" (3rd Edition) by R. Bryant and D. O'Hallaron, with additional material.

Prerequisites / notice
252-0029-00L Parallel Programming
252-0028-00L Design of Digital Circuits
Objective

Do you want to be able to query your own data productively and efficiently in your future semester projects, bachelor's thesis, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This course teaches you how to do so as well as the dos and don'ts.

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook

Literature

- Lecture material (slides).
- Book: "Database Systems: The Complete Book", H. Garcia-Molina, J.D. Ullman, J. Widom (It is not required to buy the book, as the library has it)

Prerequisites / notice

For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logic
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: fostered

Social Competencies
- Communication: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: assessed

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252-0836-00L Computer Science II

| W | 4 credits | 2V+2U | R. Sasse, F. Friedrich Wicker |

Abstract
The course covers the foundations of design and analysis of algorithms and data structures, including graph theory and graph problems. It also introduces generic and parallel programming.

Objective
- Understanding design, analysis and implementation of fundamental algorithms and data structures. Overview of the concepts of generic and parallel programming. Hands-on experience with implementing the aforementioned in C++.

Content
- Asymptotic runtime (algorithmic complexity)
- Fundamental algorithmic problems, e.g. searching, sorting, shortest paths, spanning trees
- Classical data structures, e.g. search trees, balanced trees, heaps, hash tables
- Graph theory and graph problems
- Problem solving strategies as design patterns for algorithms, e.g. induction, divide and conquer, backtracking, dynamic programming
- Generic programming: C++ templates, higher-order functions, lambdas, closures
- Parallel programming: (in)dependence of computations, parallelism and concurrency, shared memory, races, mutual exclusion, communication and synchronisation

Knowledge obtained in the lecture is deepened through practical and/or programming exercises (C++, Code Expert).

Lecture notes
All material (slides, lecture recordings, examples, exercises, etc.) will be published on the course website.

Literature
- B. Stroustrup, A Tour of C++, 3rd Edition, Addison-Wesley, 2022

Prerequisites / notice
Prerequisite: Computer Science I

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327-0512-00L Electronic, Optical and Magnetic Properties of Materials

| W | 7 credits | 5V+2U | P. Gambardella |

Abstract
This course provides physical foundations to understand the response of different classes of materials to electromagnetic fields, focusing on their electrical, optical, and magnetic properties, and on the basic functioning of devices that exploit such properties. The lectures build on classical and quantum mechanical concepts to provide microscopic understanding and modelling.

Objective
Student should be able to:
- Apply fundamental concepts in solid state physics to describe and explain the behavior of different types of materials, including the ability to make semi-quantitative assertions about relevant physical quantities.
- Analyze and evaluate different models and approaches to describe specific material properties, and appreciate the pertinence of these models to real-world applications, including the ability to make numerical estimates of the relevant parameters.
- Explain the working principles of a range of devices that take advantage of the physical properties of materials, including electronic, photonic, and magnetic devices.
- Develop an appreciation for the role of solid state physics in modern society and technology, and understand the importance of continued research and development in this field for future technological advancements.
Understanding the electronic properties of solids is at the heart of modern society and technology. The aim of this course is to provide fundamental physical concepts that allow one to relate the electronic structure of different types of materials to their electrical, optical, and magnetic behavior as well as the functioning of basic electronic, photonic, and magnetic devices. Beyond fundamental curiosity, such level of understanding is required in order to develop and appropriately describe new classes of materials for future technology applications. The course is divided in six parts.

PART I: The electronic structure of metals, semiconductors, and insulators
Revision of classical concepts: electric fields and currents, Ohm’s and Drude’s model of electrical conductivity, Hall effect, thermolectric effects.
Revision of quantum mechanical concepts: Electron bands, Fermi statistics, Fermi energy and Fermi surface, density of states in k-space and as a function of energy.

PART II: Semiconductors: concepts and devices

PART III: Dielectric properties of insulators

PART IV: Interaction of electromagnetic waves with matter
The electromagnetic (EM) spectrum. Electromagnetic waves in vacuum; Energy, momentum, and angular momentum of EM waves; Sources of EM radiation; EM waves in matter. The refractive index. Transmission, Reflection, and Refraction from a microscopic point of view. Optical anisotropy, Optical activity, Dichroism. Optical properties of crystalline insulators and semiconductors, glasses, and metals.

PART V: Photonic devices
Photodiodes, photovoltaic cells, light emitting devices (LEDs), Laser diodes, displays, optical fibers.

PART VI: Magnetism

Lecture notes
in English, available for download at http://www.intermag.mat.ethz.ch/education.html

Literature
C. Kittel, Introduction to Solid State Physics (Wiley, 2005), also printed in German. General text that covers many arguments from the point of view of condensed matter physics.
D. A. Neamen, Semiconductor Physics and Devices (McGraw-Hill, 2012). General treatment of semiconductor physics and devices, including both basic and more advanced topics.
Optoeletronic devices: D. A. Neamen (see above); Simon Sze, Physics of Semiconductor Devices (Wiley)

Prerequisites / notice

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4 credits

327-0515-00L Thermal and Transport Properties

Abstract
This course will introduce mass transport, heat conduction, charge transport, and flow in viscous liquids, with emphasis on their shared foundation in diffusive processes.

Objective
Students will learn how to create models describing transport processes. They will solve the resulting equations both analytically and numerically. They will apply these results to design materials processes and understand real-life experiments. A key takeaway will be the ability to construct simple order-of-magnitude estimates and scaling relationships that can be applied to efficient data analysis and design.

Lecture notes
A script in English will be provided on the Moodle course website
### Competencies

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### 401-2813-00L Programming Techniques for Scientific Simulations I

**Abstract**
This lecture provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ programming techniques and scientific software libraries. Based on an overview over the hardware components of PCs and supercomputer, optimization methods for scientific simulation codes are explained.

**Objective**
The goal of the course is that students learn basic and advanced programming techniques and scientific software libraries as used and applied for scientific simulations.

### 401-2283-00L Analysis III (Measure Theory)

**Abstract**
Measure and integration theory, including: Carathéodory’s theorem, Lebesgue measure, Radon measure, Hausdorff measure, convergence theorems, L^p spaces, Radon-Nikodym theorem, product measure and Fubini’s theorem.

**Objective**
Basics of abstract measure and integration theory

### 401-3461-00L Functional Analysis I

**Abstract**
Baire category; Banach and Hilbert spaces, bounded linear operators; basic principles: Uniform boundedness, open mapping/closed graph theorem, Hahn-Banach; convexity; dual spaces; weak and weak* topologies; Banach-Alaoglu; reflexive spaces; compact operators and Fredholm theory; closed graph theorem; spectral theory of self-adjoint operators in Hilbert spaces. Basics of Sobolev spaces.

**Objective**
Acquire a good degree of fluency with the fundamental concepts and tools belonging to the realm of linear Functional Analysis, with special emphasis on the geometric structure of Banach and Hilbert spaces, and on the basic properties of linear maps.
Literature

Recommended references include the following:


Prerequisites / notice

Solid background on the content of all Mathematics courses of the first two years of the undergraduate curriculum at ETH. Most importantly: fluency with point set topology and measure theory, in part. Lebesgue integration and L^p spaces.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Problem-solving

Method-specific Competencies
- Creative Thinking
- Critical Thinking

Social Competencies
- Sensitivity to Diversity

Personal Competencies
- Problem-solving
- Critical Thinking

Abstract

Introduction to differential manifolds and differential geometry.

Objective

Learn to compute, describe, prove, and solve problems in the language of differential geometry.

Content

Submanifolds of R^n, immersions, submersions, and embeddings, Sard's Theorem, abstract differentiable manifolds, charts, vector fields and flows, vector bundles, tensor fields, covariant derivatives, parallel transport, Riemannian metrics, geodesics, Riemann curvature tensor. Complete manifolds, Hopf-Rinow theorem. Many examples including curves, surfaces, hyperbolic space, S^3, the unit quaternions, the Gauss-Bonnet theorem, etc.

Literature

John M. Lee: Introduction to Smooth Manifolds
- Manfredo P. do Carmo: Differential Geometry of Curves and Surfaces
- S. Montiel, A. Ros: Curves and Surfaces
- S. Kobayashi: Differential Geometry of Curves and Surfaces
- Wolfgang Kühnel: Differentialgeometrie. Kurven-Flächen-Mannigfaltigkeiten
- Dennis Barden & Charles Thomas: An Introduction to Differential Manifolds

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Personal Competencies
- Creative Thinking
- Critical Thinking

Abstract

Basics of probability theory and the theory of stochastic processes in discrete time.

Data: 15.06.2024 12:39   Autumn Semester 2024   Page 2020 of 2653
Objective
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:
- measure theory formalism and probability theory, Dynkin's lemma and independence, convergence of series of independent random variables, law of large numbers, conditional expectation, martingale convergence theorems, uniform integrability, optional stopping theorem for martingales, the Bienaymé-Galton-Watson process and its R-number, convergence in distribution and the central limit theorem.

Content
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:
- measure theory formalism and probability theory, Dynkin's lemma and independence, convergence of series of independent random variables, law of large numbers, conditional expectation, martingale convergence theorems, uniform integrability, optional stopping theorem for martingales, the Bienaymé-Galton-Watson process and its R-number, convergence in distribution and the central limit theorem.

Lecture notes
will be available in electronic form.

Literature
H. Bauer, Probability Theory, de Gruyter 1996
J. Jacod and P. Protter, Probability essentials, Springer 2004
A. Klenke, Wahrscheinlichkeitsrechnung, Springer 2006
D. Williams, Probability with martingales, Cambridge University Press 1991

Prerequisites / notice
- Measure Theory
- Basic notions in probability theory (probability space, conditional probability, Borel Cantelli, Dynkin Lemma, random variables, expectation, variance, law of large numbers).

Competencies
Subject-specific Competencies Concepts and Theories Techniques and Technologies assessed
Personal Competencies Creative Thinking assessed

401-3628-14L Bayesian Statistics W 4 credits 2V

Does not take place this semester.

Abstract
Introduction to the Bayesian approach to statistics: decision theory, prior distributions, hierarchical Bayes models, empirical Bayes, Bayesian tests and model selection, empirical Bayes, Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods.

Objective
Students understand the conceptual ideas behind Bayesian statistics and are familiar with common techniques used in Bayesian data analysis.

Content
Topics that we will discuss are:

Students understand the conceptual ideas behind Bayesian statistics and are familiar with common techniques used in Bayesian data analysis.

Lecture notes
A script will be available in English.

Literature

Additional references will be given in the course.

Prerequisites / notice
- Measure Theory
- Basic notions in probability theory (probability space, conditional probability, Borel Cantelli, Dynkin Lemma, random variables, expectation, variance, law of large numbers).

Competencies
Subject-specific Competencies Concepts and Theories Techniques and Technologies assessed
Personal Competencies Creative Thinking assessed

401-3621-00L Fundamentals of Mathematical Statistics W 9 credits 4V+1U J. Ziegel

Abstract
In this course we study the basics of theoretical statistics. The course includes methods for designing estimators, confidence intervals and tests, and various ways to evaluate the accuracy of estimators, confidence intervals and tests. We consider optimality criteria such as admissibility and minimaxity, as well as Bayesian criteria. We will also present the asymptotic point of view.

Objective
The aim of this course is to gain insight into the main statistical ideas and concepts. The course considers classical low-dimensional models, with pointers towards today's highly complex models.

Competencies
Subject-specific Competencies Concepts and Theories assessed
Method-specific Competencies Analytical Competencies assessed
Problem-solving assessed

Personal Competencies Creative Thinking assessed

401-3913-01L Mathematical Foundations for Finance W 4 credits 3V+2U D. Possamaï

Abstract
First introduction to main modelling ideas and mathematical tools from mathematical finance

Objective
This course gives a first introduction to the main modelling ideas and mathematical tools from mathematical finance. It mainly aims at non-mathematicians who need an introduction to the main tools from stochastics used in mathematical finance. However, mathematicians who want to learn some basic modelling ideas and concepts for quantitative finance (before continuing with a more advanced course) may also find this of interest. The main emphasis will be on ideas, but important results will be given with (sometimes partial) proofs.

Content
Topics to be covered include
- financial market models in finite discrete time
- absence of arbitrage and martingale measures
- valuation and hedging in complete markets
- basics about Brownian motion
- stochastic integration
- stochastic calculus: Itô's formula, Girsanov transformation, Itô's representation theorem
- Black-Scholes formula

Lecture notes
See information on course homepage

Prerequisites / notice
Prerequisites: Results and facts from probability theory as in the book "Probability Essentials" by J. Jacod and P. Protter will be used freely. Especially participants who do not have a direct mathematics background are strongly advised to familiarise themselves with those tools before (or very quickly during) the course. (A possible alternative to the above English textbook are the (German) lecture notes for the standard course "Wahrscheinlichkeitsrechnung").

For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.
### 651-4101-00L  
**Physics of Glaciers**  
**W** 3 credits  
**3G**  
**M. Lüthi, F. T. Walter, M. Werder**

**Abstract**  
Understanding glaciers and ice sheets with simple physical concepts. Topics include the reaction of glaciers to the climate, flow of glacier ice, temperature in glaciers and ice sheets, glacier hydrology, glacier seismology, basal motion and calving glaciers. A special focus is the current development of the ice sheets of Greenland and Antarctica.

**Objective**  
After the course the students are able understand and interpret measurements of ice flow, subglacial water pressure and ice temperature. They will have an understanding of glaciology-related physical concepts sufficient to understand most of the contemporary literature on the topic. The students will be well equipped to work on glacier-related problems by numerical modeling, remote sensing, and field work.

**Content**  
The dynamics of glaciers and polar ice sheets is the key requisite to understand their history and their future evolution. We will take a closer look at ice deformation, basal motion, heat flow and glacier hydraulics. The specific dynamics of tide water and calving glaciers is investigated, as is the reaction of glaciers to changes in mass balance (and therefore climate).

**Lecture notes**  
Will be provided on Moodle

**Literature**  
A list of relevant literature is available on Moodle

**Prerequisites / notice**  
High-school mathematics and physics knowledge required.

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### 401-6215-00L  
**Using R for Data Analysis and Graphics (Part I)**  
**W** 1.5 credits  
**1G**  
**A. Hauser**

**Abstract**  
The course provides the first part an introduction to the statistical/graphical/data science software R (https://www.r-project.org/) for scientists. Topics covered are data generation and selection, graphical and basic statistical functions, creating simple functions, basic types of objects.

**Objective**  
The course provides the first part of an introduction to the statistical software R for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.

**Content**  
Part I of the course covers the following topics:
- What is R?
- R Basics: reading and writing data from/to files, creating vectors & matrices, selecting elements of dataframes, vectors and matrices, arithmetics;
- Types of data: numeric, character, logical and categorical data, missing values;
- Simple (statistical) functions: summary, mean, var, etc., simple statistical tests;
- Writing simple functions;
- Introduction to graphics: scatter-, boxplots and other high-level plotting functions, embellishing plots by title, axis labels, etc., adding elements (lines, points) to existing plots.

The course focuses on practical work at the computer with R. We will make use of the graphical user interface RStudio: www.rstudio.org

**Lecture notes**  
An Introduction to R. http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf

**Prerequisites / notice**  
The course resources will be provided via the Moodle web learning platform.  
Subscribing via Mystudies "automatically" makes you a student participant of the Moodle course of this lecture, which is at https://moodle-app2.let.ethz.ch/course/view.php?id=20847

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### 401-6217-00L  
**Using R for Data Analysis and Graphics (Part II)**  
**W** 1.5 credits  
**1G**  
**M. Mächler**

**Abstract**  
The course provides the second part an introduction to the statistical software R for scientists. Topics are data generation and selection, graphical functions, important statistical functions, types of objects, models, programming and writing functions.

**Objective**  
The students will be able to use the software R efficiently for data analysis, graphics and simple programming.
The course provides the second part of an introduction to the statistical software R (https://www.r-project.org/) for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.

Part II of the course builds on part I and covers the following additional topics:
- Elements of the R language: control structures (if, else, loops), lists, overview of R objects, attributes of R objects;
- More on R functions;
- Applying functions to elements of vectors, matrices and lists;
- Object oriented programming with R: classes and methods;
- Tailoring R: options;
- Extending basic R: packages

Lecture notes
An Introduction to R. http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf

Prerequisites / notice
Basic knowledge of R equivalent to "Using R ... (part 1)" (= 401-6215-00L) is a prerequisite for this course.

The course resources will be provided via the Moodle web learning platform. As from FS 2019, subscribing via Mystudies should *automatically* make you a student participant of the Moodle course of this lecture, which is at https://moodle-app2.let.ethz.ch/course/view.php?id=20848

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401-4623-00L Time Series Analysis

W 4 credits 2G F. Balabdaoui

Objective
The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

Content
This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exhibited by time series is the dependence between successive observations.

The key topics which will be covered as:
- Stationarity
- Autocorrelation
- Trend estimation
- Elimination of seasonality
- Spectral analysis, spectral densities
- ARMA, ARIMA, Introduction into GARCH models

Literature
The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis

401-0625-01L Applied Analysis of Variance and Experimental Design

W 5 credits 2V+1U L. Meier

Abstract
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Objective
Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Content
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Literature

401-0647-00L Introduction to Mathematical Optimization

W 5 credits 2V+1U D. Adjiashvili

Abstract
Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering. The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.
**401-0649-00L Applied Statistical Regression**

**Abstract**
This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning “good practice” that can be applied in every student’s own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

**Objective**
The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

**Content**
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L “Applied Statistical Regression” and 401-3622-00L “Statistical Modelling” are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

**Literature**
- Faraway (2005): Linear Models with R
- Faraway (2006): Extending the Linear Model with R
- Draper & Smith (1998): Applied Regression Analysis
- Fox (2008): Applied Regression Analysis and GLMs
- Montgomery et al. (2006): Introduction to Linear Regression Analysis

**Prerequisites / notice**
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: fostered

**Method-specific Competencies**
- Communication: assessed
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Social Competencies**
- Adaptable and Flexible: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

**701-0475-00L Atmospheric Physics**

**Abstract**
This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation, especially prediction of showers and severe convective storms, and optical phenomena.

**Objective**
Students are able:
- to explain the mechanisms of convective storm formation using knowledge of thermodynamics and cloud microphysics.
- to interpret precipitation radar images.
- to evaluate the significance of clouds and aerosol particles for artificial weather modification.

In the course “Atmospheric Physics”, the competencies of process understanding, system understanding and data analysis & interpretation are taught, applied and examined. Measurement methods are taught as well.

**Content**
The course starts with introducing selected concepts of thermodynamics for atmospheric processes: The students learn the concept of the thermodynamic equilibrium and derive the Clausius-Clapeyron equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Students also learn to use thermodynamic charts (tephigrams) and to identify cloud base, cloud top, available convective energy in radiosonde ascents. Atmospheric mixing processes are introduced as a basis for fog formation. The concept of an air parcel is used to understand convection.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

With these basics, the different forms of precipitation (convective vs. stratiform) are discussed and how they can be identified in radar images. Students will also learn under which conditions severe convective storms (especially supercells with tornados) can form.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

**Lecture notes**
Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=20400

An electronic version of this book can be obtained via the ETH library.

Prerequisites / notice
We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments.

There is an additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.

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Practical Courses

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<td>5 credits</td>
<td>4P</td>
<td>A. Eichler, M. Kroner, A. Eggenberger</td>
</tr>
</tbody>
</table>

Please make an enrolment in mystudies. Register the experiments here: https://www.lehrbetrieb.ethz.ch/laborpraktika. For further information visit: https://ap.phys.ethz.ch

Only students from 3rd Semester BSc Physics and IN are admitted to Physics Lab 2.

Abstract
Introductory lab course in experimental physics

Objective
The overarching topic of the student lab is an understanding of the fundamental challenges in experimental physics. The following aspects are particularly important:

- Why does one conduct experiments, and how should an experiment be planned?
- How does one set up an experiment? What are the important characteristics of measurement instruments and methods?
- Introduction to basic statistical data analysis
- Critical interpretation of measurement results
- Scientific communication, reporting, graphic representation of results
- Ethical aspects of experimental research and reporting

Content
Experiments with examples from mechanics, optics, thermodynamics, electronics, electricity and nuclear physics.

Manuals for the individual experiments are available in English.

Prerequisites / notice
6 Experiments have to be conducted (typically in teams of 2).

In the first week, only an introductory event is taking place in the lecture hall. This event provides relevant information regarding safety and organisational matters (e.g. testat conditions).

Students must pass an online safety test to be allowed to conduct experiments in the lab. It is recommended that every student acquires an individually adjusted safety goggle

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>fostered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>fostered</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>fostered</td>
</tr>
</tbody>
</table>

402-0000-09L | Physics Lab 3 | O | 7 credits | 13P | M. Donegà, S. Gvasaliya |

Abstract
This laboratory course provides basic training of experimental skills. These are experimental design, implementation, measurement, data analysis and interpretation, as well as error analysis. The experimental work has to be complemented by a concise written report, which trains the scientific writing skills.

Manuals for the individual experiments are available in English.

Objective
Students learn to independently perform advanced experiments and document them scientifically correct.

Students are required to attend a safety lecture on the first day of the course and pass the corresponding online moodle-test before being allowed to access the laboratory rooms and perform the experiments.

The following aspects are emphasized:

- understanding complicated physical phenomena
- structured approach to experiments with complex instruments
- various practical aspects of experimenting and determining uncertainties
- learning the relevant statistical methods for data analysis
- interpretation of measurements and uncertainties
- describing the experiments and the results in a scientifically proper manner, in direct analogy to publishing
- ethical aspects of experimental research and scientific communication

Content
We offer experiments covering the following topics:

Basic topics from mechanics, optics, thermodynamics, electromagnetism and electronics; as well as central topics from nuclear and particle physics, quantum electronics, quantum mechanics, solid state physics and astrophysics.

Lecture notes
Instructions for experiments are available in English.
Prerequisites / notice
From a variety of over 50 experiments, students have to perform 4 experiments covering different topics. The experimental work is complemented by writing a scientific report.
If a student intends to perform a semester exchange abroad, then experimental activities must be discussed with lecturers of Physics Lab 3 before beginning of the semester, and in any case before leaving.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
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<td>Assessed</td>
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<td>Techniques and Technologies</td>
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<td>Analytical Competencies</td>
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<tr>
<td>Cooperation and Teamwork</td>
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<tr>
<td>Adaptable and Flexibility</td>
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<tr>
<td>Creative Thining</td>
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<tr>
<td>Critical Thinking</td>
<td>Assessed</td>
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<tr>
<td>Integrity and Work Ethics</td>
<td>Assessed</td>
<td>Assessed</td>
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<tr>
<td>Self-direction and Self-management</td>
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<td>Assessed</td>
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</table>

Proseminars, Experimental and Theoretical Semester Papers

Detailed information at: https://www.phys.ethz.ch/studies/bachelor/semester-projects.html

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>402-0000-10L</td>
<td>Physics Lab 4</td>
<td>W</td>
<td>8</td>
<td>15P</td>
<td>M. Donegà, S. Gvasaliya</td>
</tr>
</tbody>
</table>

Prerequisite: "Physics Lab 3" completed. Before enrolling in "Physics Lab 4", please enrol in "Physics Lab 3".

Enrol at most once in the course of the Bachelor programme!

Abstract
This laboratory course provides basic training of experimental skills. These are experimental design, implementation, measurement, data analysis and interpretation, as well as error analysis. The experimental work has to be complemented by a concise written report, which trains the scientific writing skills. Manuals for the individual experiments are available in English.

Objective
Students learn to independently perform advanced experiments and document them scientifically correct.

The following aspects are emphasized:
- understanding complicated physical phenomena
- structured approach to experiments with complex instruments
- various practical aspects of experimenting and determining uncertainties
- learning the relevant statistical methods for data analysis
- interpretation of measurements and uncertainties
- describing the experiments and the results in a scientifically proper manner, in direct analogy to publishing
- ethical aspects of experimental research and scientific communication

Content
We offer experiments covering the following topics:
Basic topics from mechanics, optics, thermodynamics, electromagnetism and electronics; as well as central topics from nuclear and particle physics, quantum electronics, quantum mechanics, solid state physics and astrophysics.

402-0218-BSL Research Project W 8 credits 15A Supervisors

Abstract
Students conduct a small research project within a research group or carry out a guided self-study of original papers on a given theoretical topic. The results are submitted in a written report and an oral presentation.

Objective
Students are enabled to:
- expand their knowledge in a specific area of physics,
- conduct a project (a) in a research laboratory or (b) on a specific topic of theoretical physics,
- discuss their project results and conclusions in a team,
- present their findings in written and oral form.
Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication assessed
- Cooperation and Teamwork fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking assessed
- Critical Thinking fostered
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication assessed
- Cooperation and Teamwork fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking assessed
- Critical Thinking fostered
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

402-0219-BSL Research Project II

To register, please contact the study administration at studies.physics@ethz.ch

Abstract
Students conduct a small research project within a research group or carry out a guided self-study of original papers on a given theoretical topic. The results are submitted in a written report and an oral presentation.

Objective
Students are enabled to:
- expand their knowledge in a specific area of physics,
- conduct a project (a) in a research laboratory or (b) on a specific topic of theoretical physics,
- discuss their project results and conclusions in a team,
- present their findings in written and oral form.

Competencies
- Subject-specific Competencies
  - Concepts and Theories assessed
  - Techniques and Technologies assessed
- Method-specific Competencies
  - Analytical Competencies assessed
  - Decision-making assessed
  - Media and Digital Technologies fostered
  - Problem-solving assessed
  - Project Management fostered
- Social Competencies
  - Communication assessed
  - Cooperation and Teamwork fostered
  - Sensitivity to Diversity fostered
  - Negotiation fostered
- Personal Competencies
  - Adaptability and Flexibility fostered
  - Creative Thinking assessed
  - Critical Thinking fostered
  - Integrity and Work Ethics assessed
  - Self-awareness and Self-reflection fostered
  - Self-direction and Self-management fostered

Science in Perspective

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-PHYS

Language Courses

see Science in Perspective: Language Courses ETH/UZH

Additional Courses, Seminars and Colloquia

First or Second Year Additional Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-2003-00L</td>
<td>Algebra I</td>
<td>Z</td>
<td>7</td>
<td>3V+2U</td>
<td>L. Halbeisen</td>
</tr>
</tbody>
</table>

402-0351-00L Astronomy

Abstract
An overview of important topics in modern astronomy: planets, sun, stars, milky way, galaxies, and cosmology

Objective
This lecture gives a general introduction to main topics in modern astronomy. The lecture provides a basis for the more advanced lectures in astrophysics.

Content
- Planeten, Sonne, Sterne, Milchstrasse, Galaxien und Kosmologie.

Lecture notes
- Kopien der Präsentationen werden zur Verfügung gestellt.
- Oder sonstige Grundlehrbücher zur Astronomie.

Additional Courses (from Second Year Mathematics Bachelor)
Objective

Introduction to basic notions and results of group, ring and field theory.

Content

Group Theory: basic notions and examples of groups, subgroups, factor groups, homomorphisms, group actions, Sylow theorems, applications

Ring Theory: basic notions and examples of rings, ring homomorphisms, ideals

Field Theory: basic notions and examples of fields and field extensions, applications

Literature

J.F. Humphreys: A Course in Group Theory (Oxford University Press)
G. Smith and O. Tabachnikova: Topics in Group Theory (Springer-Verlag)

Competencies

Subject-specific Competencies
Concepts and Theories assessed

Method-specific Competencies
Analytical Competencies assessed

Personal Competencies
Creative Thinking fostered

Seminars and Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0101-00L</td>
<td>The Zurich Physics Colloquium</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>S. Huber, A. Refregier, University lecturers</td>
</tr>
<tr>
<td>402-0800-00L</td>
<td>The Zurich Theoretical Physics Colloquium</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>J. Renes, University lecturers</td>
</tr>
<tr>
<td>401-5330-00L</td>
<td>Talks in Mathematical Physics</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>M. Gaberdiel, G. M. Graf, P. Hintz, T. H. Willwacher</td>
</tr>
<tr>
<td>402-0600-00L</td>
<td>Nuclear and Particle Physics with Applications</td>
<td>E-</td>
<td>0</td>
<td>2S</td>
<td>A. Rubbia, K. S. Kirch, R. Walny</td>
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<tr>
<td>402-0893-00L</td>
<td>Particle Physics Seminar</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>T. K. Gehrmann</td>
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<tr>
<td>402-0700-00L</td>
<td>Seminar in Elementary Particle Physics</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>M. Spira</td>
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<tr>
<td>402-0746-00L</td>
<td>Seminar: Particle and Astrophysics (Aktuelles aus der E-Teilchen- und Astrophysik)</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>University lecturers</td>
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<tr>
<td>402-0300-00L</td>
<td>IPA Colloquium</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>A. Biland, A. de Cosa, A. Refregier, further lecturers</td>
</tr>
<tr>
<td>402-0530-00L</td>
<td>Mesoscopic Systems</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>T. M. Ihn</td>
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<tr>
<td>227-0980-00L</td>
<td>Seminar on Biomedical Magnetic Resonance</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>K. P. Prüssmann, S. Kozerke, M. Weiger Senften</td>
</tr>
<tr>
<td>227-1043-00L</td>
<td>Neuroinformatics - Colloquia (University of Zurich)</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>S.-C. Liu, R. Hahnloser, V. Mante</td>
</tr>
</tbody>
</table>

Abstract

Objective

The goal of this event is to bring you closer to current day research in all fields of physics. In each semester we have a set of distinguished speakers covering the full range of topics in physics. As a participating student should learn how to follow a research talk. In particular, you should be able to extract key points from a colloquium where you don't necessarily understand every detail that is presented.

Objective

The Zurich Theoretical Physics Colloquium is jointly organized by the University of Zurich and ETH Zurich. Its mission is to bring both students and faculty with diverse interests in theoretical physics together. Leading experts explain the basic questions in their field of research and communicate the fascination for their work.

Objective

Research colloquium

Research colloquium

Research colloquium

Occasionally, talks may be delivered in German.

Objective

Research colloquium

In Seminarvorträgen werden aktuelle Fragestellungen aus der Teilchenphysik vom theoretischen und experimentellen Standpunkt aus diskutiert. Besonders wichtig erscheint uns der Bezug zu den eigenen Forschungsmöglichkeiten am PSI, CERN und DESY.

Objective

Research colloquium

Objective

Research colloquium

Objective

Getting insight into advanced topics in magnetic resonance imaging

Objective

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI701

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline
Abstract
The colloquium in Neuroinformatics is a series of lectures given by invited experts. The lecture topics reflect the current themes in neurobiology and neuromorphic engineering that are relevant for our Institute.

Objective
The goal of these talks is to provide insight into recent research results. The talks are not meant for the general public, but really aimed at specialists in the field.

Content
The topics depend heavily on the invited speakers, and thus change from week to week.

### 402-0396-00L Recent Research Highlights in Astrophysics (University of Zurich)

**E-** 0 credits 1S  University lecturers

*No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.*

*UZH Module Code: AST006*

*Mind the enrolment deadlines at UZH:*

Abstract
Research colloquium

#### Selection of Higher Semester Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-2813-00L</td>
<td>Programming Techniques for Scientific Simulations I</td>
<td>W</td>
<td>5 credits</td>
<td>4G</td>
<td>R. Käppeli</td>
</tr>
</tbody>
</table>

*Students in the Master’s Degree Programme in Computational Science and Engineering must enrol only if this course unit is an additional requirement.*

**Abstract**
This lecture provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ programming techniques and scientific software libraries. Based on an overview over the hardware components of PCs and supercomputer, optimization methods for scientific simulation codes are explained.

**Objective**
The goal of the course is that students learn basic and advanced programming techniques and scientific software libraries as used and applied for scientific simulations.

| 402-0713-00L  | Astro-Particle Physics I                                | W    | 6 credits | 2V+1U | A. Biland           |

**Abstract**
This lecture gives an overview of the present research in the field of Astro-Particle Physics, including the different experimental techniques. In the first semester, main topics are the charged cosmic rays including the antimatter problem. The second semester focuses on the neutral components of the cosmic rays as well as on some aspects of Dark Matter.

**Objective**
Successful students know:
- experimental methods to measure cosmic ray particles over full energy range
- current knowledge about the composition of cosmic ray
- possible cosmic acceleration mechanisms
- correlation between astronomical object classes and cosmic accelerators
- information about our galaxy and cosmology gained from observations of cosmic ray

**Content**
First semester (Astro-Particle Physics I):
- definition of ‘Astro-Particle Physics’
- important historical experiments
- chemical composition of the cosmic rays
- direct observations of cosmic rays
- indirect observations of cosmic rays
- ‘extended air showers’ and ‘cosmic muons’
- ‘knee’ and ‘ankle’ in the energy spectrum
- the ‘anti-matter problem’ and the Big Bang
- ‘cosmic accelerators’

**Lecture notes**
See lecture home page: http://ihp-lx2.ethz.ch/AstroTeilchen/

**Literature**
See lecture home page: http://ihp-lx2.ethz.ch/AstroTeilchen/

**Competencies**

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
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<td>fostered</td>
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<tr>
<td>Techniques and Technologies</td>
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<td>Analytical Competencies</td>
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<tr>
<td>Media and Digital Technologies</td>
<td>assessed</td>
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<tr>
<td>Problem-solving</td>
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<tr>
<td>Communication</td>
<td>fostered</td>
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<td>Cooperation and Teamwork</td>
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<td>Integrity and Work Ethics</td>
<td>fostered</td>
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</table>

| Number        | Energy and Sustainability in the 21st Century (Part I) | W    | 6 credits | 2V+1U | P. Morf              |

**Abstract**
Part I of this course covers the energy-related topics in this two-semester course. The importance of energy to life and our modern culture is explored and placed in the perspective of the ongoing energy transition in the context of necessary and urgent decarbonization efforts. How much energy do we need and how can it be provided in a way that enables a sustainable existence?

**Objective**
Why is energy important for life, economy and our society?
How did energy use change over time? Which effects did these changes have on the environment?
What are the physical basics of energy technologies?
When, why and how did technology and science of energy come together?
What are the limits and benefits of all the various energy technologies?
How can different energy technologies be compared?
Can we understand the changes in the current energy systems?
How will the energy systems of the future look like?
How fast can we and should we enforce the current energy transition?
Which could be the overall guide lines for a working and sustainable energy system of the future?
Content
1. Introduction to Energy – what is it all about
2. Energy and making use of it – a short history of energy use and an overview on energy technologies
3. Coal, oil and natural gas – fossil fuels
4. Renewables I: Biomass, Hydropower, and Wind Energy – from traditional use to the modern concepts
5. Renewables II: Geothermal, Tidal power and Solar Technologies – new renewables to lead the change
6. Nuclear power, radioactivity and ultimate storage – the quest for a safe technology
7. Breeding and Nuclear Fusion – can it work at all?
8. Energy Storage – the need to increase capacity and for new technologies
9. Climate Change and Decarbonisation of the Energy Mix – how much time do we have?
11. Energy Systems – how everything can play together
12. Life Cycle Assessment of Energy Technologies – problems and possibilities
14. The Actual Energy Transition and Decarbonisation – How is your 2040, 2050?

Literature
The Physics of Energy, R.L. Jaffe, W. Taylor, 2018
Clean Disruption of Energy and Transportation, T. Seba 2014
Energy and Civilization: A History, V. Smil, 2018

Prerequisites / notice
Basics of Physics applied to Energy and Energy Technology.
Investigation on current problems (and possible solutions) related to the energy system and the environmental interactions.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered

Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Sensitivity to Diversity fostered

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed

Electives (Physics Master)

402-0580-00L Superconductivity W 6 credits 2V+1U V. Geshkenbein

Abstract

Objective
Introduction to the most important concepts of superconductivity both on phenomenological and microscopic level, including experimental and theoretical aspects.

Content
This lecture course provides an introduction to superconductivity, covering both experimental as well as theoretical aspects. The following topics are covered:
Basic phenomena of superconductivity: thermodynamics, electrodynamics, London and Pippard theory; Ginzburg-Landau theory; spontaneous symmetry breaking, flux quantization, properties of type I and II superconductors; mixed phase; microscopic BCS theory: electron-phonon mechanism, Cooper pairing, coherent state, quasiparticle spectrum, thermodynamics and response to magnetic fields; Josephson effect, superconducting quantum interference devices (SQUID) and other applications.

Lecture notes
Lecture notes and additional materials are available.

Literature
M. Tinkham "Introduction to Superconductivity"
P. G. de Gennes "Superconductivity Of Metals And Alloys"
A. A. Abrikosov "Fundamentals of the Theory of Metals"
J.B. Ketterson & S.N. Song "Superconductivity"
H. Stolz "Supraeleitung" (German)
K. Fossheim & A. Sudbo "Superconductivity: Physics and Applications"

Prerequisites / notice
The preceding attendance of the scheduled lecture courses "Introduction to Solid State Physics" and "Quantum Mechanics I" are mandatory. The lectures "Quantum Mechanics II" and "Solid State Theory" provide the most optimal conditions to follow this course.

402-0674-00L Physics in Medical Research: From Atoms to Cells W 6 credits 2V+1U B. K. R. Müller

Abstract
Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.
Objective

The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocye behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitations that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichromism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Type</th>
<th>Credits</th>
<th>Prerequisites</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1037-00L</td>
<td>Introduction to Neuroinformatics</td>
<td>W</td>
<td>6</td>
<td>V, Mante, B. Grewe, G. Indiveri, M. Payvand</td>
<td></td>
</tr>
<tr>
<td>401-3531-00L</td>
<td>Differential Geometry I</td>
<td>W</td>
<td>9</td>
<td>4V+1U</td>
<td>U. Lang</td>
</tr>
</tbody>
</table>

Abstract

The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties and neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.

Objective

Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchainments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

Content

This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

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Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- measure theory formalism and probability theory, Dynkin's lemma and independence, convergence of series of independent random variables, law of large numbers, conditional expectation, martingale convergence theorems, uniform integrability, optional stopping theorem for martingales, the Bienaymé-Galton-Watson process and its R-number, convergence in distribution and the central limit theorem.

Abstract

Baire category; Banach and Hilbert spaces, bounded linear operators; basic principles: Uniform boundedness, open mapping/closed graph theorem, Hahn-Banach; convexity; dual spaces; weak and weak* topologies; Banach-Alaoglu; reflexive spaces; compact operators and Fredholm theory; closed graph theorem; spectral theory of self-adjoint operators in Hilbert spaces. Basics of Sobolev spaces.

Objective

Acquire a good degree of fluency with the fundamental concepts and tools belonging to the realm of linear Functional Analysis, with special emphasis on the geometric structure of Banach and Hilbert spaces, and on the basic properties of linear maps.

Literature

Recommended references include the following:

Prerequisites / notice
- Measure Theory
- Basic notions in probability theory (probability space, conditional probability, Borel Cantelli, Dynkin Lemma, random variables, expectation, variance, law of large numbers).

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Techniques and Technologies</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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</table>

### 401-3621-00L Fundamentals of Mathematical Statistics

**Abstract**
In this course we study the basics of theoretical statistics. The course includes methods for designing estimators, confidence intervals and tests, and various ways to evaluate the accuracy of estimators, confidence intervals and tests. We consider optimality criteria such as admissibility and minimaxity, as well as Bayesian criteria. We will also present the asymptotic point of view.

**Objective**
The aim of this course is to gain insight into the main statistical ideas and concepts. The course considers classical low-dimensional models, with pointers towards today's highly complex models.

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<td>Techniques and Technologies</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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</table>

### 402-0247-00L Electronics for Physicists I (Analogue)

**Abstract**
Passive components, linear networks, transmission lines, simulation of analog circuits, semiconductor components: diodes, bipolar and field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise, operational amplifiers, feedback and stability, oscillators, ADCs and DACs, introduction to CMOS technology

**Objective**
The lecture provides the basic knowledge necessary to understand, design and simulate analog electronic circuits. In the exercises, the concepts can be experienced in a hands-on manner. Every student has the opportunity to go through all steps of an electronic design cycle. Those include designing schematics, generating a printed circuit board layout, and the realization of a soldered prototype.

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<tr>
<td></td>
<td>Techniques and Technologies</td>
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<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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</tbody>
</table>

### 402-0010-00L Basics of Computing Environments for Scientists

**Abstract**
Introduce IT services at D-PHYS and offer modules covering IT-related topics for scientists.

**Objective**
The "IT at D-PHYS" introduction provides a good understanding of how IT works at D-PHYS and presents an overview of the IT services and their providers. It is recommended for everyone joining the department.

The "IT and Information Security" crash course will address the most common threats you'll encounter when using the internet and teach you how to fend them off.

The remainder is structured into individual modules which can be attended separately. They give practical insights into everyday research-related IT challenges.

The "Linux Basics" modules offer an introduction to the Linux landscape and show how to work on the shell by using command line tools. The first part provides a basic understanding of Linux systems and their components. It introduces commands essential to working with local and remote machines. The second part focuses on more advanced tools and workflows and provides guidelines to scripting, automation and customization.

The "Python Ecosystem" modules present various aspects of the environment around Python. Without teaching the Python programming language itself, it aims at providing understanding of various concepts surrounding it. The first part focuses on getting ready to run code. It discusses the management of Python interpreters, packages and virtual environments. The second part presents tools for writing Python code and interacting with strings. From development environments (IDE, Jupyter), over code formatters and linters, to string formatting and parsing with regular expressions. The third part sits at the interface between Python code and external data files. We explain how to read or write files, discuss data types and file formats. We show how to handle configuration parameters and mention tools to automate the data analysis.

The "System Aspects module" deals with the hardware-related side of scientific computing. To get the best performance out of your scientific code, you have to be aware of the underlying hardware and adapt to it.

Use the dedicated web page https://www.lehrbetrieb.ethz.ch/laborpraktika to register. Enrolled students are eligible for an attestation of attendance after visiting at least 3 out of the 5 modules. Refer to https://compenv.phys.ethz.ch for the detailed contents.

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Content

Introduction:

IT at D-PHYS (IT service providers and IT services at D-PHYS)
IT and Information Security

Modules:

Linux Basics I (system components, basic shell usage)
Linux Basics II (advanced tools, scripting)
Python Ecosystem I (interpreters, packages, virtual environments)
Python Ecosystem II (development environments, formatter and linter, string formatting, regexp)
Python Ecosystem III (external data files, config parameters and automation)
System Aspects (how the hardware affects your scientific code and vice versa)

Competencies

Subject-specific Competencies
Concepts and Theories
Method-specific Competencies
Analytical Competencies
Problem-solving

Physics Bachelor - Key for Type

<table>
<thead>
<tr>
<th>Key for Type</th>
<th>Subject-specific Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<th>Key for Hours</th>
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<tr>
<th>Key for Hours</th>
<th>Subject-specific Competencies</th>
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<tbody>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<tr>
<td>O</td>
<td>Compulsory</td>
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</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Educational Science

General course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>871-0240-00L</td>
<td>Human Learning (EW)</td>
<td></td>
<td>2</td>
<td></td>
<td>E. Stern, M. Rau</td>
</tr>
<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in the programs &quot;Teaching Diploma&quot; or &quot;Teaching Certificate&quot;). It is about learning in childhood and adolescence.</td>
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<tr>
<td>Abstract</td>
<td>This course looks into scientific theories and also empirical studies on human learning and relates them to the school.</td>
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<tr>
<td>Objective</td>
<td>Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process successful information and on human process information and behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.</td>
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<tr>
<td>Content</td>
<td>Thematische Schwerpunkte:</td>
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<tr>
<td></td>
<td>Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>This lecture is only apt for students who intend to enrol in the programs &quot;Lehrdiplom&quot; or &quot;Didaktisches Zertifikat&quot;. It is about learning in childhood and adolescence.</td>
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Coping with Psychosocial Demands of Teaching (EW4 W DZ) ■ The successful participation in EW1 ("Human Learning") and EW2 ("Designing Learning Environments for School") is recommended, but not a mandatory prerequisite.

<table>
<thead>
<tr>
<th>Number</th>
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</tr>
</thead>
<tbody>
<tr>
<td>871-0240-22L</td>
<td>Coping with Psychosocial Demands of Teaching (EW4 W DZ) ■ The successful participation in EW1 (&quot;Human Learning&quot;) and EW2 (&quot;Designing Learning Environments for School&quot;) is recommended, but not a mandatory prerequisite.</td>
<td></td>
<td>3</td>
<td></td>
<td>S. Maurer, P. Caprez, I. Sargenti</td>
</tr>
<tr>
<td>Abstract</td>
<td>In this class, students will learn concepts and skills for coping with psychosocial demands of teaching.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Students possess theoretical knowledge and practical competences to be able to cope with the psychosocial demands of teaching.</td>
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<tr>
<td>(1)</td>
<td>They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks).</td>
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<tr>
<td>(2)</td>
<td>They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. illegal or psychological services).</td>
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Cognitively Activating Instructions in MINT Subjects ■ W

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<thead>
<tr>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>871-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects ■ W</td>
<td></td>
<td>2</td>
<td></td>
<td>R. Schumacher</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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</tr>
</tbody>
</table>
| Objective  | - Get to know cognitively activating instructions in MINT subjects  
- Get information about recent literature on learning and instruction  
Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erschein ist der erste Lehrveranstaltungstermin ersucht. |      |      |       |                            |

Human Intelligence

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
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<tbody>
<tr>
<td>871-0242-07L</td>
<td>Human Intelligence</td>
<td></td>
<td>1</td>
<td></td>
<td>E. Stern</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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</tbody>
</table>
| Objective  | - Understanding of research methods used in the empirical human sciences  
- Getting to know intelligence tests  
- Understanding findings relevant for education |      |      |       |                            |

Formation of Knowledge in STEM Fields in Primary and Secondary School ■ Adresses to students enrolled either in Teaching Diploma* (TD) or Teaching Certificate (TC) (excluding Teaching

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<th>Number</th>
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<tbody>
<tr>
<td>871-0228-00L</td>
<td>Formation of Knowledge in STEM Fields in Primary and Secondary School ■ Adresses to students enrolled either in Teaching Diploma* (TD) or Teaching Certificate (TC) (excluding Teaching</td>
<td></td>
<td>2</td>
<td></td>
<td>U. Markwalder</td>
</tr>
<tr>
<td>Abstract</td>
<td>The focus will be on the book &quot;Intelligenz: Grosse Unterschiede und ihre Folgen&quot; by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.</td>
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</table>
| Objective  | - Understanding of research methods used in the empirical human sciences  
- Getting to know intelligence tests  
- Understanding findings relevant for education |      |      |       |                            |
Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.

Examination Lessons are to be repeated. Repetition of the Teaching Internship is excluded even if the block seminar, pre-concepts are discussed in their own subject as well as theoretical inputs from developmental and cognitive psychology. During the cooperation phase, a teaching task defined by the primary and secondary school teachers is actively undertaken in a class. Finally, a final report is written, which contains a description of the students' level of knowledge. This seminar is only suitable for students who can adapt flexibly to the needs of pupils from lower class levels.

Subject Didactics and Professional Training

**Important:** You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
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<tbody>
<tr>
<td>402-0910-00L</td>
<td><strong>Physics Didactics I: Special Didactics of Physics</strong></td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>M. Mohr</td>
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<td><strong>Teaching</strong></td>
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<td></td>
<td><strong>Limited number of participants.</strong></td>
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<td><strong>Simultaneous enrolment in Introductory Internship Physics</strong></td>
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<tr>
<td></td>
<td>- course 402-0920-00L - is compulsory for Teaching Diploma Physic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Objective**


**Content**


**Lecture notes**

Folien und weitere Unterlagen werden zur Verfügung gestellt

**Literature**

wird während der Veranstaltung mitgeteilt

**Prerequisites / notice**

Die Veranstaltung ist zusammen mit dem Einführungspraktikum zu belegen

**402-0915-00L**

**Teaching Internship Including Examination Lessons**

**Physics**

Teaching Internship Physics for TC, Repetition of the Teaching Internship is excluded even if Examination Lessons are to be repeated.

**Abstract**

Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.

**Objective**

- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to discuss the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They practice finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Anlässlich der Hospitationen erläutert die Praktikumslehrperson ihre fachlichen, fachdidaktischen und pädagogischen Überlegungen, auf deren Basis sie den Unterricht geplant hat und tauscht sich mit dem/der Studierenden aus. Die von dem/der Studierenden gehaltenen Lektionen werden vor- und nachbesprochen.

Die Themen für die beiden Prüfungslektionen am Schluss des Praktikums erfahren die Studierenden in der Regel eine Woche vor dem Prüfungstermin. Sie erstellen eine Vorbereitung gemäß Anleitung und reichen sie bis am Vortrag um 12 Uhr den beiden Prüfungsexperten (Fachdidaktiker/-in, Departementsvertreter/-in) ein. Die gehaltenen Lektionen werden kriteriumsbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/der Kandidatin über die gehaltenen Lektionen im Rahmen eines kurzen Kolloquiums.

**Content**

**Lecture notes**

Dokument: schriftliche Vorbereitung für Prüfungslektionen.

**Literature**

Wird von der Praktikumslehrperson bestimmt.

---

### 402-0917-00L Mentored Work Subject Didactics Physics A

- **Type**: O
- **ECTS**: 2
- **AUS**: 4A
- **Instructors**: G. Schiltz, A. Vaterlaus

**Abstract**

In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

**Objective**

The objective is for the students:
- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

**Content**

Thematic Focus

The topics of the mentored work are mostly chosen from the high school curriculum.

**Lecture notes**

http://www.fachdidaktik.physik.ethz.ch/unterlagen.html

**Prerequisites / notice**

The mentored work should usually be finished before the teaching internship. FD2 (402-0909-00L) is required or should be achieved in the same semester.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Problem-solving: assessed
  - Project Management: assessed

- **Social Competencies**
  - Cooperation and Teamwork: assessed
  - Customer Orientation: assessed
  - Leadership and Responsibility: assessed
  - Self-presentation and Social Influence: assessed
  - Sensitivity to Diversity: assessed
  - Negotiation: assessed

- **Personal Competencies**
  - Adaptability and Flexibility: assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: assessed
  - Self-direction and Self-management: assessed

---

### Specialized Courses in Respective Subject with Educational Focus

**Number**

<table>
<thead>
<tr>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0737-00L</td>
<td>Energy and Sustainability in the 21st Century (Part I)</td>
<td>W</td>
<td>6</td>
<td>P. Morf</td>
</tr>
</tbody>
</table>

**Abstract**

Part I of this course covers the energy-related topics in this two-semester course. The importance of energy to life and our modern culture is explored and placed in the perspective of the ongoing energy transition in the context of necessary and urgent decarbonization efforts. How much energy do we need and how can it be provided in a way that enables a sustainable existence?

**Objective**

- Why is energy important for life, economy and our society?
- How did energy use change over time? Which effects did these changes have on the environment?
- What are the physical basics of energy technologies?
- When, why and how did technology and science of energy come together?
- What are the limits and benefits of all the various energy technologies?
- How can different energy technologies be compared?
- Can we understand the changes in the current energy systems?
- How will the energy systems of the future look like?
- How fast can we and should we enforce the current energy transition?
- Which could be the overall guide lines for a working and sustainable energy system of the future?
Content
1. Introduction to Energy – what is it all about
2. Energy and making use of it – a short history of energy use and an overview on energy technologies
3. Coal, oil and natural gas – fossil fuels
4. Renewables I: Biomass, Hydropower, and Wind Energy – from traditional use to the modern concepts
5. Renewables II: Geothermal, Tidal power and Solar Technologies – new renewables to lead the change
6. Nuclear power, radioactivity and ultimate storage – the quest for a safe technology
7. Breeding and Nuclear Fusion – can it work at all?
8. Energy Storage – the need to increase capacity and for new technologies
9. Climate Change and Decarbonisation of the Energy Mix – how much time do we have?
11. Energy Systems – how everything can play together
12. Life Cycle Assessment of Energy Technologies – problems and possibilities
14. The Actual Energy Transition and Decarbonisation – How is your 2040, 2050?

Literature
The Physics of Energy, R.L. Jaffe, W. Taylor, 2018
Clean Disruption of Energy and Transportation, T. Seba 2014
Renewable Energy – Without the Hot Air, D.J.C. Mackay 2009

Prerequisites / notice
Basics of Physics applied to Energy and Energy Technology.
Investigation on current problems (and possible solutions) related to the energy system and the environmental interactions.

402-0922-00L Mentored Work Specialised Courses in Physics with an Educational Focus A
Mentored Work Specialised Courses in the Respective Subject with an Educational Focus in Physics for TC and Teaching Diploma.

Abstract
In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

Objective
Practice in the explanation of complex topics in physics as the core competence of the teaching profession
Improvement of the physics education by providing attractive recent topics with regard to future curricular decisions and the public view of physics

Content
Choice of topic by individual arrangement

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management assessed

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Sensitivity to Diversity assessed
Negotiation assessed

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed

402-0247-00L Electronics for Physicists I (Analogue)
W 4 credits 2V+2P G. Bison, W. Erdmann

Abstract
Passive components, linear networks, transmission lines, simulation of analog circuits, semiconductor components: diodes, bipolar and field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise, operational amplifiers, feedback and stability, oscillators, ADCs and DACs, introduction to CMOS technology

Objective
The lecture provides the basic knowledge necessary to understand, design and simulate analog electronic circuits. In the exercises, the concepts can be experienced in a hands-on manner. Every student has the opportunity to go through all steps of an electronic design cycle. Those include designing schematics, generating a printed circuit board layout, and the realization of a soldered prototype.
Content

Passive elements, linear complex networks, transmission lines, simulation of analog circuits (SPICE), semiconductor elements: diodes, bipolar and fieldeffect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise in analog circuits, operational amplifiers, feedback and stability in amplifiers, oscillators, ADC's and DAC's, introduction in CMOS technology.

Practical exercises in small groups to the above themes complement the lectures.

Prerequisites / notice

no prior knowledge in electronics is required

Competencies

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Problem-solving

Social Competencies
Cooperation and Teamwork

Personal Competencies
Creative Thinking
Critical Thinking

Physics TC - Key for Type

W+ Eligible for credits and recommended
W Eligible for credits
E- Recommended, not eligible for credits
Z Courses outside the curriculum
Dr Suitable for doctorate
O Compulsory

Key for Hours

V lecture
G lecture with exercise
U exercise
S seminar
K colloquium
P practical/laboratory course
A independent project
D diploma thesis
R revision course / private study

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Physics Teaching Diploma

Detailed information on the programme at: www.didaktischeausbildung.ethz.ch

Please note that the course number will change from HS24 onwards. This change will have no effect on the courses and performances already completed and will be recognised for the respective degree.

Educational Science

Course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>871-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>R. Schumacher</td>
</tr>
</tbody>
</table>

This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)".

Abstract
This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.

Objective
- Get to know cognitively activating instructions in MINT subjects
- Get information about recent literature on learning and instruction

Prerequisites / notice
Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>871-0242-07L</td>
<td>Human Intelligence</td>
<td>W</td>
<td>1 credit</td>
<td>1S</td>
<td>E. Stern</td>
</tr>
</tbody>
</table>

Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).

This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)".

Abstract
The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.

Objective
- Understanding of research methods used in the empirical human sciences
- Getting to know intelligence tests
- Understanding findings relevant for education

see Educational Science Teaching Diploma

Subject Didactics in Physics

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0910-00L</td>
<td>Physics Didactics I: Special Didactics of Physics Teaching</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Mohr</td>
</tr>
</tbody>
</table>

Limited number of participants.

Further information is available from the lecturer via email: mamohr@ethz.ch

Simultaneous enrolment in Introductory Internship Physics - course 402-0920-00L - is compulsory for Teaching Diploma Physic

Objective
Die Studierenden verfügen über fachdidaktisches Grundwissen für den Physikunterricht an einer Mittelschule. Sie können eigene Lektionen unter Berücksichtigung der vielfältigen Rahmenbedingungen planen, durchführen und evaluieren. Sie reflektieren ihren Unterricht und sind bestrebt, ihn didaktisch und pädagogisch weiter zu entwickeln.

Die Studierenden kennen die Einsatzmöglichkeiten, Chancen und Schwierigkeiten verschiedener Unterrichtsmethoden und Hilfsmittel. Sie können die Eignung von Unterrichtsformen im Hinblick auf eine Lernsituation beurteilen. Sie bemühen sich in ihrem Unterricht, geeignete Methoden und Medien angesagt an die Klasse und das Thema einzusetzen.


Content
Thematische Schwerpunkte
Fachspezifisches: Sachstrukturen der gängigen Unterrichtsthemen, Alltagsbezüge, Fehlvorstellungen, Demonstrations- und Schülerexperimente, Arbeitsmittel zu physikalischen Themen des Grundlagen- und Schwerpunktsunterrichts
Einsatz verschiedener Unterrichtsmaterialien: Experimente, Computer, Taschenrechner, Video, Simulation Unterrichtsformen: Lernaufgabe, Werkstatt, Puzzle, Projekt, Gruppenarbeit, Praktikum
Lernformen
Interaktive Lehr-Lernveranstaltung mit Vorträgen und Demonstrationen des Dozenten, studentischer Einzel- und Kleingruppenarbeit, kurzen Präsentationen der Studierenden, Vertiefung der Inhalte durch Bearbeitung von Aufträgen ausserhalb der Kontaktstunden

Lecture notes
Literature
Prerequisites / notice
Folien und weitere Unterlagen werden zur Verfügung gestellt
Die Veranstaltung wird während der Veranstaltung mitgeteilt
Die Veranstaltung ist zusammen mit dem Einführungspraktikum zu belegen.

402-0917-00L Mentored Work Subject Didactics Physics A

Mentored Work Subject Didactics in Physics for TC and Teaching Diploma.

Abstract
In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.
Objective

The objective is for the students:
- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

Content

**Thematic Focus**
The topics of the mentored work are mostly chosen from the high school curriculum.

**Methods**
With the help of the mentor the students individually work on a topic and write a thesis about it.

**Lecture notes**
http://www.fachdidaktik.physik.ethz.ch/unterlagen.html

**Prerequisites / notice**
The mentored work should usually be finished before the teaching internship. FD2 (402-0909-00L) is required or should be achieved in the same semester.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

- **Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Problem-solving
  - Project Management

- **Social Competencies**
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
  - Negotiation

- **Personal Competencies**
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

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**402-0920-00L**

**Introductory Internship Physics**

**Type**
- O 2 credits 4A

**Lecturers**
- G. Schiltz, A. Vaterlaus

**Abstract**
In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

**Objective**
The objective is for the students:
- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

**Content**
The topics of the mentored work are mostly chosen from the high school curriculum.

**Methods**
With the help of the mentor the students individually work on a topic and write a thesis about it.

**Lecture notes**
http://www.fachdidaktik.physik.ethz.ch/unterlagen.html

**Prerequisites / notice**
The mentored work should usually be finished before the teaching internship. FD2 (402-0909-00L) is required or should be achieved in the same semester.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

- **Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Problem-solving
  - Project Management

- **Social Competencies**
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
  - Negotiation

- **Personal Competencies**
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

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**Professional Training in Physics**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0920-00L</td>
<td>Introductory Internship Physics</td>
<td>O</td>
<td>3</td>
<td>6P</td>
<td>M. Mohr</td>
</tr>
</tbody>
</table>
Simultaneous enrolment in Physics Didactics: Special Didactics of Physics Teaching - course 402-0910-00L - is compulsory.

Abstract
During the introductory teaching practice, the students sit in on five lessons given by the teacher responsible for their teaching practice, and teach five lessons themselves. The students are given observation and reflection assignments by the teacher responsible for their teaching practice.

Objective
Right at the start of their training, students acquire initial experience with the observation of teaching, the establishment of concepts for teaching and the implementation of teaching. This early confrontation with the complexity of everything that teaching involves helps students decide whether they wish to and, indeed, ought to, continue with the training. It forms a basis for the subsequent pedagogical and subject-didactics training.

Content

Literature
Wird von der Praktikumslehrperson bestimmt.

402-0911-00L Teaching Internship Physics ■ O 8 credits 17P M. Mohr

Abstract
The teaching practice takes in 50 lessons: 30 are taught by the students, and the students sit in on 20 lessons. The teaching practice lasts 4-6 weeks. It gives students the opportunity to implement the contents of their specialist-subject, educational science and subject-didactics training in the classroom. Students also conduct work assignments in parallel to their teaching practice.

Objective
- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics in their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They acquire the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Content

Literature
Wird von der Praktikumslehrperson bestimmt.

402-0913-00L Teaching Internship Physics II ■ W 4 credits 9P M. Mohr

Abstract
This is a supplement to the Teaching Internship required to obtain a Master of Advanced Studies in Secondary and Higher Education in the corresponding subject. It is aimed at enlarging the already acquired teaching experience. Students observe 10 lessons and teach 15 lessons independently.

Objective
Die Studierenden können die Bedeutung von Unterrichtsthemen in ihrem Fach unter verschiedenen Blickwinkeln einschätzen. Sie kennen und beherrschen das Unterrichtshandwerk. Sie können ein gegebenes Unterrichtsthema für eine Gruppe von Lernenden fachlich und didaktisch korrekt strukturieren und in eine adäquate Lernumgebung umsetzen. Es gelingt ihnen, die Balance zwischen Anleitung und Offenheit zu finden, sodass die Lernenden sowohl über den nötigen Freiraum wie über ausreichend Orientierung verfügen, um aktiv und effektiv flexibel nutzbares (Fach-)Wissen zu erwerben.

Content
Die Studierenden können die Bedeutung von Unterrichtsthemen in ihrem Fach unter verschiedenen Blickwinkeln einschätzen. Sie kennen und beherrschen das Unterrichtshandwerk. Sie können ein gegebenes Unterrichtsthema für eine Gruppe von Lernenden fachlich und didaktisch korrekt strukturieren und in eine adäquate Lernumgebung umsetzen. Es gelingt ihnen, die Balance zwischen Anleitung und Offenheit zu finden, sodass die Lernenden sowohl über den nötigen Freiraum wie über ausreichend Orientierung verfügen, um aktiv und effektiv flexibel nutzbares (Fach-)Wissen zu erwerben.

Simultaneous enrolment in “Examination Lesson II Physics” (402-0921-02L) is compulsory.

Abstract
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

Objective
- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle
- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

Content

Literature
Wird von der Praktikumslehrperson bestimmt.

402-0921-01L Examination Lesson I Physics ■ O 1 credit 2P M. Mohr

Abstract
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

Objective
- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle
- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

Content

402-0921-02L Examination Lesson II Physics ■ O 1 credit 2P M. Mohr

Abstract
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

Objective
- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle
- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

Content
Objective

On the basis of a specified topic, the candidate shows that they are in a position
- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle
- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

Content

Die Studierenden erfahren das Lektionsthema in der Regel eine Woche vor dem Prüfungstermin. Von der zuständigen Lehrperson erhalten sie Informationen über den Wissensstand der zu unterrichtenden Klasse und können sie vor dem Prüfungstermin besuchen.

Sie erstellen eine Vorbereitung gemäss Anleitung und reichen sie bis am Vortag um 12 Uhr den beiden Prüfungsexperten ein.

Die gehaltene Lektion wird kriterienbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/ der Kandidatin über die gehaltene Lektion im Rahmen eines kurzen Kolloquiums.

Lecture notes

Dokument: Schriftliche Vorbereitung für Prüfungslektionen.

Prerequisites / notice

Nach Abschluss der übrigen Ausbildung.


Core courses that counted towards the Bachelor or Master programme in physics or comprised additional admission requirements in subject didactics are not eligible for the teaching diploma.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0351-00L</td>
<td>Astronomy</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>A. M. Glauser</td>
</tr>
<tr>
<td>Abstract</td>
<td>An overview of important topics in modern astronomy: planets, sun, stars, milky way, galaxies, and cosmology</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>This lecture gives a general introduction to main topics in modern astronomy. The lecture provides a basis for the more advanced lectures in astrophysics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>Planeten, Sonne, Sterne, Milchstrasse, Galaxien und Kosmologie</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Kopien der Präsentationen werden zur Verfügung gestellt.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Literature</td>
<td>Der Neue Kosmos. A. Unsöld, B. Baschek, Springer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>402-0737-00L</td>
<td>Energy and Sustainability in the 21st Century (Part I)</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>P. Morf</td>
</tr>
<tr>
<td>Abstract</td>
<td>Part I of this course covers the energy-related topics in this two-semester course. The importance of energy to life and our modern culture is explored and placed in the perspective of the ongoing energy transition in the context of necessary and urgent decarbonization efforts.</td>
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<tr>
<td>Objective</td>
<td>Why is energy important for life, economy and our society?</td>
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<td></td>
<td>How did energy use change over time? Which effects did these changes have on the environment?</td>
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<td></td>
<td>What are the physical basics of energy technologies?</td>
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<td>When, why and how did technology and science of energy come together?</td>
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<td>What are the limits and benefits of all the various energy technologies?</td>
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<td>How can different energy technologies be compared?</td>
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<td>Can we understand the changes in the current energy systems?</td>
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<td>How will the energy systems of the future look like?</td>
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<td>How fast can we and should we enforce the current energy transition?</td>
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<td>Which could be the overall guide lines for a working and sustainable energy system of the future?</td>
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<tr>
<td>Content</td>
<td>1. Introduction to Energy – what is it all about</td>
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<td></td>
<td>2. Energy and making use of it – a short history of energy use and an overview on energy technologies</td>
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<td>3. Coal, oil and natural gas – fossil fuels</td>
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<td>4. Renewables I: Biomass, Hydropower, and Wind Energy – from traditional use to the modern concepts</td>
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<td>5. Renewables II: Geothermal, Tidal power and Solar Technologies – new renewables to lead the change</td>
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<td>6. Nuclear power, radioactivity and ultimate storage – the quest for a safe technology</td>
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<td>7. Breeding and Nuclear Fusion – can it work at all?</td>
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<td>8. Energy Storage – the need to increase capacity and for new technologies</td>
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<td>9. Climate Change and Decarbonisation of the Energy Mix – how much time do we have?</td>
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<td>11. Energy Systems – how everything can play together</td>
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<td>12. Life Cycle Assessment of Energy Technologies – problems and possibilities</td>
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<td></td>
<td>14. The Actual Energy Transition and Decarbonisation – How is your 2040, 2050?</td>
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<tr>
<td>Literature</td>
<td>The Physics of Energy, R.L. Jaffe, W. Taylor, 2018</td>
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<tr>
<td></td>
<td>Clean Disruption of Energy and Transportation, T. Seba 2014</td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>Basics of Physics applied to Energy and Energy Technology.</td>
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<td></td>
<td>Investigation on current problems (and possible solutions) related to the energy system and the environmental interactions.</td>
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<td></td>
<td>Training of scientific and multi-disciplinary methods, approaches and their limits in the exercises and discussions.</td>
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<tr>
<td>402-0922-00L</td>
<td>Mentored Work Specialised Courses in Physics with</td>
<td>W</td>
<td>2</td>
<td>4A</td>
<td>G. Schiltz, A. Vaterlaus</td>
</tr>
</tbody>
</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2043 of 2653
an Educational Focus A
Mentored Work Specialised Courses in the Respective Subject with an Educational Focus in Physics for TC and Teaching Diploma.

Abstract
In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

Objective
Practice in the explanation of complex topics in physics as the core competence of the teaching profession.

Content
Choice of topic by individual arrangement

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Problem-solving assessed

Social Competencies
- Communication assessed
- Cooperation and Teamwork assessed
- Customer Orientation assessed

Personal Competencies
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed

402-0923-00L Mentored Work Specialised Courses in Physics with an Educational Focus B
Mentored Work Specialised Courses in the Respective Subject with an Educational Focus in Physics for Teaching Diploma and for students upgrading TC to Teaching Diploma.

Abstract
In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

Objective
Practice in the explanation of complex topics in physics as the core competence of the teaching profession.

Content
Choice of topic by individual arrangement

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Problem-solving assessed

Social Competencies
- Communication assessed
- Cooperation and Teamwork assessed
- Customer Orientation assessed

Personal Competencies
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed

402-0924-00L Internship Physics Didactics
Internship Physics Didactics

Abstract
During the Internship Physics Didactics students teach 8 lessons in the classes of an internship teaching person. Students develop, test and analyze teaching arrangement under the guidance of a mentor (one of the lecturers).

Objective
Basic knowledge for the design of teaching arrangements is the topic of the Physics Didactics I and II courses. In the subsequent Internship Physics Didactics students combine the theoretical knowledge acquired in the didactics courses with practical aspects of teaching. During the internship students learn to transform their teaching goals into a real live class room setting considering subject specific, didactical and pedagogical aspects.

Content

Lecture notes
Wird vom Mentor bestimmt.
Das Fachdidaktikpraktikum kann erst nach dem Besuch der FD1 und frühdestens mit der FD2 durchgeführt werden (eine gleichzeitige Belegung von Fachdidaktik 2 und Fachdidaktikpraktikum ist möglich).

**Prerequisites / notice**

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: fostered
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: assessed

**Social Competencies**
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

**402-0263-00L Astrophysics I**

*Physics BSc students with programme regulations 2016 need to register for "402-0263-10L Astrophysics".*

**Abstract**
This introductory course will develop basic concepts in astrophysics as applied to the understanding of the physics of planets, stars, galaxies, and the Universe.

**Objective**
The course provides an overview of fundamental concepts and physical processes in astrophysics with the dual goals of: i) illustrating physical principles through a variety of astrophysical applications; and ii) providing an overview of research topics in astrophysics.

**Literature**
- Astrophysics for physicist, Arnab Ray Choudhuri

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

**Method-specific Competencies**
- Analytical Competencies: fostered
- Decision-making: assessed
- Problem-solving: assessed

**Personal Competencies**
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered

**402-0255-00L Introduction to Solid State Physics**

*Physics BSc students with programme regulations 2016 need to register for "402-0255-10L Einführung in die Festkörperphysik".*

**Abstract**
The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, electronic properties of insulators, metals, semiconductors, transport properties, and magnetism.

**Objective**
Introduction to Solid State Physics.

**Content**
The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, thermal properties of insulators; metals (classical and quantum mechanical description of electronic states, thermal and transport properties of metals); semiconductors (bandstructure and n/p-type doping); magnetism.

**Lecture notes**
The script will be available on moodle.

**Literature**
- C. Kittel, Festkörperphysik
- Ashcroft & Mermin, Festkörperphysik

**Prerequisites / notice**
Voraussetzungen: Physik I, II, III wünschenswert

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Analytical Competencies: assessed

**Method-specific Competencies**
- Decision-making: assessed
- Problem-solving: assessed

**Personal Competencies**
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered

**402-0247-00L Electronics for Physicists I (Analogue)**

Passive components, linear networks, transmission lines, simulation of analog circuits, semiconductor components: diodes, bipolar and field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise, operational amplifiers, feedback and stability, oscillators, ADCs and DACs, introduction to CMOS technology

**Objective**
The lecture provides the basic knowledge necessary to understand, design and simulate analog electronic circuits. In the exercises, the concepts can be experienced in a hands-on manner. Every student has the opportunity to go through all steps of an electronic design cycle. Those include designing schematics, generating a printed circuit board layout, and the realization of a soldered prototype.

**Content**
Passive elements, linear complex networks, transmission lines, simulation of analog circuits (SPICE), semiconductor elements: diodes, bipolar and field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise in analog circuits, operational amplifiers, feedback and stability in amplifiers, oscillators, ADC’s and DAC’s, introduction in CMOS technology. Practical exercices in small groups to the above themes complement the lectures.

**Prerequisites / notice**
no prior knowledge in electronics is required
## Compulsory Elective Courses

Further course offerings from the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
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<td>402-0737-00L</td>
<td>Energy and Sustainability in the 21st Century (Part I)</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>P. Morf</td>
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</table>

### Abstract

Part I of this course covers the energy-related topics in this two-semester course. The importance of energy to life and our modern culture is explored and placed in the perspective of the ongoing energy transition in the context of necessary and urgent decarbonization efforts. How much energy do we need and how can it be provided in a way that enables a sustainable existence?

### Objective

Why is energy important for life, economy and our society?

How did energy use change over time? Which effects did these changes have on the environment?

What are the physical basics of energy technologies?

When, why and how did technology and science of energy come together?

What are the limits and benefits of all the various energy technologies?

How can different energy technologies be compared?

Can we understand the changes in the current energy systems?

How will the energy systems of the future look like?

How fast can we and should we enforce the current energy transition?

Which could be the overall guide lines for a working and sustainable energy system of the future?

### Content

1. Introduction to Energy – what is it all about
2. Energy and making use of it – a short history of energy use and an overview on energy technologies
3. Coal, oil and natural gas – fossil fuels
4. Renewables I: Biomass, Hydropower, and Wind Energy – from traditional use to the modern concepts
5. Renewables II: Geothermal, Tidal power and Solar Technologies – new renewables to lead the change
6. Nuclear power, radioactivity and ultimate storage – the quest for a safe technology
7. Breeding and Nuclear Fusion – can it work at all?
8. Energy Storage – the need to increase capacity and for new technologies
9. Climate Change and Decarbonisation of the Energy Mix – how much time do we have?
11. Energy Systems – how everything can play together
12. Life Cycle Assessment of Energy Technologies – problems and possibilities
14. The Actual Energy Transition and Decarbonisation – How is your 2040, 2050?

### Literature

- The Physics of Energy, R.L. Jaffe, W. Taylor, 2018
- Clean Disruption of Energy and Transportation, T. Seba 2014
- Energy and Civilization: A History, V. Smil, 2018

### Prerequisites / notice

Basics of Physics applied to Energy and Energy Technology.

Training of scientific and multi-disciplinary methods, approaches and their limits in the exercises and discussions.

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: fostered

- **Social Competencies**
  - Communication: assessed
  - Cooperation and Teamwork: fostered
  - Sensitivity to Diversity: fostered
  - Negotiation: fostered

- **Personal Competencies**
  - Adaptability and Flexibility: assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered
  - Self-awareness and Self-reflection: fostered

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<tr>
<th>Number</th>
<th>Computer Science in Secondary School Mathematics</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>252-0855-00L</td>
<td>Computer Science in Secondary School Mathematics</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>D. Komm, J. Hromkovic, G. Serafini</td>
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</table>

### Abstract

The unit "Computer Science in Secondary School Mathematics" addresses key contributions of computer science to general education, the tight relations between the algorithmic and the mathematical way of thinking, and the thoughtful choice of computer science topics for high school mathematics classes.
The general goal of the course consists in presenting ways to teach fundamentals of computer science, which are closely related to
contents and methods of mathematics. After attending the course unit, a mathematics teacher is able to teach selected fundamentals of
computer science in mathematics classes.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this
understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on
to their pupils.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior
knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support.

They encourage the autonomy of the learners, manage to work with diverse target groups and to establish a positive learning environment.

The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written
way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding
German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching
materials.

In a semester exercise, the students develop and document an adaptive teaching unit for computer science. They learn to employ the
didactics methods and techniques that are introduced at the beginning of the semester.

Literature wird angegeben. Zusätzliche Unterlagen und Folien werden zur Verfügung gestellt.


Passive components, linear networks, transmission lines, simulation of analog circuits, semiconductor components: diodes, bipolar and
field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise, operational amplifiers, feedback and
stability, oscillators, ADCs and DACs, introduction to CMOS technology

The course covers the didactics of logic, of cryptography, of finite state automata, of computability and of the introduction to programming.
The students develop the understanding of fundamental scientific concepts such as algorithm, program, complexity, determinism,
computation, automata, verification, testing, security of a cryptosystem and secure communication. They reflect on ways to embed them
into a scientifically sound and didactically sustainable mathematics course.

Prerequisites / notice

no prior knowledge in electronics is required

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Problem-solving

Social Competencies

Cooperation and Teamwork

Personal Competencies

Creative Thinking

Critical Thinking

see Compulsory Elective Courses Teaching Diploma
Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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<tr>
<td>V</td>
<td>lecture</td>
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<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

ECTS  European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Physics Master

Core Courses

One Core Course in Experimental or Theoretical Physics from Physics Bachelor is eligible; however, this Core Course from Physics Bachelor cannot be used to compensate for the mandatory Core Course in Experimental or Theoretical Physics.

For the category assignment keep the choice "no category" and take contact with the Study Administration (www.phys.ethz.ch/studies/study-administration.html) after having received the credits.

Core Courses in Theoretical Physics

<table>
<thead>
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<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
<th>Abstract</th>
<th>Objective</th>
<th>Content</th>
<th>Lecture notes</th>
<th>Literature</th>
<th>Prerequisites / notice</th>
<th>Competencies</th>
</tr>
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<tbody>
<tr>
<td>402-0861-00L</td>
<td>Statistical Physics</td>
<td>W</td>
<td>10</td>
<td>4V+2U</td>
<td>M. Sigrist</td>
<td>This lecture covers the concepts of classical and quantum statistical physics. Several techniques such as second quantization formalism for fermions, bosons, photons and phonons as well as mean field theory and self-consistent field approximation. These are used to discuss phase transitions, critical phenomena and superfluidity.</td>
<td>This lecture gives an introduction in the basic concepts and applications of statistical physics for the general use in physics and, in particular, as a preparation for the theoretical solid state physics.</td>
<td>Kinetic approach to statistical physics: H-theorem, detailed balance and equilibrium conditions. Classical statistical physics: microcanonical ensembles, canonical ensembles and grandcanonical ensembles, applications to simple systems. Quantum statistical physics: density matrix, ensembles, Fermi gas, Bose gas (Bose-Einstein condensation), photons and phonons. Identical quantum particles: many body wave functions, second quantization formalism, equation of motion, correlation functions, selected applications, e.g. Bose-Einstein condensate and coherent state, phonons in elastic media and melting. One-dimensional interacting systems. Phase transitions: mean field approach to Ising model, Gaussian transformation, Ginzburg-Landau theory (Ginzburg criterion), self-consistent field approach, critical phenomena, Peierls' arguments on long-range order. Superfluidity: Quantum liquid Helium: Bogolyubov theory and collective excitations, Gross-Pitaevskii equations, Berezinskii-Kosterlitz-Thouless transition.</td>
<td>Lecture notes available in English.</td>
<td>No specific book is used for the course. Relevant literature will be given in the course.</td>
<td>Knowledge in basic thermodynamics and quantum mechanics.</td>
<td>Subject-specific Competencies: Concepts and Theories, Techniques and Technologies. Method-specific Competencies: Analytical Competencies, Problem-solving. Personal Competencies: Adaptability and Flexibility, Creative Thinking.</td>
</tr>
<tr>
<td>402-0830-00L</td>
<td>General Relativity</td>
<td>W</td>
<td>10</td>
<td>4V+2U</td>
<td>R. Renner</td>
<td>Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations of the theory as well as the underlying physical principles and concepts. It covers selected applications, such as the Schwarzschild solution and gravitational waves.</td>
<td>The goal of this course is to provide a solid introduction to the formalism, the techniques, and important physical applications of quantum field theory. Furthermore it prepares students for the advanced course in quantum field theory (Quantum Field Theory II), and for work on research projects in theoretical physics, particle physics, and condensed-matter physics.</td>
<td></td>
<td>Lecture notes: Will be provided as the course progresses.</td>
<td>Competencies: Subject-specific Competencies: Concepts and Theories, Techniques and Technologies. Method-specific Competencies: Analytical Competencies, Decision-making, Media and Digital Technologies, Problem-solving. Social Competencies: Communication, Cooperation and Teamwork, Customer Orientation. Leadership and Responsibility: Leadership and Responsibility. Self-presentation and Social Influence: Self-presentation and Social Influence. Sensitivity to Diversity, Negotiation. Personal Competencies: Adaptability and Flexibility, Creative Thinking, Critical Thinking, Integrity and Work Ethics, Self-awareness and Self-reflection, Self-direction and Self-management.</td>
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<tr>
<td>402-0843-00L</td>
<td>Quantum Field Theory I</td>
<td>W</td>
<td>10</td>
<td>4V+2U</td>
<td>L. Senatore</td>
<td>Special Students UZH must book the module PHY551 directly at UZH.</td>
<td>This course discusses the quantisation of fields in order to introduce a coherent formalism for the combination of quantum mechanics and special relativity. Topics include: - Relativistic quantum mechanics - Quantisation of bosonic and fermionic fields - Interactions in perturbation theory - Scattering processes and decays - Elementary processes in QED - Radiative corrections</td>
<td>The goal of this course is to provide a solid introduction to the formalism, the techniques, and important physical applications of quantum field theory. Furthermore it prepares students for the advanced course in quantum field theory (Quantum Field Theory II), and for work on research projects in theoretical physics, particle physics, and condensed-matter physics.</td>
<td>Lecture notes: Will be provided as the course progresses.</td>
<td>Competencies: Subject-specific Competencies: Concepts and Theories, Techniques and Technologies. Method-specific Competencies: Analytical Competencies, Decision-making, Media and Digital Technologies, Problem-solving. Social Competencies: Communication, Cooperation and Teamwork, Customer Orientation. Leadership and Responsibility: Leadership and Responsibility. Self-presentation and Social Influence: Self-presentation and Social Influence. Sensitivity to Diversity, Negotiation. Personal Competencies: Adaptability and Flexibility, Creative Thinking, Critical Thinking, Integrity and Work Ethics, Self-awareness and Self-reflection, Self-direction and Self-management.</td>
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</table>
Objectives
- Basic understanding of general relativity, its mathematical foundations (in particular the relevant aspects of differential geometry), and of some of the phenomena it predicts (with a focus on black holes).

Content
- Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations, such as differential manifolds, the Riemannian and Lorentzian metric, connections, and curvature. It discusses the underlying physical principles, e.g., the equivalence principle, and concepts, such as curved spacetime and the energy-momentum tensor. The course covers some basic applications and special cases, including the Newtonian limit, post-Newtonian expansions, the Schwarzschild solution, light deflection, and gravitational waves.

Literature
- Suggested textbooks:
  - C. Misner, K. Thorne and J. Wheeler: Gravitation
  - S. Carroll - Spacetime and Geometry: An Introduction to General Relativity
  - R. Wald - General Relativity
  - S. Weinberg - Gravitation and Cosmology

Core Courses: Experimental Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0257-00L</td>
<td>Advanced Solid State Physics</td>
<td>W</td>
<td>10</td>
<td>3V+2U</td>
<td>W. Wegscheider</td>
</tr>
</tbody>
</table>

Abstract
- This course is an extension of the introductory course on solid state physics.
- The purpose of this course is to learn to navigate the complex collective quantum phases, excitations and phase transitions that are the dominant theme in modern solid state physics. The emphasis is on the main concepts and on specific experimental examples, both classic ones and those from more recent research.

Objective
- The goal is to study how novel phenomena emerge in the solid state.

Content
- Today's challenges and opportunities in Solid State Physics:
  - Phase transitions and critical phenomena, Fermi surface instabilities, Superconductors, Magnetism of insulators, Semiconductors

Lecture notes
- The printed material for this course involves:
  - (1) a self-contained script, distributed electronically at semester start.
  - (2) experimental examples (Power Point slide-style) selected from original publications, distributed at the start of every lecture.

Literature
- A list of books will be distributed. Numerous references to useful published scientific papers will be provided.

Prerequisites / notice
- This course is for students who like to be actively engaged in learning. The "exercise classes" are organized in a non-traditional way:
  - Examples (Power Point slide-style) selected from original publications, distributed at the start of every lecture.
  - The "required performance element" of this lecture is a presentation of a paper complementing the lecture topics. Several topics and corresponding papers will be offered on the Moodle page of this lecture.

Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: fostered

- Method-specific Competencies
  - Analytical Competencies: fostered
  - Decision-making: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: fostered

- Social Competencies
  - Communication: fostered
  - Cooperation and Teamwork: fostered
  - Self-presentation and Social Influence: fostered

- Personal Competencies
  - Creative Thinking: fostered
  - Critical Thinking: fostered

402-0442-00L Quantum Optics W 10 credits 3V+2U A. Imamoglu

Abstract
- This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics covered include the quantum nature of light, semi-classical and quantum mechanical description of light-matter interaction, laser manipulation of atoms and ions, optomechanics, and quantum computation.

Objective
- The course aims to provide the knowledge necessary for pursuing research in the field of Quantum Optics. Fundamental concepts and techniques of Quantum Optics will be linked to modern experimental research. During the course the students should acquire the capability to understand currently published research in the field.

Content
- This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics that are covered include:
  - Coherence properties of light
  - Quantum nature of light: statistics and non-classical states of light
  - Light matter interaction: density matrix formalism and Bloch equations
  - Quantum description of light matter interaction: the Jaynes-Cummings model, photon blockade
  - Laser manipulation of atoms and ions: laser cooling and trapping, atom interferometry
  - Further topics: Rydberg atoms, optomechanics, quantum computing, complex quantum systems

Lecture notes
- Selected book chapters will be distributed.

Literature
- Textbooks:
  - G. Grynberg, A. Aspect and C. Fabre, Introduction to Quantum Optics
  - R. Loudon, The Quantum Theory of Light
  - Atomic Physics, Christopher J. Foot
  - Advances in Atomic Physics, Claude Cohen-Tannoudji and David Guéry-Odelin
  - C. Cohen-Tannoudji et al., Atom-Photon-Interactions
  - M. Scully and M.S. Zubairy, Quantum Optics
  - Y. Yamamoto and A. Imamoglu, Mesoscopic Quantum Optics
The lecture covers the following topics:

**Concepts and Theories**

- The students will deepen the knowledge on particle physics acquired during their bachelor studies. They will be able to apply the basics of relativistic quantum field theory (QFT) to derive the Feynman rules and to apply those to compute QED and QCD processes. They will be able to explain and discuss the connection between theory and experiments.

- Scattering processes in QED/QCD and running of $\alpha$ and $\alpha_s$ from the S-matrix to the Feynman rules of QED.

- From the quantisation of Klein-Gordon (boson) and Dirac (fermion)'s fields to decay rates and cross sections.

**Analytical Competencies**

- Understanding of basic physics and technology for pursuing research in ultrafast laser science. How are ultrashort laser pulses generated, how do they interact with matter, how can we measure these shortest man-made events and how can we use them to time-resolve ultrafast processes in nature? Fundamental concepts and techniques will be linked to a selection of hot topics in current research and applications.

- How do they interact with matter, how can we measure these shortest man-made events and how can we use them to time-resolve ultrafast processes in nature? Fundamental concepts and techniques will be linked to a selection of hot topics in current research and applications.

**Creative Thinking**

- Relaxation oscillations: dynamical behavior of rate equations after perturbation.

- Second-order nonlinearities with ultrashort pulses: phase-matching with short pulses and real beams, quasi-phase matching, second-harmonic and sum-frequency generation, parametric amplification and generation.

**Method-specific Competencies**

- Pulse duration measurements: rf cables and electronics, fast photodiodes, linear system theory for microwave test systems, optical gating and more.

- Frequency combs and carrier-envelope offset phase: measurement and stabilization of carrier-envelope offset phase (CEP), time and frequency domain applications of CEP-stabilized sources.

- High-harmonic generation and attosecond science: non-perturbative nonlinear optics / strong-field phenomena, high-harmonic generation (HHG), phase-matching in HHG, attosecond pulse generation, attosecond technology: detectors and diagnostics, attosecond metrology (streaking, RABBITT, transient absorption, attoclock), example experiments.

- Ultrafast THz science: generation and detection, physics in THz domain, weak-field and strong-field applications.

- Photonics: strong-field phenomena, high-harmonic generation (HHG), phase-matching in HHG, attosecond pulse generation, attosecond technology: detectors and diagnostics, attosecond metrology (streaking, RABBITT, transient absorption, attoclock), example experiments.

**Techniques and Technologies**

- Ultrashort pulse propagation in linear optical systems, effect of dispersion on ultrashort pulses, concepts of pulse carrier and envelope, time-bandwidth product.

- Pulse propagation: mathematical description of pulses and their propagation in linear optical systems, effect of dispersion on ultrashort pulses, concepts of pulse carrier and envelope, time-bandwidth product.

- Pulse shaping, measurement of dispersion.

- Pulse shaping, measurement of dispersion.

- Pulse shaping, measurement of dispersion.

- Pulse shaping, measurement of dispersion.

- Pulse shaping, measurement of dispersion.

- Pulse shaping, measurement of dispersion.

- Pulse shaping, measurement of dispersion.

- Ultrashort pulse propagation in linear optical systems, effect of dispersion on ultrashort pulses, concepts of pulse carrier and envelope, time-bandwidth product.
Quantum Computation and Quantum Information

Adaptability and Flexibility

Throughout the past 20 years the realm of quantum physics has entered the domain of information technology in more and more prominent ways. Enormous progress in the physical sciences and in engineering and technology has allowed us to build novel types of information processors based on the concepts of quantum physics. In these processors information is stored in the quantum state of physical systems in ways. The interaction between qubits is controlled and the resulting states are read out on the single quanta in order to process information. Realizing such challenging tasks is believed to allow constructing an information processor much more powerful than a classical computer. This task is taken on by academic labs, startups and major industry. The aim of this class is to give a thorough introduction to physical implementations pursued in current research for realizing quantum information processors. The field of quantum information science is one of the fastest growing and most active domains of research in modern physics.

Prerequisites / notice
A good understanding of finite dimensional linear algebra is recommended.

 Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies fostered
Decision-making fostered
Problem-solving fostered
Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered

402-0448-01L Quantum Information Processing I: Concepts
This theory part QIP I together with the experimental part 402-0448-02L QIP II (both offered in the autumn semester) combine to the core course in experimental physics "Quantum Information Processing" (totally 10 ECTS credits). This applies to the Master's degree programme in Physics.

Objective
By the end of the course students are able to explain the basic mathematical formalism of quantum mechanics and apply it to quantum circuits, quantum algorithms (Shor, Grover, Deutsch-Josza,...), stabilizer-based quantum error correction, fault-tolerant designs, the BB84 quantum key distribution protocol, and simple methods of quantum metrology.

Abstract
The course covers the key concepts and formalism of quantum information processing. Topics include quantum algorithms, quantum error correction, quantum cryptography, and quantum metrology, with an emphasis on the power of quantum information processing beyond that of classical information processing. The formalism of quantum states, measurements, and channels is developed in detail.

Content
The topics covered in the course will include quantum circuits, gate decomposition and universal sets of gates, efficiency of quantum protocols, quantum information processing problems. They are able to adapt and apply these concepts and methods to analyze and discuss quantum algorithms and other quantum information-processing protocols.

Lecture notes
Will be provided.

Literature
Quantum Computation and Quantum Information
Michael Nielsen and Isaac Chuang
Cambridge University Press

402-0448-02L Quantum Information Processing II: Implementations
This experimental part QIP II together with the theory part 402-0448-01L QIP I (both offered in the autumn semester) combine to the core course in experimental physics "Quantum Information Processing" (totally 10 ECTS credits). This applies to the Master's degree programme in Physics.

Abstract

Objective
Throughout the past 20 years the realm of quantum physics has entered the domain of information technology in more and more prominent ways. Enormous progress in the physical sciences and in engineering and technology has allowed us to build novel types of information processors based on the concepts of quantum physics. In these processors information is stored in the quantum state of physical systems forming quantum bits (qubits). The interaction between qubits is controlled and the resulting states are read out on the level of single quanta in order to process information. Realizing such challenging tasks is believed to allow constructing an information processor much more powerful than a classical computer. This task is taken on by academic labs, startups and major industry. The aim of this class is to give a thorough introduction to physical implementations pursued in current research for realizing quantum information processors. The field of quantum information science is one of the fastest growing and most active domains of research in modern physics.

Content
Introduction to experimental systems for quantum information processing (QIP).
- Quantum bits
- Coherent Control
- Measurement
- Decoherence
QIP with
- Ions
- Superconducting Circuits
- Photons
- NMR
- Rydberg atoms
- NV-centers
- Quantum dots

Lecture notes
Course material be made available at www.qudev.ethz.ch and on the Moodle platform for the course. More details to follow.

Literature
Quantum Computation and Quantum Information
Michael Nielsen and Isaac Chuang
Cambridge University Press

Prerequisites / notice
Basic knowledge of concepts of quantum physics and quantum systems, e.g from courses such as Physics III, Quantum Mechanics I and II or courses on topics such as atomic physics, solid state physics, quantum electronics are considered helpful.

More information on this class can be found on the web site www.qudev.ethz.ch

Electives

Electives: Physics and Mathematics
### Classical and Quantum Parametric Phenomena

**402-0469-67L**

**Title**
Classical and Quantum Parametric Phenomena

**Type**
W

**ECTS**
6 credits

**Hours**
3G

**Lecturers**
A. Eichler, A. Grimm

**Abstract**
There are numerous physical phenomena that rely on time-dependent Hamiltonians (or parametric driving) to amplify, cool, squeeze or couple resonating systems. In this course, we will introduce parametric phenomena in different fields of physics, ranging from classical engineering ideas to devices proposed for quantum computing.

**Objective**
This course is intended for
- Experimentalists who desire to gain a solid theoretical understanding of nonlinear driven-dissipative systems,
- Theorists looking to enter a topical new field,
- Any scientist interested to learn what lies beyond the harmonic resonator.

In the course, the students will grasp the ubiquitous nature of parametric phenomena and apply it to both classical and quantum systems. The students will understand both the theoretical foundations leading to the parametric drive as well as the experimental aspect related to the realizations of the effect. Each student will analyze an independent system using the tools acquired in the course and will present his/her insights to the class.

**Content**
This course will provide a general framework for understanding and linking various phenomena, ranging from the child-on-a-swing problem to quantum-limited amplifiers, to optical frequency combs, and to optomechanical sensors used in the LIGO experiment. The course will combine theoretical lectures and the study of important experiments through literature.

The students will receive an extended lecture summary as well as numerous Python scripts, including some that are base on the QuTiP library. These tools will enable them to apply analytical and numerical methods to a wide range of systems beyond the duration of the course.

**Lecture notes**
A full script will be available in the form of chapters from a dedicated book ("Classical and Quantum Parametric Phenomena").

**Prerequisites / notice**
The students should be familiar with wave mechanics as well as second quantization. Following the course requires a laptop with Python installed to run Jupyter notebooks, including the QuTiP library.

### Ultrafast Processes in Solids

**402-0526-00L**

**Title**
Ultrafast Processes in Solids

**Type**
W

**ECTS**
6 credits

**Hours**
2V+1U

**Lecturers**
Y. M. Acremann

**Abstract**
Ultrafast processes in solids are of fundamental interest as well as relevant for modern technological applications. The dynamics of the lattice, the electron gas as well as the spin system of a solid are discussed. The focus is on time resolved experiments which provide insight into pico- and femtosecond dynamics.

**Objective**
After attending this course you understand the dynamics of essential excitation processes which occur in solids and you have an overview over state of the art experimental techniques used to study fast processes.

**Content**

1. Experimental techniques, an overview
   2. Dynamics of the electron gas
      2.1 First experiments on electron dynamics and lattice heating
      2.2 The finite lifetime of excited states
      2.3 Detection of lifetime effects
      2.4 Dynamical properties of reactions and adsorbents
   3. Dynamics of the lattice
      3.1 Phonons
      3.2 Non-thermal melting
   4. Dynamics of the spin system
      4.1 Laser induced ultrafast demagnetization
      4.2 Ultrafast spin currents generated by lasers
      4.3 Landau-Lifschitz-Dynamics
      4.4 Laser induced switching
   5. Correlated materials

**Lecture notes**
will be distributed

**Literature**
relevant publications will be cited

**Prerequisites / notice**
The lecture can also be followed by interested non-physics students as basic concepts will be introduced.
In addition to the lecture notes, the following supplementary books can be recommended:

Creative Thinking

Concepts and Theories

W

fostered

assessed

Problem-solving

fostered

assessed

Analytical Competencies

Decision-making

fostered

assessed

Social Competencies

Communication

assessed

fostered

Personal Competencies

Creative Thinking

fostered

fostered

Critical Thinking

fostered

Fostered

Assessed

Creative Thinking

The course covers the foundations of semiconductor nanostructures, e.g., materials, band structures, bandgap engineering and doping, field-effect transistors. The physics of the quantum Hall effect and of common nanostructures based on two-dimensional electron gases will be discussed, i.e., quantum point contacts, Aharonov-Bohm rings and quantum dots.

402-0595-00L

Semiconductor Nanostructures

W

6 credits

2V+1U

T. M. Ihn

Abstract

The course covers the foundations of semiconductor nanostructures, e.g., materials, band structures, bandgap engineering and doping, field-effect transistors. The physics of the quantum Hall effect and of common nanostructures based on two-dimensional electron gases will be discussed, i.e., quantum point contacts, Aharonov-Bohm rings and quantum dots.

Objective

At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:

1. The integer quantum Hall effect
2. Conductance quantization in quantum point contacts
3. the Aharonov-Bohm effect
4. Coulomb blockade in quantum dots

Content

1. Introduction and overview
2. Semiconductor crystals: Fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k.p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

Lecture notes


Literature

In addition to the lecture notes, the following supplementary books can be recommended:


Prerequisites / notice

The lecture is suitable for all physics students, students of Quantum Engineering, and students of Micro- and Nanosystems beyond the bachelor of science degree. Basic knowledge of solid state physics is a prerequisite. Very ambitioned students in the third year of Physics may be able to follow. The lecture can be chosen as part of the PhD-program. The course is taught in English.
Semiconductor Materials: Fundamentals and Fabrication

W 6 credits 2V+1U S. Schön, W. Wegscheider

Abstract
This course gives an introduction into the fundamentals of semiconductor materials. The main focus is on state-of-the-art fabrication and characterization methods. The course will be continued in the spring term with a focus on applications.

Objective
Basic knowledge of semiconductor physics and technology. Application of this knowledge for state-of-the-art semiconductor device processing

Content
1. Fundamentals of Solid State Physics
   1.1 Semiconductor materials
   1.2 Band structures
   1.3 Carrier statistics in intrinsic and doped semiconductors
   1.4 p-n junctions
   1.5 Low-dimensional structures
2. Bulk Material growth of Semiconductors
   2.1 Czochalski method
   2.2 Floating zone method
   2.3 High pressure synthesis
3. Semiconductor Epitaxy
   3.1 Fundamentals of Epitaxy
   3.2 Molecular Beam Epitaxy (MBE)
   3.3 Metal-Organic Chemical Vapor Deposition (MOCVD)
   3.4 Liquid Phase Epitaxy (LPE)
4. In situ characterization
   4.1 Pressure and temperature
   4.2 Reflectometry
   4.3 Ellipsometry and RAS
   4.4 LEED, AES, XPS
   4.5 STM, AFM
5. The invention of the transistor - Christmas lecture

Lecture notes
https://moodle-app2.let.ethz.ch/course/view.php?id=20749

Prerequisites / notice
The "compulsory performance element" of this lecture is a short presentation of a research paper complementing the lecture topics.
Several topics and corresponding papers will be offered on the moodle page of this lecture.

Competencies
Subject-specific Competencies
Concepts and Theories fostered
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies fostered
Media and Digital Technologies fostered
Problem-solving fostered

Social Competencies
Communication fostered
Self-presentation and Social Influence assessed
Sensitivity to Diversity fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-direction and Self-management fostered

-selection: Quantum Electronics

Advanced Topics in Quantum Optics

W 4 credits 2G T. Esslinger

Abstract
The lecture will cover current topics and papers in the wider field of quantum optics in an interactive format. Several papers will be presented by the students in the style of a journal club. Selected papers will be contrasted and their strengths and weaknesses discussed by the students in panel discussions. Recent papers on arXiv.org will be discussed and referee reports referee reports.

Objective
The aim of the lecture is to deepen and broaden the knowledge about current research in the field of quantum optics. In addition, it will also be discussed and critically examined how research results are communicated via publications and lectures and which techniques are used in the process.

Content
We will select topical fields in quantum optics and quantum science and discuss recently published work.

Topics:
- Atoms or ions-based quantum computing
- Quantum simulation
- Opto-mechanics
- Driven and dissipative quantum systems
- Cavity based atom-light interaction
- Topological photonics

The interactive part of the lecture will include presentations of recent papers, panel discussions of recent papers and the writing of a critical assessment of an arXiv paper in the style of a referee report.

Competencies
Subject-specific Competencies
Concepts and Theories fostered

Method-specific Competencies
Analytical Competencies fostered

Social Competencies
Communication fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking fostered

Dissipative Quantum Systems

W 6 credits 2V+1U A. Imamoglu

Does not take place this semester.

Abstract
This course builds up on the material covered in the Quantum Optics course. The emphasis will be on quantum optics in condensed-matter systems.
Intersubband transitions in quantum wells are transitions between states created by quantum confinement in ultra-thin layers of

Lecture notes
Lecture notes will be provided

Literature
C. Cohen-Tannoudji et al., Atom-Photon-Interactions (recommended)
Y. Yamamoto and A. Imamoglu, Mesoscopic Quantum Optics (recommended)
A collection of review articles (will be pointed out during the lecture)

Prerequisites / notice
Masters level quantum optics knowledge

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Conceptual and Theoretical Knowledge</th>
<th>Analytical Competencies</th>
<th>Method-specific Competencies</th>
<th>Problem-solving</th>
<th>Social Competencies</th>
<th>Cooperation and Teamwork</th>
<th>Personal Competencies</th>
<th>Critical Thinking</th>
<th>Communication Skills</th>
<th>Problem-solving</th>
</tr>
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<tbody>
<tr>
<td>402-0457-00L Quantum Technologies for Searches of New Physics</td>
<td>W 6 credits 2V+1U P. Crivelli</td>
<td>Does not take place this semester.</td>
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<tr>
<td>Objective</td>
<td>The course aims to provide the knowledge necessary for pursuing advanced research in the field of Quantum Optics in condensed matter systems. Fundamental concepts and techniques of Quantum Optics will be linked to experimental research in systems such as quantum dots, exciton-polaritons, quantum Hall fluids and graphene-like materials.</td>
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<tr>
<td>Literature</td>
<td>Lecture notes will be provided</td>
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<td>Prerequisites / notice</td>
<td>The preceding attendance of introductory particle physics, quantum mechanics and quantum electronics courses at the bachelor level is recommended.</td>
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402-0464-00L Light-Matter Interaction in Semiconductors: Physics and Applications

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Conceptual and Theoretical Knowledge</th>
<th>Analytical Competencies</th>
<th>Method-specific Competencies</th>
<th>Problem-solving</th>
<th>Social Competencies</th>
<th>Cooperation and Teamwork</th>
<th>Personal Competencies</th>
<th>Critical Thinking</th>
<th>Communication Skills</th>
<th>Problem-solving</th>
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<tbody>
<tr>
<td>Objective</td>
<td>The course presents fundamental aspects of light-matter interaction in semiconductor materials, from basic research topics to opto-electronic devices.</td>
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<tr>
<td>Content</td>
<td>The rich physics of the optical properties of semiconductors, as well as the advanced processing available on these materials, enabled numerous applications as well as the realization of new physical concepts. In this course, we will learn the principles of light-matter interaction in semiconductors for single and multiple particle excitations, and cover opto-electronic applications based on these principles. We will study systems that include quantum dots, exciton-polaritons, quantum Hall fluids and graphene-like materials.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Quantum Mechanics II, Introduction to Solid State Physics, Quantum Electronics</td>
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402-0465-58L Intersubband Optoelectronics

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Conceptual and Theoretical Knowledge</th>
<th>Analytical Competencies</th>
<th>Method-specific Competencies</th>
<th>Problem-solving</th>
<th>Social Competencies</th>
<th>Cooperation and Teamwork</th>
<th>Personal Competencies</th>
<th>Critical Thinking</th>
<th>Communication Skills</th>
<th>Problem-solving</th>
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<tr>
<td>Objective</td>
<td>The course will treat the following chapters:</td>
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<td>Content</td>
<td>- Introduction: intersubband optoelectronics as an example of quantum engineering</td>
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<td></td>
<td>-Technological aspects</td>
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<td>- Electronic states in semiconductor quantum wells</td>
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<td>- Intersubband absorption and scattering processes</td>
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<td>- Mid-IR and THz ISB Detectors</td>
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<td>-Mid-infrared and THz photonics: waveguides, resonators, metamaterials</td>
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<td>-THZ QCLs (direct and non-linear generation)</td>
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<td>-Further electronic confinement: interlevel Qdot transitions and magnetic field effects</td>
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<td>-Strong light-matter coupling in Mid-IR and THz range</td>
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Lecture notes
The reference book for the lecture is "Quantum Cascade Lasers" by Jerome Faist , published by Oxford University Press.

Literature
- E. Rosencher and B. Vinter, Optoelectronics , Cambridge Univ. Press
- G. Bastard, Wave mechanics applied to semiconductor heterostructures, Halsted press

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2056 of 2653
Abstract
The lecture describes various nanomaterials (semiconductor, metal, dielectric, carbon-based...) for photonic applications (optoelectronics, plasmonics, photonic integrated circuits, ordered and disordered structures...). It starts with concepts of light-matter interactions, fabrication and characterization, the description of the properties and thinnest-of-the-art applications and devices.

Objective
The students will acquire theoretical and experimental knowledge about the different types of nanomaterials (semiconductors, metals, dielectric, carbon-based, ...) and their uses as building blocks for advanced applications in photonics (optoelectronics, plasmonics, photonic crystal, ...). Together with the exercises, the students will learn (1) to read, summarize and discuss scientific articles related to the lecture, (2) to estimate order of magnitudes with calculations using the theory seen during the lecture, (3) to prepare a short oral presentation and report about one topic related to the lecture, and (4) to imagine an original photonic device.

Content
1. Introduction to nanophotonics
2. Wave physics for nanophotonics
3. Characterization of nanomaterials
4. Semiconductors
5. Nonlinear crystals
6. Photonic integrated circuits
7. Optical quantum devices
8. Plasmonics
9. Metasurfaces
10. Graphene & 2D Materials
11. Nanocomposites
Abstract

We will cover experimental issues in making measurements in modern physics experiments. The primary challenge in any measurement is achieving good signal to noise. We will cover areas such as optical propagation, electronics, noise limits and feedback control. Methods for stabilizing frequencies and intensities of laser systems will also be described.

Objective

I aim to give an in depth understanding of experimental issues for students wishing to work on experimental science. The methods covered are widely applicable in modern physics, since light and electronics are the primary methods by which measurements are made across the field.

Content

The course will cover a number of different areas of experimental physics, including:

- Optical elements and propagation
- Electronics and Electronic Noise
- Optical Detection
- Control Theory

Examples from a modern quantum information laboratory will be discussed and illustrated through active devices in the lecture.

### Selection: Particle Physics

**402-0457-00L Quantum Technologies for Searches of New Physics**

- **Number**: 402-0457-00L
- **Title**: Quantum Technologies for Searches of New Physics
- **Type**: Does not take place this semester.
- **ECTS**: 6 credits
- **Hours**: 2V+1U
- **Lecturers**: P. Crivelli

**Abstract**

Recent years have witnessed incredible progress in the development of new quantum technologies driven by their application in quantum information, metrology, high precision spectroscopy and quantum sensing. This course will present how these emerging technologies are powerful tools to address open questions of the Standard Model in a complementary way to what is done at the high energy frontier.

**Objective**

The aim of this course is to equip students of different backgrounds with a solid base to follow this rapidly developing and exciting multi-disciplinary field.

**Content**

The first lectures will be dedicated to review the open questions of the Standard Model and the different Beyond Standard Model extensions which can be probed with quantum technologies. This will include searches for dark sector, dark matter, axion and axion-like particles, new gauge bosons (e.g. Dark photons) and extra short-range forces.

The main part of the course will introduce the following (quantum) technologies and systems, and how they can be used for probing New Physics:

- Cold atoms
- Trapped ions
- Atoms interferometry
- Atomic clocks
- Cold molecules and molecular clocks
- Exotic Atoms
- Anti-matter
- Quantum Sensors

**Prerequisites / notice**

The preceding attendance of introductory particle physics, quantum mechanics and quantum electronics courses at the bachelor level is recommended.

**402-0621-00L Introduction to Accelerator Mass Spectrometry**

- **Number**: 402-0621-00L
- **Title**: Introduction to Accelerator Mass Spectrometry
- **Type**: W
- **ECTS**: 6 credits
- **Hours**: 2V+1U
- **Lecturers**: C. Vockenhuber, M. Christl, A. Müller, L. Wacker

**Abstract**

This course gives an introduction into Accelerator Mass Spectrometry (AMS), the most sensitive method for measuring long-lived radionuclides in natural samples.

**Objective**

Students learn the basic concepts of Accelerator Mass Spectrometry. Based on the underlying physics of ion matter interaction they learn the measurement methods and interpretation of the results for most of the important AMS radionuclides, e.g. radiocarbon (14C), the cosmogenic radionuclides 10Be, 26Al, 36Cl, and anthropogenic nuclides 129I, 236U and other actinides.

**Content**

- Ion optics and ion acceleration.
- Mass separation, molecular destruction and isobar separation.
- Ion detection and identification.

The measurement methods for all the important radionuclides and the interpretation of their results are discussed on a few examples from the application:

- 14C – radiocarbon dating and environmental studies
- 10Be, 26Al, 36Cl – cosmogenic dating and ice core research
- 129I, 236U, actinides – anthropogenic tracers in the environment
- 14C, 41Ca – biomedical studies
- 60Fe, 244Pu – astrophysics

**Alternative methods**: ICP-MS, RIMS, ATTA

A visit to the Tandem accelerator and AMS facilities at ETH Hönggerberg is organized as part of lectures and exercises.

**Lecture notes**

Lecture notes will be distributed in pdf

**402-0715-00L Low Energy Particle Physics**

- **Number**: 402-0715-00L
- **Title**: Low Energy Particle Physics
- **Type**: W
- **ECTS**: 6 credits
- **Hours**: 2V+1U
- **Lecturers**: A. S. Antognini, D. Ries

**Abstract**

Low energy particle physics provides complementary information to high energy physics with colliders. In this lecture, we will concentrate on flagship experiments which have significantly improved our understanding of particle physics today, concentrating mainly on precision experiments with neutrons, muons and exotic atoms.

**Objective**

You will be able to present and discuss:

- the principle of the experiments
- the underlying technique and methods
- the context and the impact of these experiments on particle physics
Low energy particle physics provides complementary information to high energy physics with colliders. At the Large Hadron Collider one directly searches for new particles at energies up to the TeV range. In a complementary way, low energy particle physics indirectly probes the existence of such particles and provides constraints for "new physics", making use of high precision and high intensities.

Besides the sensitivity to effects related with new physics (e.g. lepton flavor violation, symmetry violations, CPT tests, search for electric dipole moments, new low mass exchange bosons etc.), low energy physics provides the best test of QED (electron g-2), the best tests of bound-state QED (atomic physics and exotic atoms), precise determinations of fundamental constants, information about the CKM matrix, precise information on the weak and strong force even in the non-perturbative regime etc.

Starting from a general introduction on high intensity/high precision particle physics and the main characteristics of muons and neutrons and their production, we will then focus on the discussion of fundamental problems and ground-breaking experiments:

- search for rare decays and charged lepton flavor violation
- electric dipole moments and CP violation
- spectroscopy of exotic atoms and symmetries of the standard model
- what atomic physics can do for particle physics and vice versa
- neutron decay and primordial nucleosynthesis
- atomic clock
- Penning traps
- Ramsey spectroscopy
- Spin manipulation
- neutron-matter interaction
- ultra-cold neutron production
- various techniques: detectors, cryogenics, particle beams, laser cooling....

**Literature**

- Golub, Richardson & Lamoreaux: "Ultra-Cold Neutrons"
- Rauch & Werner: "Neutron Interferometry"
- Carlile & Willis: "Experimental Neutron Scattering"
- Byrne: "Neutrons, Nuclei and Matter"
- Klappdor-Kleingrothaus: "Non-Accelerator Particle Physics"

**Abstract**

Theoretical basis and selected experiments to determine the properties of neutrinos and their interactions (mass, spin, helicity, chirality, oscillations, charge-parity violation, interactions with leptons and quarks) and implications on physics beyond the Standard Model of elementary particles as well as on Cosmology.

**Objective**

Critically analyze and elaborate the neutrino production and detection techniques. Derive the theory of neutrino scattering and analyze its implications in neutrino experiments. Analyze the phenomenology of neutrino oscillations and its implication on the physics Beyond the Standard Model of particles. Derive the main concepts of the theory of neutrino masses within and beyond the Standard Model of particles and analyze the experimental techniques related to the measurement of the neutrino masses. Describe the role of neutrinos in Cosmology and make connections with current and future neutrino experiments. Review the experimental configurations and analyze the challenges in searches for leptonic Charge-Parity symmetry violation and the measurement of the neutrino mass hierarchy.

**Content**

1. Introduction to Neutrinos and Neutrino Sources;
2. Neutrino Detectors
3. Neutrino Interactions
4. Neutrino Oscillations
5. Nature of Neutrino masses
6. Neutrinos in Cosmology
7. Search for leptonic Charge Parity violation and precision measurement of the neutrino oscillation probability

**Literature**

- K.Zuber, *“Neutrino Physics” CRC Press 2020*

**Competencies**

- Subject-specific Competencies: Concepts and Theories assessed
- Method-specific Competencies: Analytical Competencies assessed
- Personal Competencies: Critical Thinking assessed

**Prerequisites / notice**

Einführung in die Kern- und Teilchenphysik / Introduction to Nuclear- and Particle-Physics
Lecture notes
Slides are handed out regularly

Literature
H. Kolosinski and N. Wermes, "Particle Detectors: Fundamentals and Applications".
C. Grupen and B. Schwartz, "Particle Detectors".
G. F. Knoll, "Radiation Detection and Measurements".

Competencies

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402-0777-00L

**Title**
Particle Accelerator Physics and Modeling I

**Module Code**
W

**ECTS Credits**
6

**Hours**
2V+1U

**Lecturers**
A. Adelmann

**Abstract**
This is the first of two courses, introducing particle accelerators from a theoretical point of view and covers state-of-the-art modelling techniques.

**Objective**
You obtain a theoretical understanding of the building blocks of particle accelerators. Modern numerical analysis tools allows you to model state-of-the-art particle accelerators. We will develop a Julia simulation tool (JuliAccel.jl) that reflects the theory from the lecture.

**Content**
Here is the rough plan of the topics, however the actual pace may vary relative to this plan.

- Recap of Relativistic Classical Mechanics and Electrodynamics
- Building Blocks of Particle Accelerators
- Lie Algebraic Structure of Classical Mechanics and Application to Particle Accelerators
- Symplectic Maps & Analysis of Maps
- Symplectic Particle Tracking
- Collective Effects
- Linear & Circular Accelerators

**Lecture notes**
Lecture notes

**Prerequisites / notice**
Physics, Computational Science (RW) at MSc. Level
In exceptional cases students at BSc level can attend.
This lecture is also suited for PhD. students

**Competencies**
Subject-specific Competencies

402-0851-00L

**Title**
QCD: Theory and Experiment

**Module Code**
W

**ECTS Credits**
3

**Hours**
3G

**Lecturers**
A. Gehrmann-De Ridder, R. Wallny

**Abstract**
An introduction to the theoretical aspects and experimental tests of QCD, with emphasis on perturbative QCD and related experiments at colliders.

**Objective**
Knowledge acquired on basics of perturbative QCD, both of theoretical and experimental nature. Ability to perform simple calculations of perturbative QCD, as well as to understand modern publications on theoretical and experimental aspects of perturbative QCD.

**Content**
QCD Lagrangian and Feynman Rules
QCD running coupling
Parton model
DGLAP
Basic processes
Experimental tests at lepton and hadron colliders
Measurements of the strong coupling constant

**Literature**
2) R. K. Ellis, W. J. Stirling, B. R. Webber: "QCD and Collider Physics" (Cambridge Monographs on Particle Physics, Nuclear Physics & Cosmology)

**Prerequisites / notice**
Will be given as block course, language: English.
For students of both ETH and University of Zurich.

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### Selection: Theoretical Physics

**Number**
401-2813-00L

**Title**
Programming Techniques for Scientific Simulations I

**Module Code**
W

**ECTS Credits**
5

**Hours**
4G

**Lecturers**
R. Käppeli

**Abstract**
This lecture provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ programming techniques and scientific software libraries. Based on an overview over the hardware components of PCs and supercomputer, optimization methods for scientific simulation codes are explained.

**Objective**
The goal of the course is that students learn basic and advanced programming techniques and scientific software libraries as used and applied for scientific simulations.

**Literature**
M. Tinkham "Introduction to Superconductivity"
P. G. de Gennes "Superconductivity Of Metals And Alloys"
A. A. Abrikosov "Fundamentals of the Theory of Metals"
J.B. Keterson & S.N. Song "Superconductivity"
H. Stolz "Supraleitung" (German)
K. Fossheim & A. Sudbo "Superconductivity: Physics and Applications"

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**Number**
402-0580-00L

**Title**
Superconductivity

**Module Code**
W

**ECTS Credits**
6

**Hours**
2V+1U

**Lecturers**
V. Geshkenbein

**Abstract**

**Objective**
Introduction to the most important concepts of superconductivity both on phenomenological and microscopic level, including experimental and theoretical aspects.

**Content**
This lecture course provides an introduction to superconductivity, covering both experimental as well as theoretical aspects. The following topics are covered:
Basic phenomena of superconductivity: thermodynamics, electrodynamics, London and Pippard theory; Ginsburg-Landau theory: spontaneous symmetry breaking, flux quantization, properties of type I and II superconductors; mixed phase, microscopic BCS theory: electron-phonon mechanism, Cooper pairing, coherent state, quasiparticle spectrum, thermodynamics and response to magnetic fields; Josephson effect, superconducting quantum interference devices (SQUID) and other applications.

**Lecture notes**
Lecture notes and additional materials are available.

**Literature**
M. Tinkham "Introduction to Superconductivity"
Quantum Simulations of Gauge Theories

Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical systems. Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

Content

Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

Lecture notes and slides are available online and will be distributed if desired.

Literature

Lecture notes and references are included in the lecture notes.

Prerequisites / notice

Lecture notes and slides are available online and will be distributed if desired.

Competencies

Subject-specific Competencies

Concepts and Theories

Method-specific Competencies

Analytical Competencies

Literature

402-0836-16L
Quantum Simulations of Gauge Theories

Does not take place this semester.

Abstract

Divided into three parts, the course introduces various aspects of lattice quantum field theory (QFT), gauge symmetries, quantum simulators, and implementation schemes. Other than highlighting the strengths and weaknesses of the lattice formulation of QFTs suitable for Monte Carlo simulations, the course discusses practical realization of quantum simulators for gauge theories.

Objective

After acquiring the foundations on lattice formulation of gauge theories, and challenges of conventional Monte Carlo simulation approaches, the students will learn about different strategies for quantum simulation of gauge theories and their implementation on digital and analog quantum devices.

Content

1. Background and Motivation

1.1. From Quantum Field Theories to Lattice field theories;
1.2. Lattice Gauge Theories - Lagrangian formulation, gauge symmetries, observables;
1.3. Monte Carlo simulations, sign problems, and complex actions.

2. Road-map for Quantum Simulation of Gauge Theories

2.1. Hamiltonian formulation, Wilson's formulation, and the infinite Hilbert spaces;
2.2. Finite Hilbert spaces: Z(N) gauge theories. Dualizing the Ising model and relation with the toric code;
2.3. Finite Hilbert spaces: Quantum link models for Abelian gauge theories;
2.4. Finite Hilbert spaces: Quantum link models for non-Abelian gauge theories;
2.5. Exploring the physics of gauge theories - phases, dynamics, and thermalization;

3. Quantum Simulation Approaches and Platforms

3.1. Digital vs. analog quantum simulations;
3.2. Proposals for simulations of gauge theories, realization, and perspectives.
### Effective Field Theories for Particle Physics

**402-0845-61L**

**Effective Field Theories for Particle Physics**

- **W 6 credits 2V+1U**
- **A. Signer**

**Abstract**

The focus of the course is on Effective Field Theories (EFTs) and their interplay with dispersion theory. These topics will be discussed both in general terms and with specific phenomenological applications in the context of physics beyond the Standard Model, effective description of the weak interaction, as well as the description of non-perturbative strong interaction at low energies.

**Objective**

This course covers the basic concepts of effective field theories (EFTs) and dispersion theory. We will start by introducing the core concept of constructing EFTs and apply them to the low-energy description of the weak interaction and the effective description of heavy physics beyond the Standard Model.

In the next part of the course, we will discuss Chiral Perturbation Theory (ChPT), the low-energy effective theory of Quantum Chromodynamics (QCD). We will briefly discuss the application of this concept to describe a class of theories beyond the SM in which the SM Higgs arises as a composite state of a new confining sector.

The second focus of the course is on dispersion theory and its interplay with EFTs. We will discuss how to make use of the constraints from unitarity of the S-matrix and analyticity of scattering amplitudes, in order to extend the range of validity of the theoretical description compared to pure EFT methods. We will also discuss how to obtain constraints on EFT parameters from unitarity and analyticity. We will discuss the application of these methods both in the context of low-energy strong interaction and physics beyond the Standard Model.

**Content**

- Introduction to Effective Field Theories
- Decoupling and matching
- Renormalization group resummation
- The Standard Model Effective Field Theory (SMEFT)
- Chiral Lagrangians
- Unitarity of the S-matrix
- Analyticity and dispersion relations

**Prerequisites / notice**

QFT-I (mandatory) and QFT-II (highly recommended)

### Strongly Correlated Systems in Atomic and Condensed Matter Physics

**402-0865-70L**

**Strongly Correlated Systems in Atomic and Condensed Matter Physics**

- **W 8 credits 3V+1U**
- **E. Demler**

**Abstract**

This course will review recent progress in realizing strongly correlated many-body systems with ultracold atoms. Both theory and experiments will be discussed with an emphasis on the connection between the physics of ultracold atoms and correlated electron systems. The course will explore unique features of ultracold atoms such as dynamical control of Hamiltonians and single atom resolution.

**Objective**

This course provides the background needed to understand current research in ultracold atoms. Lecture material is complemented by homework problems that give hands-on experience with the concepts introduced in class, as well as a final project that involves reviewing an influential paper in a relevant research area and presenting a summary in class.

**Content**

Subjects covered in this class include: Bose-Einstein condensation of weakly interacting atomic gases; analogue gravity with BEC; spinor condensates; noninteracting atoms in optical lattices and probes of band structure; state dependent lattices and synthetic gauge fields; Bose Hubbard model; quantum magnetism with ultracold atoms in optical lattices; quantum noise measurements as a probe of many-body states; Feshbach resonance; fermion pairing close to Feshbach resonance; the BCS-BEC crossover; polarons in systems of bosonic and fermionic ultracold atoms; fermionic Hubbard model; realizing and probing topological states with ultracold atoms; one dimensional systems; SU(N) magnetism and Kondo physics with alkaline-earth atoms; systems with long range interactions; many body localization; superradiance and Dicke quantum phase transitions in optical cavities for bosonic and fermionic atoms.

**Lecture notes / notice**

Lecture notes will be handed out (in English).

**Prerequisites / notice**

This course requires knowledge of MSc level Quantum Mechanics and Statistical Physics. Prior knowledge of atomic and solid state physics is useful but not necessary.

### Introduction to Quantum Electrodynamics

**402-0870-00L**

**Introduction to Quantum Electrodynamics**

- **W 6 credits 2V+1U**
- **A. Lazopoulos**

**Abstract**

This course provides a pedagogical introduction to Quantum Electrodynamics.

**Objective**

Students will be introduced to the theory of Quantum Electrodynamics, and the use of Feynman diagrams to arrive at theoretical predictions for phenomena related to the interaction of light and matter. The course is designed to complement Quantum Field Theory I for those students with a special interest in theoretical elementary particle physics.

**Content**

The course will cover:
- an introduction to QED as the quantum theory of interactions of light and matter.
- Feynman rules for QED
- Amplitudes and cross sections for simple processes in QED
- Gauge invariance and the Ward identity
- Ultraviolet singularities and Renormalization
- Infrared singularities and their cancelation
- The Uehling potential and the Lamb shift
- Anomalous magnetic moments

**Lecture notes / Literature**

Will be provided at the Moodle site for the course.

**Competencies**

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**402-0883-63L**

**Symmetries in Physics**

- **W 6 credits 3G**
- **G. M. Graf**

**Abstract**

The course gives an introduction to symmetry groups in physics. It explains the relevant mathematical background (finite groups, Lie groups and algebras as well as their representations), and illustrates their important role across modern physics.

**Objective**

The aim of the course is to give a self-contained introduction into finite group theory as well as Lie theory from a physicists point of view. Abstract mathematical constructions will be illustrated with examples from physics.
Content
Finite group theory, including representation theory and character methods; applications to crystallography and solid state physics. The symmetric group and the structure of its representations; applications to identical particles. Clifford algebras; application to relativistic wave equations equations. Simple Lie algebras and their finite-dimensional representations. Description of representations of SU(N) in terms of Young diagrams; applications in particle physics.

Competencies

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402-0886-00L QCD and Scattering Amplitudes W 6 credits 2V+1U A. Gehrmann-De Ridder

Abstract
The course presents the quantum field theory of the strong interaction (quantum chromodynamics, QCD) and discusses its applications to particle physics observables.

Objective
The course aims to familiarize the students with the concepts and applications of QCD and to introduce them to modern techniques for computations in QCD.

Content
Content:
- Review of non-Abelian gauge theories
- Renormalization of QCD and running coupling constant
- Jet observables in e+e- annihilation
- QCD at lepton-proton colliders
- Multiparticle production
- Spinor-helicity formalism
- Perturbation theory techniques: loops and phase space

Compétences

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402-0897-00L Introduction to String Theory W 6 credits 2V+1U J. Brödel

Abstract
String theory is an attempt to quantise gravity and unite it with the other fundamental forces of nature. It is related to numerous interesting topics and questions in quantum field theory. In this course, an introduction to the basics of string theory is provided.

Objective
Within this course, a basic understanding and overview of the concepts and notions employed in string theory shall be given. More advanced topics will be touched upon towards the end of the course briefly in order to foster further research.

Content
- Mechanics of point particles and extended objects
- String modes and their quantisation; higher dimensions, supersymmetry
- Critical dimension and no-ghost theorem
- D-branes, T-duality
- Two-dimensional conformal field theories

Literature
M.B. Green, J.H. Schwarz, E. Witten, Superstring Theory I, CUP (1987).

Prerequisites / notice
Recommended: Quantum Field Theory I (in parallel)

402-0352-00L Astronomical Observations and Instrumentation W 6 credits 2V+1U L. Harra

Abstract
Astronomical techniques and observing strategies are presented with a particular emphasis on currently available professional telescopes of the European Southern Observatory.

Objective
The course shall provide a basic understanding of the potential and limitation of different types of modern astronomical observations for early career researchers. The course will present technical aspects which are important to prepare, to carry out and to calibrate different types of astronomical measurements: photometry, spectroscopy, astrometry, polarimetry and others. Many practical examples will be discussed including methods for the detection of physical samples of cosmic dust. Also scientific aspects of instrumental projects and observational programs are addressed. An opportunity to contribute to solar spacecraft operations will be available during the course.

Content
1. Introduction: research projects in astronomical observations
2. Observables: electromagnetic radiation, particles
3. Optical telescopes: Optics, types, mechanical concepts, examples
4. Detectors: CCDs, IR detectors, basic data reduction steps
5. Photometry: signal extraction, calibration, faint sources, etc.
6. Spectroscopy: spectrographs, calibration, spectral features
7. Introduction to solar space instrumentation
8. Space observations of cosmic dust: introduction, remote sensing, in situ instruments, sample return, calibration, data analysis and practical examples
9. Speckles and adaptive optics: atmosphere, AO-systems
10. Polarimetry: measuring principles
11. Interferometry

Lecture notes
Notes will be distributed.

Literature

402-0355-00L Planet Formation W 4 credits 2V J. Szulágyi
This lecture focuses on our home planet - Earth - from an interdisciplinary perspective. As the search for habitable - and potentially even

The field of space research and exploration is intrinsically interdisciplinary. Cutting edge space activities are dominated by an interplay

Overview the state of the art planet- and moon formation models and identify open questions in the field. Understanding the formation

Lecture Series about selected topics of space research and exploration consisting of individual talks given by different leading experts from

No prerequisites.
Max. 20 participants.

Concepts and Theories
Techniques and Technologies

Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving

Communication
Cooperation and Teamwork
Self-presentation and Social Influence
Sensitivity to Diversity

Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Attending students will

- experience the interdisciplinarity of space research and exploration spanning physics, engineering, geosciences, biology and more
- get familiar with the Swiss space research and industry landscape
- enhance their communication skills by broadening their research horizon
- have the opportunity for direct learning by posing questions to experts

The field of space research and exploration is intrinsically interdisciplinary. Cutting edge space activities are dominated by an interplay

between the scientifically desirable and the technologically possible. The ‘Lecture Series: Space Research and Exploration’ aims to shed

light on key questions engaged by leading scientists and engineers today. It consists of weekly lectures, given by different speakers with

vast experience in their respective field (e.g., Human Spaceflight, System Engineering of Spacecraft, Space Life Sciences, Space-based

astrophysics). Subsequent to the talk, the student will have the opportunity to deepen their understanding by asking questions to the

presenter in a moderated Q&A.

Confirmed speakers will be announced by the start of the semester (see lecture from last year for previous speakers).

Attending students will

- understand Earth place in the cosmos
- learn tools to discern the history of Earth and other planets
- explore the origin and co-evolution of Earth and life
- put Earth in context with extrasolar planets

This lecture focuses on our home planet - Earth - from an interdisciplinary perspective. As the search for habitable - and potentially even

inhabited - extrasolar planets is one of the most dynamic research fields in modern astrophysics, understanding what makes a planet

habitable is a topic of increasing importance; and a highly interdisciplinary topic. In broad brushes, this lecture will discuss the building

blocks of planetary systems and their formation, how we can learn about the history of Earth and other planets, what major epochs we can

identify over the course of Earth’s 4.5 billion year history, when life arose on Earth and what impact it had on Earth’s evolution, how the

future Earth might look like, and - last but certainly not least - how we can search for an Earth-like planet in our cosmic neighbourhood and

what our chances are to be successful.

Data: 15.06.2024 12:39   Autumn Semester 2024   Page 2064 of 2653
Abstract

Our understanding of the universe has made great progress recently thanks to the combination of several cosmological probes such as the cosmic microwave background, galaxy clustering, gravitational lensing, and supernovae. After a review of cosmology, this course will cover the physics of these different probes along with their application, combination and use to measure cosmological parameters.

Objective

The goal of this course is to provide an understanding of the physics, application and combination of cosmological probes, and highlight current research topics.

Prerequisites

Credits or current enrollment in Astrophysics I and II is recommended but not required.

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>W</th>
<th>Credits</th>
<th>V+U</th>
<th>Instructor</th>
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<tr>
<td>402-0398-00L</td>
<td>Cosmic Dust in the Solar System: From Science Case to Mission Design</td>
<td></td>
<td>3</td>
<td>1V+1U</td>
<td>V. J. Sterken</td>
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<td>Abstract</td>
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<td>Slides will be provided before each lecture.</td>
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<td>This course provides students with a basic understanding of the science of cosmic dust in the solar system and how to measure it with space-based satellites and instrumentation. The lectures include the physical processes of both interplanetary and interstellar dust, trajectory simulations (i.e. orbital dynamics), in situ measurement techniques, and mission design aspects. At the end of the course, students are able to classify the different types of dust in the solar system, and to relate them to their sources, sinks, their importance for planetary science and astronomy, physical processes, and appropriate measurement techniques. They will be able to simulate dust trajectories and use them to gain insight in how orbital dynamics and the space environment shape them. Students can design a basic concept of a space mission for dust measurements. The skills taught in this course will be useful to students in a broader way for planetary sciences.</td>
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<td>Interplanetary dust (freely available online)</td>
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<td></td>
<td>1. Introduction, course outline, historical notes, interstellar and interplanetary dust, dust in the solar system, sources, sinks, importance for science</td>
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<td>2. Dust instrumentation and observables: ground-based, space-based and sample return techniques, calibration of dust instruments in the lab</td>
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<td>3. Dust dynamics: recap basic aspects of orbital dynamics, the SPICE toolkit, types of orbits</td>
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<td>4. Dust dynamics: space environment, dust processes and implications (e.g. in the early solar system), dust charging, consequences for dynamics, comparison with spacecraft dynamics</td>
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<td>5. Dust models and dust data analysis: types of models and their limitations, data analysis</td>
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<td>6. Mission design aspects: orbits, mission design limitations, advantages, disadvantages, instrument accommodation, example missions</td>
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<td>Cosmic dust from the laboratory to the stars (ETH Library)</td>
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<td>402-0713-00L Astro-Particle Physics I</td>
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<td>2V+1U</td>
<td>A. Biland</td>
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<td>See lecture home page: <a href="http://ihp-ix2.ethz.ch/AstroTeilchen/">http://ihp-ix2.ethz.ch/AstroTeilchen/</a></td>
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<td>This lecture gives an overview of the present research in the field of Astro-Particle Physics, including the different experimental techniques. In the first semester, main topics are the charged cosmic rays including the antimatter problem. The second semester focuses on the neutral components of the cosmic rays as well as on some aspects of Dark Matter.</td>
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<td>- experimental methods to measure cosmic ray particles over full energy range</td>
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</tbody>
</table>
**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed

**Social Competencies**
- Communication: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

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### 402-0738-10L Bayesian Statistical Methods and Data Analysis

#### Abstract
The course covers various data analysis methods using Bayesian statistics, with a focus on practical problem solving. We will go over a brief introduction to probability theory, Bayesian reasoning, and how to build a statistical model and compare it to data. The course builds towards analysing data from real astrophysical problems, using both classical statistical methods and machine learning.

#### Objective
The goal of this course is to introduce students to Bayesian statistics and prepare them to solve statistical inference problems in contemporary (astrophysics) research. After introducing Bayesian statistics and general methodology, the course focuses on building up a structured approach to analyse increasingly complex data and models. The methods are general and applicable beyond (astro)physics, however.

#### Content
Topics covered include:
- Review of probability theory:
  - Independence, joint and conditional probabilities
  - Univariate and multivariate probability distributions
  - Change of variables
- Bayesian statistics:
  - Bayes' theorem
  - Priors
  - Bayesian reasoning
  - Posterior distributions, model checking, and model comparison
- Tools for statistical inference:
  - Various sampling methods, such as Markov chain Monte Carlo (Metropolis Hastings, slice sampling, Hamiltonian Monte Carlo) and nested sampling
  - Simulation-based inference
  - PCA, bootstrap
  - Gaussian processes and Gaussian random fields
  - Machine learning and probabilistic programming

The lectures are accompanied with code examples, both to illustrate the covered topics and to demonstrate how the theoretical concepts can be implemented in practical computational inference problems.

#### Prerequisites / notice
Prior knowledge of probability theory and statistics would be useful but not required. Since most of the course makes use of computational methods, some knowledge of scientific computing with Python (e.g., numpy, scipy) will be assumed.

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### Selection: Further Electives

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0220-MSL</td>
<td>Extended Research Project</td>
<td>W</td>
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<td>Supervisors</td>
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</table>

This course can only be booked together with a research project (402-0218-MS). This extension is not available for the options Proseminars, Particle Physics at PSI, Medical Physics and Experimental Foundations of Particle Physics.

The extension must be booked at the same time as the research project.

**Abstract**
Extension of the Research Project

**Objective**
Students are enabled to:
- Expand their knowledge in a specific area of physics,
- Conduct a project (a) in a research laboratory or (b) on a specific topic of theoretical physics,
- Discuss their project results and conclusions in a team,
- Present their findings in written and oral form.

The extension allows for a more in-depth research experience.
402-0247-00L  Electronics for Physicists I (Analogue)  W  4 credits  2V+2P  G. Bison, W. Erdmann

Abstract
Passive components, linear networks, transmission lines, simulation of analog circuits, semiconductor components: diodes, bipolar and field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise, operational amplifiers, feedback and stability, oscillators, ADCs and DACs, introduction to CMOS technology

Objective
The lecture provides the basic knowledge necessary to understand, design and simulate analog electronic circuits. In the exercises, the concepts can be experienced in a hands-on manner. Every student has the opportunity to go through all steps of an electronic design cycle. Those include designing schematics, generating a printed circuit board layout, and the realization of a soldered prototype.

Content
Passive elements, linear complex networks, transmission lines, simulation of analog circuits (SPICE), semiconductor elements: diodes, bipolar and field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise in analog circuits, operational amplifiers, feedback and stability in amplifiers, oscillators, ADC’s and DAC’s, introduction in CMOS technology.

Prerequisites / notice
no prior knowledge in electronics is required

402-0737-00L  Energy and Sustainability in the 21st Century (Part I)  W  6 credits  2V+1U  P. Morf

Abstract
Part I of this course covers the energy-related topics in this two-semester course. The importance of energy to life and our modern culture is explored and placed in the perspective of the ongoing energy transition in the context of necessary and urgent decarbonization efforts. How much energy do we need and how can it be provided in a way that enables a sustainable existence?

Objective
Why is energy important for life, economy and our society?
How did energy use change over time? Which effects did these changes have on the environment?
What are the physical basics of energy technologies?
When, why and how did technology and science of energy come together?
What are the limits and benefits of all the various energy technologies?
How can different energy technologies be compared?
Can we understand the changes in the current energy systems?
How will the energy systems of the future look like?
How fast can we and should we enforce the current energy transition?
Which could be the overall guidelines for a working and sustainable energy system of the future?

Content
1. Introduction to Energy – what is it all about
2. Energy and making use of it – a short history of energy use and an overview on energy technologies
3. Coal, oil and natural gas – fossil fuels
4. Renewables I: Biomass, Hydropower, and Wind Energy – from traditional use to the modern concepts
5. Renewables II: Geothermal, Tidal power and Solar Technologies – new renewables to lead the change
6. Nuclear power, radioactivity and ultimate storage – the quest for a safe technology
7. Breeding and Nuclear Fusion – can it work at all?
8. Energy Storage – the need to increase capacity and for new technologies
9. Climate Change and Decarbonisation of the Energy Mix – how much time do we have?
11. Energy Systems – how everything can play together
12. Life Cycle Assessment of Energy Technologies – problems and possibilities
14. The Actual Energy Transition and Decarbonisation – How is your 2040, 2050?

Literature
The Physics of Energy, R.L. Jaffe, W. Taylor, 2018
Clean Disruption of Energy and Transportation, T. Seba 2014
Energy and Civilization: A History, V. Smil, 2018

Prerequisites / notice
Basics of Physics applied to Energy and Energy Technology.
Investigation on current problems (and possible solutions) related to the energy system and the environmental interactions.
Training of scientific and multi-disciplinary methods, approaches and their limits in the exercises and discussions.
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered

151-0409-00L
Multiphysics Modeling and Simulation
W 4 credits 2V+2U C. I. Roman

Abstract
This class introduces both theoretical and practical aspects related to the modeling and simulation of multiphysics systems. Students will learn how to set up multiphysics models systematically, and therefore reduce time-consuming trial-and-error. Comsol Multiphysics will be utilized to apply the concepts learned during the lectures to solve exercises.

Objective
As information technology continues its fast-paced evolution, solid-state devices and systems increase in complexity. Engineers and scientists are thus increasingly facing the need to model and simulate their problems numerically where analytic textbook solution cease to exist. Moreover, boundaries between traditional disciplines are harder to maintain, as a proper description of the system might involve phenomena from several domains. Examples include—but not limited to—mechatronics which relies on mechanical, electrical and electronic engineering, and transducers (sensors and actuators) which are by definition devices that convert signals from one physical domain to another. Simulation platforms such as Comsol Multiphysics have truly opened the way to easy multi-domain numerical simulation, offering tools that cover all operations from geometry definition, to meshing, to physics and boundary conditions setting to simulation and result post-processing and analysis in a unified, domain-independent fashion. However, this high degree of freedom has its price, as inexperienced users may face cryptic error messages, incomprehensible or even incorrect results. It is the mission of this course to show how to properly set up a problem by exposing some of the most common misconceptions and pitfalls in multiphysics modeling. Good practices will be taught that should simplify the modeling process and increase the likelihood of correct results. Examples will mainly come from the fields of mechanics (continuum solid mechanics), electromagnetism (electrostatics and conductive media), heat transfer (conductive not convective) and combinations of these domains.

Content
- Recap of ordinary and partial differential equations
- The Finite Element Method (and the Method of Lines)
- Numerical solvers
- Geometry simplification and discretization
- Continuous and discrete symmetries
- Approximate and simplified formulations; domains of applicability
- Boundary conditions and constraints
- Solution-appropriate discretization; hp-refinement, local/global adaptive meshing
- Ramping of nonlinearities and couplings
- Coupling and segregation of multiphysics

Lecture notes
Lecture handouts will be posted online.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

Selection: Neuroinformatics

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<td>227-1033-00L</td>
<td>Neuroromorphic Engineering I</td>
<td>W</td>
<td>6 credits</td>
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<td>T. Deibrück, G. Indiveri, S.-C. Liu, M. Payvand</td>
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</table>

Registration in this class requires the permission of the instructors. Class size will be limited to available lab spots. Preference is given to students that require this class as part of their major.

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module IN404 at UZH.
Please mind the ETH enrolment deadlines for UZH students: https://ethz.ch/en/studies/non-
Understanding the functional chain from primary physical effects of ionizing radiation to clinical radiation effects. Dealing with dose as a quantitative measure of medical exposure. Getting familiar with methods to generate ionizing radiation in medicine and learn how they are applied for medical purposes. Eventually, the lecture aims to show the students that medical physics is a fascinating and evolving discipline fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.

#### Selection: Medical Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0341-00L</td>
<td>Medical Physics I</td>
<td>W</td>
<td>6</td>
<td>2+1U</td>
<td>P. Manser</td>
</tr>
<tr>
<td>402-0674-00L</td>
<td>Physics in Medical Research: From Atoms to Cells</td>
<td>W</td>
<td>6</td>
<td>2+1U</td>
<td>B. K. R. Müller</td>
</tr>
</tbody>
</table>

A script will be provided.

For students of the MAS in Medical Physics (Specialization A) the performance assessment is offered at the earliest in the second year of the studies.

Concepts and Theories assessed
Techniques and Technologies assessed
Image Guided Medical Interventions

G. Fattori

Physical and chemical principles:

- The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

- As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

- The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

- High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

- Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

- Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

- X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

<table>
<thead>
<tr>
<th>465-0970-00L</th>
<th>Image Guided Medical Interventions</th>
<th>W</th>
<th>6 credits</th>
<th>2V+1U</th>
<th>G. Fattori</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Computer assistance and robotics have entered many fields of interventional medicine, shaping the way high-precision procedures are performed today. In this lecture series, we will present the methods and technologies used in image-guided radiotherapy, from the use of medical images to model the patient's anatomy to intraoperative navigation and registration.</td>
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<tr>
<td>Objective</td>
<td>Upon completion of the course, students are able to explain the methods and technologies for image guidance and stereotactic radiotherapy. In particular, they are able to design the calibration of in-room imaging solutions and other navigation systems to verify and correct patient position in high-precision radiotherapy. In addition, they are familiar with common tools used in medical image processing research.</td>
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<tr>
<td>Content</td>
<td>Basics of imaging and image processing for IGRT:</td>
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<tr>
<td></td>
<td>* 3D/4D imaging.</td>
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<td></td>
<td>* Segmentation (thresholding, region growing and similar).</td>
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<tr>
<td></td>
<td>* Filtering (morphological filters and similar fundamentals).</td>
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<td></td>
<td>* Modelling and rendering of volumes and surfaces.</td>
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<td></td>
<td>* Image registration.</td>
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<td></td>
<td>* Conventions for position and orientation representation.</td>
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<td>Technologies and methods for localisation and navigation:</td>
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<td></td>
<td>* Reference systems mapping.</td>
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<td></td>
<td>* Kinematic of a robotic treatment couch.</td>
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<tr>
<td></td>
<td>* Optical tracking systems, calibration and use.</td>
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<tr>
<td></td>
<td>* Registration of points and surfaces.</td>
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<td></td>
<td>* In-room imaging and geometry calibration of X-ray systems.</td>
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<td></td>
<td>* 2D/3D and 3D/3D registration.</td>
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<td></td>
<td>* Organ motion.</td>
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<td>Technologies and methods for on-line treatment verification</td>
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<td></td>
<td>* In-room imaging for verification of proton therapy treatment</td>
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<tr>
<td>Selection: Environmental Physics</td>
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</table>

- If you like playing with medical imaging and computer vision tools, you could be interested in this course.

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-1239-00L</td>
<td>Aerosols I: Physical and Chemical Principles</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>M. Gysel Beer, D. Bell, E. Weingartner</td>
</tr>
<tr>
<td>Abstract</td>
<td>Aerosols I deals with basic physical and chemical properties of aerosol particles. The importance of aerosols in the atmosphere and in other fields is discussed.</td>
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<tr>
<td>Objective</td>
<td>Physical and chemical principles:</td>
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<td></td>
<td>- know the processes and physical laws of aerosol dynamics.</td>
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<td>- understand the thermodynamics of phase equilibria and chemical equilibria.</td>
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<td>- know the photo-chemical formation of particulate matter from inorganic and organic precursor gases.</td>
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<td>Experimental methods: The students...</td>
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<td>- know the most important chemical and physical measurement instruments.</td>
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<td>- understand the underlying chemistry and physics.</td>
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<td>Environmental impacts: The students...</td>
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<td></td>
<td>- know the major sources of atmospheric aerosols, their chemical composition and key physical properties.</td>
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<td>- know the most important climate impacts of atmospheric aerosols.</td>
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<td></td>
<td>are aware of the health impacts of atmospheric aerosols.</td>
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<tr>
<td>Lecture notes</td>
<td>The students are aware of the health impacts of atmospheric aerosols.</td>
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<tr>
<td></td>
<td>- know the major sources of atmospheric aerosols, their chemical composition and key physical properties.</td>
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<td></td>
<td>- know the most important climate impacts of atmospheric aerosols.</td>
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<td>are aware of the health impacts of atmospheric aerosols.</td>
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</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2070 of 2653
The course starts with introducing selected concepts of thermodynamics for atmospheric processes: The students learn the concept of assessed
fostered
Subject-specific Competencies fostered
Concepts and Theories fostered
Analytical Competencies fostered
Media and Digital Technologies fostered
Problem-solving fostered
Project Management fostered
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

701-0475-00L Atmospheric Physics

W 3 credits 2G U. Lohmann

Abstract
This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation, especially prediction of showers and severe convective storms, and optical phenomena.

Objective
Students are able
- to explain the mechanisms of convective storm formation using knowledge of thermodynamics and cloud microphysics.
- to interpret precipitation radar images.
- to evaluate the significance of clouds and aerosol particles for artificial weather modification.

In the course "Atmospheric Physics", the competencies of process understanding, system understanding and data analysis & interpretation are taught, applied and examined. Measurement methods are taught as well.

Content
The course starts with introducing selected concepts of thermodynamics for atmospheric processes: The students learn the concept of the thermodynamic equilibrium and derive the Clausius-Clapeyron equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Students also learn to use thermodynamic charts (tephigrams) and to identify cloud base, cloud top, available convective energy in radiosonde ascents. Atmospheric mixing processes are introduced as a basis for fog formation. The concept of an air parcel is used to understand convection.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

With these basics, the different forms of precipitation (convective vs. stratiform) are discussed and how they can be identified in radar images. Students will also learn under which conditions severe convective storms (especially supercells with tornados) can form.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

Lecture notes
Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=20400

An electronic version of this book can be obtained via the ETH library.

Prerequisites / notice
We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments.

There is a additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.

701-1221-00L Dynamics of Large-Scale Atmospheric Flow

W 4 credits 2V+1U H. Wernli, J. Riboldi

Abstract
This lecture course is about the fundamental aspects of the dynamics of extratropical weather systems (quasi-geostrophic dynamics, potential vorticity, Rossby waves, baroclinic instability). The fundamental concepts are formally introduced, quantitatively applied and illustrated with examples from the real atmosphere. Exercises (quantitative and qualitative) form an essential part of the course.

Objective
Understanding of dynamic processes of large-scale atmospheric flow and their mathematical-physical formulation.
Content

Dynamical Meteorology is concerned with the dynamical processes of the earth's atmosphere. The fundamental equations of motion in the atmosphere will be discussed along with the dynamics and interactions of synoptic system - i.e. the low and high pressure systems that determine our weather. The motion of such systems can be understood in terms of quasi-geostrophic theory. The lecture course provides a derivation of the mathematical basis along with some interpretations and applications of the concept.

Lecture notes
Dynamics of large-scale atmospheric flow

Literature
- Pichler H., Dynamik der Atmosphäre, Bibliographisches Institut, 456 pp. 1997

Prerequisites / notice
Physics I, II, Environmental Fluid Dynamics

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Social Competencies
- Cooperation and Teamwork

Personal Competencies
- Creative Thinking
- Critical Thinking

651-4053-05L Boundary Layer Meteorology

Abstract
The Planetary Boundary Layer (PBL) constitutes the lower part of the atmosphere, is characterized by turbulent mixing and ensures the exchange of energy, mass and momentum between the Earth's surface and the atmosphere. The course provides the theoretical background for understanding the structure and dynamics of the PBL. Idealized concepts are reviewed and contrasted to real-world applications.

Objective
Students are able to:
- Name the basic approaches needed to describe planetary boundary layer flows and associated turbulent exchange processes.
- Apply these concepts to answer comprehension questions and solve simple problems related to the structure and dynamics of the PBL.
- Independently judge the applicability of learned concepts and tools to real-world situations.

Content

- Introduction
- PBL structure and stability
- Turbulence and turbulent transport
- Scaling and similarity theory
- Spectral characteristics
- Conservation equations in a turbulent flow
- Closure problem and closure assumptions
- Rough surfaces and the roughness sublayer
- Complex terrain

Lecture notes
available (i.e. in English)

Literature

Prerequisites / notice
Umwelt-Fluidynamik (701-0479-00L) (environment fluid dynamics) or equivalent and basic knowledge in atmospheric science

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Personal Competencies
- Creative Thinking

Selection: Mathematics

Number Title Type ECTS Hours Lecturers
401-3531-00L Differential Geometry I W 9 credits 4V+1U U. Lang

Abstract
Introduction to differential manifolds and differential geometry.

Introduce the language, tools, and basic results of differentiable manifolds, tensors, Riemannian geometry, and related geometric structures. Relate geometric intuition to formulas involving curvature, derivatives and tensors.

Objective
Learn to compute, describe, prove, and solve problems in the language of differential geometry.

Content
Submanifolds of $\mathbb{R}^n$, immersions, submersions, and embeddings, Sard's Theorem, abstract differentiable manifolds, charts, vector fields and flows, vector bundles, tensor fields, covariant derivatives, parallel transport, Riemannian metrics, geodesics, Riemann curvature tensor. Complete manifolds, Hopf-Rinow theorem. Many examples including curves, surfaces, hyperbolic space, $S^2$, the unit quaternions, the Gauss-Bonnet theorem, etc.
This following books were inherited from before. The only one I know is DoCarmo.

- Manfredo P. do Carmo: Differential Geometry of Curves and Surfaces
- S. Montiel, A. Ros: Curves and Surfaces
- S. Kobayashi: Differential Geometry of Curves and Surfaces
- Wolfgang Kühnel: Differentialgeometrie, Kurven-Flächen-Mannigfaltigkeiten
- Dennis Barden & Charles Thomas: An Introduction to Differential Manifolds

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Social Competencies</td>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
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<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
</tbody>
</table>

401-3461-00L Functional Analysis I

Abstract

Baire category; Banach and Hilbert spaces, bounded linear operators; basic principles: Uniform boundedness, open mapping/closed graph theorem, Hahn-Banach; convexity; dual spaces; weak and weak* topologies; Banach-Alaoglu; reflexive spaces; compact operators and Fredholm theory; closed graph theorem; spectral theory of self-adjoint operators in Hilbert spaces. Basics of Sobolev spaces.

Objective

Acquire a good degree of fluency with the fundamental concepts and tools belonging to the realm of linear Functional Analysis, with special emphasis on the geometric structure of Banach and Hilbert spaces, and on the basic properties of linear maps.

Literature

Recommended references include the following:


401-3601-00L Probability Theory

Abstract

Basics of probability theory and the theory of stochastic processes in discrete time

Objective

This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

measure theory formalism and probability theory, Dynkin's lemma and independence, convergence of series of independent random variables, law of large numbers, conditional expectation, martingale convergence theorems, uniform integrability, optional stopping theorem for martingales, the Bienaymé-Galton-Watson process and its R-number, convergence in distribution and the central limit theorem.
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- Measure theory formalism and probability theory
- Dynkin's lemma and independence
- Convergence of series of independent random variables
- Law of large numbers
- Conditional expectation
- Martingale convergence theorems
- Uniform integrability
- Optional stopping theorem for martingales
- The Bienaymé-Galton-Watson process and its R-number
- Convergence in distribution and the central limit theorem.

Lecture notes will be available in electronic form.

**Literature**


**Prerequisites / notice**

- Measure Theory
- Basic notions in probability theory (probability space, conditional probability, Borel-Cantelli, Dynkin Lemma, random variables, expectation, variance, law of large numbers).

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Personal Competencies**
  - Creative Thinking: assessed

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### 401-3621-00L Fundamentals of Mathematical Statistics

**Abstract**

In this course we study the basics of theoretical statistics. The course includes methods for designing estimators, confidence intervals and tests, and various ways to evaluate the accuracy of estimators, confidence intervals and tests. We consider optimality criteria such as admissibility and minimaxity, as well as Bayesian criteria. We will also present the asymptotic point of view.

**Objective**

The aim of this course is to gain insight into the main statistical ideas and concepts. The course considers classical low-dimensional models, with pointers towards today's highly complex models.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Problem-solving: assessed

- **Personal Competencies**
  - Creative Thinking: assessed

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### 401-7851-00L Theoretical Astrophysics (University of Zurich)

**Abstract**

This course covers the foundations of astrophysical fluid dynamics, the Boltzmann equation, equilibrium systems and their stability, the structure of stars, astrophysical turbulence, accretion disks and their stability, the foundations of radiative transfer, collisionless systems, the structure and stability of dark matter halos and stellar galactic disks.

**Content**

This course covers the foundations of astrophysical fluid dynamics, the theory of collisions and the Boltzmann equation, the notion of equilibrium systems and their stability, the structure of stars, the theory of astrophysical turbulence, the theory of accretion disks and their stability, the foundations of astrophysical radiative transfer, the theory of collisionless system, the structure and stability of dark matter halos and stellar galactic disks.

**Literature**

3. *Foundations of radiation hydrodynamics*, Dimitri Mihalas and Barbara Weibel-Mihalas
5. *Galactic Dynamics*, James Binney and Scott Tremaine

**Prerequisites / notice**

This is a full black board ad chalk experience for students with a strong background in mathematics and physics.

- **Prerequisites**:
  - Introduction to Astrophysics
  - Mathematical Methods for the Physicist
  - Quantum Mechanics
  - (All preferred but not obligatory)

- **Prior Knowledge**
  - Mechanics
  - Quantum Mechanics and atomic physics
  - Thermodynamics
  - Fluid Dynamics
  - Electrodynamics

---

### 401-7855-00L Computational Astrophysics (University of Zurich)

**Abstract**

This course covers the foundations of computer-based models of astrophysical systems, the physical equations behind them, and train such knowledge with simple examples of computer programmes.

**Prerequisites / notice**

This course is a full black board ad chalk experience for students with a strong background in mathematics and physics.

- **Prerequisites**:
  - Introduction to Astrophysics
  - Mathematical Methods for the Physicist
  - Quantum Mechanics
  - (All preferred but not obligatory)

- **Prior Knowledge**
  - Mechanics
  - Quantum Mechanics and atomic physics
  - Thermodynamics
  - Fluid Dynamics
  - Electrodynamics

---

### 401-7851-00L Theoretical Astrophysics (University of Zurich)

**Abstract**

This course covers the foundations of astrophysical fluid dynamics, the Boltzmann equation, equilibrium systems and their stability, the structure of stars, astrophysical turbulence, accretion disks and their stability, the foundations of radiative transfer, collisionless systems, the structure and stability of dark matter halos and stellar galactic disks.

**Content**

This course covers the foundations of astrophysical fluid dynamics, the theory of collisions and the Boltzmann equation, the notion of equilibrium systems and their stability, the structure of stars, the theory of astrophysical turbulence, the theory of accretion disks and their stability, the foundations of astrophysical radiative transfer, the theory of collisionless system, the structure and stability of dark matter halos and stellar galactic disks.

**Literature**

3. *Foundations of radiation hydrodynamics*, Dimitri Mihalas and Barbara Weibel-Mihalas
5. *Galactic Dynamics*, James Binney and Scott Tremaine

**Prerequisites / notice**

This course is a full black board ad chalk experience for students with a strong background in mathematics and physics.

- **Prerequisites**:
  - Introduction to Astrophysics
  - Mathematical Methods for the Physicist
  - Quantum Mechanics
  - (All preferred but not obligatory)

- **Prior Knowledge**
  - Mechanics
  - Quantum Mechanics and atomic physics
  - Thermodynamics
  - Fluid Dynamics
  - Electrodynamics

---

### 401-7855-00L Computational Astrophysics (University of Zurich)

**Abstract**

This course covers the foundations of computer-based models of astrophysical systems, the physical equations behind them, and train such knowledge with simple examples of computer programmes.

**Prerequisites / notice**

This course is a full black board ad chalk experience for students with a strong background in mathematics and physics.

- **Prerequisites**:
  - Introduction to Astrophysics
  - Mathematical Methods for the Physicist
  - Quantum Mechanics
  - (All preferred but not obligatory)

- **Prior Knowledge**
  - Mechanics
  - Quantum Mechanics and atomic physics
  - Thermodynamics
  - Fluid Dynamics
  - Electrodynamics
Content
1. Integration of ODE, Hamiltonians and Symplectic integration techniques, time adaptivity, time reversibility
2. Large-N gravity calculation, collisionless N-body systems and their simulation
3. Fast Fourier Transform and spectral methods in general
4. Eulerian Hydrodynamics: Upwinding, Riemann solvers, Limiters
5. Lagrangian Hydrodynamics: The SPH method
6. Resolution and instabilities in Hydrodynamics
7. Initial Conditions: Cosmological Simulations and Astrophysical Disks
8. Physical Approximations and Methods for Radiative Transfer in Astrophysics

Literature
Galactic Dynamics (Binney & Tremaine, Princeton University Press),
Computer Simulation using Particles (Hockney & Eastwood CRC press),
Targeted journal reviews on computational methods for astrophysical fluids (SPH, AMR, moving mesh)

Prerequisites / notice
Some knowledge of UNIX, scripting languages (see www.physik.uzh.ch/lectures/informatik/python/ as an example), some prior experience programming, knowledge of C, C++ beneficial

402-6394-00L Advanced Topics of Theoretical Cosmology (University of Zurich) W 4 credits 1V University lecturers

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: AST802

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html

Abstract
The course will cover a selection of advanced topics:
- Hamiltonian formulation of general relativity
- Quantum cosmology
- Cosmic Microwave Background
- Dark Matter and Dark Energy
- Nonlinear structure formation
- Galaxy clustering and large-scale structure
- Model selection and Bayesian inference in cosmology

Content
The topics in the course are as follows:
- spherical collapse model, Press-Schechter formalism, applications
- Standard Newtonian and Lagrangian Perturbation Theory
- galaxy bias
- nonlinear relativistic dynamics: ADM formalism
- inflationary models, effective field theory
- modification of gravity
- weak gravitational lensing, CMB anisotropies

Prerequisites / notice
Prerequisite: 402-0394-00L Theoretical Astrophysics and Cosmology
402-0831-67L Advanced Topics in General Relativity and Gravitational Waves (University of Zurich) W 6 credits 2V+1U

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH.

UZH Module Code: PHY529

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html

Abstract
The aim of this lecture is to discuss some advanced topics in general relativity, which are useful to understand the present research activities in the field. A list of possible topics is given below. A basic knowledge of general relativity is required (ideally having followed the lecture on General Relativity). The course is particularly suited for master and PhD students.

Objective
Is to be able to read and understand the original literature and the presently published papers in the field of the discussed advanced topics.
This might be also useful in view of doing afterwards a master thesis in the field of general relativity.

Content
Possible content:
- General relativistic stellar structure equations (Neutron stars)
- Tetrad formalism
- Spinors in GR
- Klein-Gordon & Dirac eqs. in GR
- Thermodynamics of black holes and Hawking radiation
- Topics in gravitational waves: GW generation by PN sources, GW from elliptic, hyperbolic binaries
- Tests of the equivalence principle

Competencies
Subject-specific Competencies
Concepts and Theories assessed

402-0810-70L Advanced Quantum Algorithms (University of Zurich) W 6 credits 2V+1U G. Mazzola

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: PHY582

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html

Abstract
The course treats selected families of quantum algorithms, currently the best candidates to achieve a practical quantum advantage over classical computation in physics, chemistry, optimization, sampling and machine learning.
Starting from the basics, quantum algorithms are introduced and their feasibility to solve real-world problems in science and industry is critically discussed.

Objective
The course aims to provide a balanced outlook of this transformative technology, discussing strengths and possible limitations of all discussed algorithms, especially in the context of concrete today and future hardware implementation.
After the course, students will have a clear understanding of the state-of-the-art of this field (i.e., the applications and algorithms amenable to quantum speedup, types of hardware, and quantum software).
The course content is devised to provide first-hand experience with quantum algorithms and stimulate critical thinking. The course will be instrumental for the student's career development in quantum technology and computational science, in academia or industry.
Content
Course content:
- Quantum gates and circuits basics
- Quantum annealing
- Hamiltonian simulations (Trotter, LCU, circuit decompositions)
- Mapping fermionic, bosonic operators to qubits
- Quantum phase estimation and applications
- Variational quantum algorithms (VQE, QAOA)
- Algorithms for sampling and search (Amplitude amplification, estimation, quantum walks, quantum enhanced Markov chains)
- Selected Quantum Machine learning algorithms
- Prospects for quantum advantage

Lecture notes
Lecture notes covering in detail all the course content will be provided.

Literature
- My lecture notes and references therein which are open-access will be more than enough to follow.
- For an introduction to quantum computing and information it could be useful to read specific chapters of Nielsen and Chuang book.

Prerequisites / notice
The course is designed to be self-contained concerning the basics: ie. the definition of quantum gates and circuits. Prior knowledge in quantum information science is beneficial but not required. Knowledge of basic statistical mechanics and quantum mechanics is required, specifically: linear algebra, spin operators, many-body wavefunctions, Hamiltonians in second quantisation formalism.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Analytical Competencies assessed
Problem-solving assessed

Method-specific Competencies
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed

Personal Competencies

402-0889-90L Geometry and Topology in Condensed Matter Physics (University of Zurich) W 6 credits 2V+2U T. Bzdusek

Abstract
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH.
UZH Module Code: PHY542

Objective
The objective of the course is to familiarize the student with selected techniques from differential geometry and algebraic topology, and with their applications in the field of condensed matter physics. The course is aimed at the graduate level and requires a basic knowledge of quantum mechanics, solid state physics, and elementary group theory. By the end of this course, the students will understand the relevance of these advanced mathematical tools to diverse physics problems, and they will become familiar with selected topics from recent research of classical and quantum topical matter.

Content
The covered mathematical topics include: homotopy groups, singular homology, Morse theory, Riemannian geometry, vector bundles, parallel transport, characteristic classes, cohomology theory, and Clifford algebras. The applications to condensed matter physics include: defects of order parameters, Van Hove singularities, flat energy bands, topological band theory, gauge fields, tenfold way classification, and topologically ordered phases.

Lecture notes
Lecture notes will be provided at the beginning of the semester.

Suggested complementary literature will be provided in the class.

General Electives
Students may choose General Electives from the entire course programme of ETH Zurich - with the following restrictions: courses that belong to the first or second year of a Bachelor curriculum at ETH Zurich as well as courses from GESS "Science in Perspective" are not eligible here. The following courses are explicitly recommended to physics students by their lecturers. (Courses in this list may be assigned to the category "General Electives" directly in myStudies. For the category assignment of other eligible courses keep the choice "no category" and take contact with the Study Administration (www.phys.ethz.ch/studies/study-administration.html) after having received the credits.)

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
052-0579-24L | Understanding Light | W | 2 credits | 2S | R. Barba, P. Anantha Murthy

Abstract
The seminar explores light from the perspectives of Physics and Art, opening up new dimensions for collaboration across disciplines by tackling questions such as: What is the origin and nature of light? How does it travel through space and time? How can it be made productive in an artistic sense and what, in turn, can artistic methodologies contribute to experimenting and thinking about light?

Objective
- Learn about the properties of light: intensities, phases, colors, and interactions with matter
- Explore optical effects: reflection, refraction, dispersion
- Learn to plan and carry out an art project based on research inputs from other sciences
- Enhance conceptual and interdisciplinary thinking in unusual set-ups
- Learn to cope with unforeseen results and make random events productive for the successful implementation of a project
- Fostering communication and presentation skills

Content
In this course, we will set a performative frame for experimentation and exploration.

Coupled with experiments in the Dep. of Physics, students will be introduced to concepts such as the origin of light and color, and the interpretation of the optical world that surrounds us to understand what actually gives rise to the effects we see everyday—from butterfly wings and autumn colors to the appearance of buildings and cities. In addition, we will perform practical experiments with basic optical components like lenses, mirrors, and prisms, in order to understand how they can be used to capture images. Inputs by guest lecturers (e.g. on light in photography, anthropology or urban landscapes) are planned. Students will be asked to present related topics.

At the end of the semester, the artistic experiments will be presented.

Prerequisites / notice
Max. number of participants: 15
Please send a short motivation letter (max. 300 words) to artpointandtime@arch.ethz.ch by 05 September 2024.
Renewable Energy Technologies

**Abstract**
The first part of the course covers the engineering aspects of the prominent renewable energy technologies: solar (PV and thermal), wind, hydro, geothermal and bioenergy. We further discuss energy storage, renewable transport and renewable heating & cooling. Finally, we introduce the key concepts of the economics of renewable energy and its integration in the energy system.

**Objective**
Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization.

**Lecture notes**
Lecture Notes containing copies of the presented slides.

**Prerequisites / notice**
Prerequisite: strong background on the fundamentals of engineering thermodynamics, equivalent to the material taught in the courses Thermodynamics I, II, and III of D-MAVT.

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Nonlinear Dynamics and Chaos I

**Abstract**

**Objective**
This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.

**Content**
1. Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
2. Near equilibrium dynamics: Linear and Lyapunov stability
3. Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations
4. Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
5. Time-dependent dynamical systems: Floquet theory, Poincaré maps, averaging methods, resonance.

**Lecture notes**
The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

**Prerequisites / notice**
- Prerequisites: Analysis, linear algebra and a basic course in differential equations.

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Embedded MEMS Lab

**Abstract**
Practical course: Students are introduced to the process steps required for the fabrication of MEMS (Micro Electro Mechanical System) and carry out the fabrication and testing steps in the clean rooms by themselves. Additionally, they learn the requirements for working in clean rooms. Processing and characterization will be documented and analyzed in a final report.

**Objective**
Students learn the individual process steps that are required to make a MEMS (Micro Electro Mechanical System). Students carry out the process steps themselves in laboratories and clean rooms. Furthermore, participants become familiar with the special requirements (cleanliness, safety, operation of equipment and handling hazardous chemicals) of working in the clean rooms and laboratories. The entire production, processing, and characterization of the MEMS is documented and evaluated in a final report.

**Content**
With guidance from a tutor, the individual silicon microsystem process steps that are required for the fabrication of an accelerometer are carried out:
- Photolithography, dry etching, wet etching, sacrificial layer etching, various cleaning procedures
- Packaging and electrical connection of a MEMS device
- Testing and characterization of the MEMS device
- Written documentation and evaluation of the entire production, processing and characterization
Methods like molecular dynamics, DSMC, lattice Boltzmann etc are being increasingly used by engineers all over and these methods require knowledge of kinetic theory and statistical mechanics which are traditionally not taught at engineering departments. The goal of this course is to give an introduction to ideas of kinetic theory and non-equilibrium thermodynamics with a focus on developing simulation algorithms and their realizations.

During the course, students will be able to develop a lattice Boltzmann code on their own. Practical issues about implementation and performance on parallel machines will be demonstrated hands on.

Central element of the course is the completion of a lattice Boltzmann code (using the framework specifically designed for this course).

The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.

Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.

The course builds upon three parts:
- I Elementary kinetic theory and lattice Boltzmann simulations introduced on simple examples.
- II Theoretical basis of statistical mechanics and kinetic equations.
- III Lattice Boltzmann method for real-world applications.

The content of the course includes:

1. Background: Elements of statistical mechanics and kinetic theory:
   - Particle's distribution function, Liouville equation, entropy, ensembles; Kinetic theory: Boltzmann equation for rarefied gas, H-theorem, hydrodynamic limit and derivation of Navier-Stokes equations, Chapman-Enskog method, Grad method, boundary conditions; mean-field interactions, Vlasov equation; Kinetic models: BGK model, generalized BGK model for mixtures, chemical reactions and other fluids.

2. Basics of the Lattice Boltzmann Method and Simulations:
   - Minimal kinetic models: lattice Boltzmann method for single-component fluid, discretization of velocity space, time-space discretization, boundary conditions, forcing, thermal models, mixtures.

3. Hands on:
   - Development of the basic lattice Boltzmann code and its validation on standard benchmarks (Taylor-Green vortex, lid-driven cavity flow etc).

4. Practical issues of LBM for fluid dynamics simulations:
   - Lattice Boltzmann simulations of turbulent flows; numerical stability and accuracy.

5. Microflow:
   - Rarefaction effects in moderately dilute gases; Boundary conditions, exact solutions to Couette and Poiseuille flows; micro-channel simulations.

6. Advanced lattice Boltzmann methods:
   - Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

7. Introduction to LB models beyond hydrodynamics:
   - Relativistic fluid dynamics; flows with phase transitions.

Lecture notes on the theoretical parts of the course will be made available. Selected original and review papers are provided for some of the lectures on advanced topics. Handouts and basic code framework for implementation of the lattice Boltzmann models will be provided.

The course addresses mainly graduate students (MSc/Ph D) but BSc students can also attend.

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151-0213-00L Fluid Dynamics with the Lattice Boltzmann Method

**Objective**

Methods like molecular dynamics, DSMC, lattice Boltzmann etc are being increasingly used by engineers all over and these methods require knowledge of kinetic theory and statistical mechanics which are traditionally not taught at engineering departments. The goal of this course is to give an introduction to ideas of kinetic theory and non-equilibrium thermodynamics with a focus on developing simulation algorithms and their realizations.

During the course, students will be able to develop a lattice Boltzmann code on their own. Practical issues about implementation and performance on parallel machines will be demonstrated hands on.

Central element of the course is the completion of a lattice Boltzmann code (using the framework specifically designed for this course).

The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.

Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.

The course builds upon three parts:
- I Elementary kinetic theory and lattice Boltzmann simulations introduced on simple examples.
- II Theoretical basis of statistical mechanics and kinetic equations.
- III Lattice Boltzmann method for real-world applications.

The content of the course includes:

1. Background: Elements of statistical mechanics and kinetic theory:
   - Particle's distribution function, Liouville equation, entropy, ensembles; Kinetic theory: Boltzmann equation for rarefied gas, H-theorem, hydrodynamic limit and derivation of Navier-Stokes equations, Chapman-Enskog method, Grad method, boundary conditions; mean-field interactions, Vlasov equation; Kinetic models: BGK model, generalized BGK model for mixtures, chemical reactions and other fluids.

2. Basics of the Lattice Boltzmann Method and Simulations:
   - Minimal kinetic models: lattice Boltzmann method for single-component fluid, discretization of velocity space, time-space discretization, boundary conditions, forcing, thermal models, mixtures.

3. Hands on:
   - Development of the basic lattice Boltzmann code and its validation on standard benchmarks (Taylor-Green vortex, lid-driven cavity flow etc).

4. Practical issues of LBM for fluid dynamics simulations:
   - Lattice Boltzmann simulations of turbulent flows; numerical stability and accuracy.

5. Microflow:
   - Rarefaction effects in moderately dilute gases; Boundary conditions, exact solutions to Couette and Poiseuille flows; micro-channel simulations.

6. Advanced lattice Boltzmann methods:
   - Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

7. Introduction to LB models beyond hydrodynamics:
   - Relativistic fluid dynamics; flows with phase transitions.

Lecture notes on the theoretical parts of the course will be made available. Selected original and review papers are provided for some of the lectures on advanced topics. Handouts and basic code framework for implementation of the lattice Boltzmann models will be provided.

The course addresses mainly graduate students (MSc/Ph D) but BSc students can also attend.
Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystem devices by the combination of unit process steps ( = process flow).

- Introduction to microsystems technology (MST) and micro electro mechanical systems (MEMS)
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.
- Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties.

Application of selected technologies will be demonstrated on case studies.

Lecture notes
Handouts (available online)

Literature
- S.M. Sze: Semiconductor Devices, Physics and Technology
- W. Menz, J. Mohr, O.Paul: Microsystem Technology
- Hong Xiao: Introduction to Semiconductor Manufacturing Technology
- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications

Prerequisites / notice
Prerequisites: Physics I and II

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<tr>
<th>Code</th>
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<th>Type</th>
<th>Credits</th>
<th>Group</th>
<th>Authors</th>
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<tbody>
<tr>
<td>227-0385-10L</td>
<td>Biomedical Imaging</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>S. Kozerke, K. P. Prüssmann</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>Introduction to diagnostic medical imaging based on electromagnetic and acoustic fields including X-ray planar and tomographic imaging, radio-tracer based nuclear imaging techniques, magnetic resonance imaging and ultrasound-based procedures.</td>
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<td>Objective</td>
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<td>Upon completion of the course students are able to:</td>
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<td>• Explain the physical and mathematical foundations of diagnostic medical imaging systems</td>
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<td>• Characterize system performance based on signal-to-noise ratio, contrast-to-noise ratio and transfer function</td>
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<td>• Design a basic diagnostic imaging system chain including data acquisition and data reconstruction</td>
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<td>• Identify advantages and limitations of different imaging methods in relation to medical diagnostic applications</td>
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<td>Content</td>
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<td>• Introduction (intro, overview, history)</td>
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<td>• Signal theory and processing (foundations, transforms, filtering, signal-to-noise ratio)</td>
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<td>• X-rays (production, tissue interaction, contrast, modular transfer function)</td>
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<td>• X-rays (resolution, detection, digital subtraction angiography, Radon transform)</td>
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<td>• X-rays (filtered back-projection, spiral computed tomography, image quality, dose)</td>
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<td>• Nuclear imaging (radioactive tracer, collimation, point spread function, SPECT/PET)</td>
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<td>• Nuclear imaging (detection principles, image reconstruction, kinetic modelling)</td>
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<td>• Magnetic Resonance (magnetic moment, spin transitions, excitation, relaxation, detection)</td>
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<td>• Magnetic Resonance (plane wave encoding, Fourier reconstruction, pulse sequences)</td>
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<td>• Magnetic Resonance (contrast mechanisms, gradient- and spin-echo, applications)</td>
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<td>• Ultrasound (mechanical wave generation, propagation in tissue, reflection, transmission)</td>
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<td>• Ultrasound (spatial and temporal resolution, phased arrays)</td>
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<td>• Ultrasound (Doppler shift, implementations, applications)</td>
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<td>• Summary, example exam questions</td>
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<td></td>
<td>Lecture notes</td>
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<td>Lecture notes and handouts</td>
</tr>
<tr>
<td></td>
<td>Literature</td>
<td></td>
<td></td>
<td></td>
<td>Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011</td>
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<tr>
<td></td>
<td>Analysis</td>
<td></td>
<td></td>
<td></td>
<td>Linear algebra, Physics, Basics of signal theory, Basic skills in Matlab/Python programming</td>
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<tr>
<td>227-0386-00L</td>
<td>Biomedical Engineering</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the basic vocabulary of biomedical engineering and getting familiar with concepts that govern common medical instruments and the most important organs from an engineering point of view.</td>
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<tr>
<td></td>
<td>Objective</td>
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<td>Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations. It also serves as an introduction to the field for students of the ITET, MAVT, HEST and other bachelor programs. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.</td>
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<tr>
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<td>Content</td>
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<td>History of BME and the role of biomedical engineers. Ethical issues related to BME. Bioelectronic sensors both wearable and also biochemical sensors. Bioinformatics: genomic and proteomic tools, databases and basic calculations. Equations describing basic reactions and enzyme kinetics. Medical optics: Optical components and systems used in hospitals. Basic concepts of tissue engineering and organ printing. Biomatertials and their medical applications. Function of the heart and the circulatory system. Transport and exchange of substances in the human body, compartment modeling. The respiratory system. Bioimaging. Orthopedic biomechanics. Lectures (2h), discussion of practical exercises (1h) and homework exercises.</td>
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<td>Lecture notes</td>
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<tr>
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<td>Literature</td>
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<td>Analysis</td>
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</table>
Introduction to Biomedical Engineering
by Enderle, Banchard, and Bronzino

AND

moodle page of the course

Prerequisites / notice
No specific requirements, BUT
ITET, MAVT, PHYS students will have to learn a lot of new words related to biochemistry, biology and medicine, while
HEST and BIOL students will have to grasp basic engineering concepts (circuits, equations, etc.).

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving fostered
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

227-1047-00L Consciousness: From Philosophy to Neuroscience
(University of Zurich)
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
UZH Module Code: INI410

Mind the enrolment deadlines at UZH:

Abstract
This seminar reviews the philosophical and phenomenological as well as the neurobiological aspects of consciousness. The subjective features of consciousness are explored, and modern research into its neural substrate, particularly in the visual domain, is explained.

Objective
The course’s goal is to give an overview of the contemporary state of consciousness research, with emphasis on the contributions brought by modern cognitive neuroscience. We aim to clarify concepts, explain their philosophical and scientific backgrounds, and to present experimental protocols that shed light on a variety of consciousness related issues.

Content
The course includes discussions of scientific as well as philosophical articles. We review current schools of thought, models of consciousness, and proposals for the neural correlate of consciousness (NCC).

Lecture notes
None

Literature
We display articles pertaining to the issues we cover in the class on the course’s webpage.

Prerequisites / notice
Since we are all experts on consciousness, we expect active participation and discussions!

227-0939-00L Cell Biophysics

Abstract
Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.

Objective
Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars of thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding experimental results from the literature.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.
Content
- Basics of theory of probability
- Boltzmann's law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns

Lecture notes
Theory and corresponding exercises are merged together during the classes.

I am willingly available Mondays 17.00 o’clock - 18.00 in my office GLC F12.2 for whatever discussion about the lessons and the exercises.

Literature

As further deepening:

Prerequisites / notice
Participants need a good command of
- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton’s and Coulomb’s laws (basics of Mechanics and Electrostatics).

No lecture notes because the two proposed textbooks are more than exhaustive!

Notions of vectors in 2D and 3D are beneficial.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
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<th>Social Competencies</th>
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<tr>
<td>Concepts and Theories</td>
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<td>Project Management</td>
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<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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Adaptability and Flexibility       assessed

Creative Thinking                  assessed

Critical Thinking                  assessed

Integrity and Work Ethics          assessed

Self-awareness and Self-reflection assessed

Self-direction and Self-management assessed

Neural Network Theory
Does not take place this semester.

Abstract
The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation theorems, capacity of separating surfaces, generalization, fundamental limits of deep neural network learning, VC dimension.

Objective
After attending this lecture, participating in the exercise sessions, and working on the homework problem sets, students will have acquired a working knowledge of the mathematical foundations of neural networks.

Content
1. Universal approximation with single- and multi-layer networks
2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory
3. Fundamental limits of deep neural network learning
4. Geometry of decision surfaces
5. Separating capacity of nonlinear decision surfaces
6. Vapnik-Chervonenkis (VC) dimension
7. VC dimension of neural networks
8. Generalization error in neural network learning

Lecture notes
Detailed lecture notes are available on the course web page
https://www.mins.ee.ethz.ch/teaching/nnt/
This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

227-0553-00L  
**Quantum Measurements and Optomechanics**  
W 4 credits 2V+1U  M. Frimmer

*Does not take place this semester.*

**Quantum Measurements and Optomechanics**

**Abstract**  
The measurement process is at the heart of both science and engineering. The limitations of measurement precision is ultimately dictated by the laws of quantum mechanics. This course provides the knowledge necessary to understand current state-of-the-art quantum measurement systems operating at their fundamental limits with a particular focus on optomechanical implementations.

**Objective**  
The goal of this course is to understand both the standard and the ultimate quantum limits of measurement precision.

**Content**  
The lecture starts with summarizing the relevant fundamentals of the treatment of noisy signals. We familiarize ourselves with the concept of measurement imprecision in light-based measurement systems. To this end, we consider the process of photodetection and discuss the statistical fluctuations arising from the quantization of the electromagnetic field into photons. We exemplify our insight at hand of concrete examples, such as homodyne and heterodyne photodetection. Furthermore, we focus on the process of measurement backaction, the inevitable result of the interaction of the probe with the system under investigation. We discuss the "standard quantum limit" as it arises from the balance of measurement imprecision and backaction, before turning to approaches to overcome it and reach the fundamental "Heisenberg limit". The course emphasizes the connection between the taught concepts and current state-of-the-art research carried out in the field of optomechanics. Exercises serve to consolidate our understanding and insight.

**Prerequisites / notice**

1. Electrodynamics
2. Physics 1,2
3. Introduction to quantum mechanics

**Competencies**

- Subject-specific Competencies  
  - Concepts and Theories  
  - Techniques and Technologies  
- Method-specific Competencies  
  - Analytical Competencies  
  - Decision-making  
  - Media and Digital Technologies  
  - Problem-solving
- Social Competencies  
  - Communication
- Personal Competencies  
  - Adaptability and Flexibility  
  - Creative Thinking  
  - Critical Thinking  
  - Integrity and Work Ethics  
  - Self-awareness and Self-reflection  
  - Self-direction and Self-management

227-0965-00L  
**Micro and Nano-Tomography of Biological Tissues**  
W 4 credits 3G  M. Stampanoni, F. Marone Welford

**Abstract**  
The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course also discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

**Objective**

Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

**Content**

Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments. The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

**Lecture notes**

Available online

**Literature**

Will be indicated during the lecture.

227-0157-00L  
**Semiconductor Devices: Physical Bases and Simulation**  
W 4 credits 3G  A. Schenk, C. I. Roman

**Abstract**

The course addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical simulation. Necessary basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided. Computer simulations of the most important devices and of interesting physical effects supplement the lectures.

**Objective**

The course aims at the understanding of the principle physics of modern semiconductor devices, of the foundations in the physical modeling of transport and its numerical simulation. During the course also basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided.

**Content**

The main topics are: transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model, hydrodynamic model), physical characterization of silicon (intrinsic properties, scattering processes), mobility of cold and hot carriers, recombination (Shockley-Read-Hall statistics, Auger recombination), impact ionization, metal-semiconductor contact, metal-insulator-semiconductor structure, and heterojunctions. The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

**Lecture notes**

The script (in book style) can be downloaded from: https://iie-students.ee.ethz.ch/lectures/

**Literature**

The script (in book style) is sufficient. Further reading will be recommended in the lecture.

**Prerequisites / notice**


227-0147-10L  
**VLSI 3: Full-Custom Digital Circuit Design**  
W 6 credits 2V+3U  C. Studer, O. Cañada Fernández

This third course in our VLSI series is concerned with full-custom digital integrated circuits. The goals include learning the design of digital circuits on the schematic, layout, gate, and register-transfer levels. The use of state-of-the-art CAD software (Cadence Virtuoso) in order to simulate, optimize, and characterize digital circuits is another important topic of this course.
Objective

At the end of this course, you will
- understand the design of the main building blocks of state-of-the-art digital integrated circuits
- be able to design and optimize digital integrated circuits on the schematic, layout, and gate levels
- be able to use standard industry software (Cadence Virtuoso) for drawing, simulating, and characterizing digital circuits
- understand the performance trade-offs between delay, area, and power consumption

Content

The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack towards logic gates and increasingly complex digital circuit structures. The topics of this course include:
- Nanometer MOSFETs
- Static and dynamic behavior of complementary MOS (CMOS) inverters
- CMOS gate design, sizing, and timing
- Full-custom standard-cell design
- Wire models and parasitics
- Latch and flip-flop circuits
- Gate-level timing analysis and optimization
- Static and dynamic power consumption; low-power techniques
- Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
- Arithmetic and logic circuits
- Fixed-point and floating-point arithmetic
- Synchronous and asynchronous design principles
- Memory circuits (ROM, SRAM, and DRAM)
- In- and near-memory processing architectures
- Full-custom accelerator circuits for machine learning

The exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

N. H. E. Weste and D. M. Harris, CMOS VLSI Design: A Circuits and Systems Perspective (4th Ed.), Addison-Wesley

Subject-specific Competencies

- Analytical Competencies
- Problem-solving

Method-specific Competencies

- Conceptual and Theoretical Competencies
- Techniques and Technologies

Prerequisites / notice

VLSI 3 can be taken in parallel with “VLSI 1: HDL-based design for FPGAs” and is designed to complement the topics of this course. Basic analog circuit knowledge is required.

Objectives

- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Aneaux diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Lecture notes

Textbook and all further documents in English.

Literature


Prerequisites / notice

Prerequisites:
- Basics of digital circuits.
- Examination:
  - In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English or German.

Further details:
- https://itis-students.ee.ethz.ch/lectures/vlsi-i/

Optical Communication Fundamentals

- Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA).
- Know their organization and be able to identify suitable application areas.
- Become fluent in front-end design from architectural conception to gate-level netlists.
- How to model digital circuits with SystemVerilog.
- How to ensure they behave as expected with the aid of simulation, testbenches, and assertions.
- How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits.
- Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

Objective

- An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the important elements will be passed on.
- Students attending the lecture will further get engaged in critical discussion on societal, economical and environmental aspects related to the ongoing exponential growth in the field of communications.

227-0301-00L

Optical Communication Fundamentals

- 6 credits
- 2V+1U+1P
- J. Leuthold

Abstract

The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and electronic components in a fiber communication system.

This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

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Autumn Semester 2024
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This course focuses on the current state and prospects of memory technologies, emerging beyond the silicon transistor era. We explore resistive PCM and RRAM, magnetic MRAM and ferroelectric FRAM memories, covering physics, device aspects and the latest research in the field. Through interactive lectures and laboratory sessions, students gain up-to-date knowledge and compare emerging memory techs.

In this course, students will learn about the leading contenders for post-silicon storage-class and main memory technologies. Decades of research have yielded several efficient memory device working principles, including phase-change of the structure (PCM), materials conversion (OxRAM), ion diffusion (CBRAM), magnetic properties (STT-MRAM, MTJ), and ferroelectricity (FRAM, FeFET). Currently, these memory technologies are transitioning from research to industry, and are predicted to have at least niche applications in the ever-growing hardware market. Some technologies, such as PCM, may even eventually surpass silicon-based flash memory, providing better performance and unique features.

The course is organized as a series of lectures, focusing on selected memory technologies. This class also includes practical laboratory sessions for the PCM research topics. Students will spend 2 hours per week in the class or laboratory and additional 2-3 hours per week to prepare for the exam.

The course also includes a presentation by each student in which a related scientific publication is discussed. This presentation is compulsory and accounts for 50% of the grade.

Students will have the opportunity to compare emerging memory technologies with state-of-the-art SSD Flash, DRAM, and SRAM, as well as evaluate their potential. Through critical thinking discussions, students will acquire important skills for assessing the strengths and limitations of these emerging technologies.

The course will cover the following carbon-based materials:
- Single-molecule
- Graphene (single layer, bilayer, twisted bilayer)
- Graphene nanoribbons
- Carbon nanotubes

For each material, we will discuss:
- Electronic structure and charge transport properties
- Material synthesis and characterization
- Device integration and characterization

The course also includes a presentation by each student in which a related scientific publication is discussed. This presentation is compulsory and accounts for 50% of the grade.

Lecture notes and Literature:
Lecture notes are handed out.

Prerequisites / notice:
A basic knowledge of solid-state physics and quantum mechanics is required. The course is taught in English.

Literature:
Govind P. Agrawal; "Fiber-Optic Communication Systems"; Wiley, 2010
Emerging Memory Technologies
The course will cover the following carbon-based materials:
- Graphene, carbon nanotubes, graphene nanoribbons, and single molecules are used for building electronic devices.

On the experimental side, we'll cover how such devices are fabricated, including how the materials are synthesized. We'll also discuss how to characterize the devices and assess their performance.

In addition to the slides, the following supplementary books can be recommended:

Prerequisites / notice:
A basic knowledge of solid-state physics and quantum mechanics is required. The course is taught in English.


227-0621-00L
Emerging Memory Technologies
W 3 credits 1V+1U M. Yarema

Abstract
This course focuses on the current state and prospects of memory technologies, emerging beyond the silicon transistor era. We explore resistive PCM and RRAM, magnetic MRAM and ferroelectric FRAM memories, covering physics, device aspects and the latest research in the field. Through interactive lectures and laboratory sessions, students gain up-to-date knowledge and compare emerging memory techs.

Objective
In this course, students will learn about the leading contenders for post-silicon storage-class and main memory technologies. Decades of research have yielded several efficient memory device working principles, including phase-change of the structure (PCM), materials conversion (OxRAM), ion diffusion (CBRAM), magnetic properties (STT-MRAM, MTJ), and ferroelectricity (FRAM, FeFET). Currently, these memory technologies are transitioning from research to industry, and are predicted to have at least niche applications in the ever-growing hardware market. Some technologies, such as PCM, may even eventually surpass silicon-based flash memory, providing better performance and unique features.

Content
The course is organized as a series of lectures, focusing on selected memory technologies. This class also includes practical laboratory sessions for the PCM research topics. Students will spend 2 hours per week in the class or laboratory and additional 2-3 hours per week to prepare for the exam.

Lecture notes are handed out.

Prerequisites / notice:
A basic knowledge of solid-state physics and quantum mechanics is required. The course is taught in English.


227-0654-00L
Carbon-based Nanoelectronics
W 3 credits 1V+1U M. Perrin

Abstract
This course explores the exciting realm of carbon-based nanoelectronics, where the remarkable quantum properties of materials like graphene, carbon nanotubes, graphene nanoribbons, and single molecules are used for building electronic devices.

Objective
The objective of this course is to understand how the electronic properties of carbon-based materials can be exploited for fabricating quantum devices. We will delve into both the theoretical and experimental aspects, discussing how these materials’ unique properties can be translated into device functionality.

On the theoretical side, we’ll cover how the chemical structure of the material and its dimensionality, ranging from 0D to 2D, affects the electronic properties. We’ll also discuss how charge carriers flow through the devices and what charge transport mechanisms are at play.

On the experimental side, we’ll discuss how such devices are fabricated, including how the materials are synthesized. We’ll also discuss how to characterize the devices and assess their performance.

Content
The course will cover the following carbon-based materials:
- Single-molecule
- Graphene (single layer, bilayer, twisted bilayer)
- Graphene nanoribbons
- Carbon nanotubes

For each material, we will discuss:
- Electronic structure and charge transport properties
- Material synthesis and characterization
- Device integration and characterization

The course also includes a presentation by each student in which a related scientific publication is discussed. This presentation is compulsory and accounts for 50% of the grade.

Lecture notes and Literature:
Lecture notes are handed out.

Prerequisites / notice:
A basic knowledge of solid-state physics and quantum mechanics is required. The course is taught in English.

Nano-Optics

**Abstract**
Nano-Optics is the study of light-matter interaction at the sub-wavelength scale. It is a flourishing field of fundamental and applied research enabled by the rapid advance of nanotechnology. Nano-optics embraces topics such as plasmonics, optical antennas, optical trapping and manipulation, and high/super-resolution imaging and spectroscopy.

**Objective**
Understanding concepts of light localization and light-matter interactions on the sub-wavelength scale.

**Content**
We start with the angular spectrum representation of fields to understand the classical resolution limit. We continue with the theory of strongly focused light, the point spread function, and resolution criteria of conventional microscopy, before turning to super-resolution techniques, based on near- and far-fields. We introduce the local density of states and approaches to control spontaneous emission rates in inhomogeneous environments, including optical antennas. Finally, we touch upon optical forces and their applications in optical tweezers.

**Prerequisites / notice**
- Electromagnetic fields and waves (or equivalent)
- Physics I+II

Nanodevices and Circuits for the Beyond-Moore Era

**Abstract**
Big Data, AI and the Internet of Things demand new hardware which overcomes the limitations of von Neumann architectures. The lecture gives an insight how the fundamental physics and the resulting complex functionalities of nanodevices and circuits offer viable alternatives. Their increased computational power and energy efficiency are demonstrated through neuromorphic computing applications.

**Objective**
The students will gain a firm understanding in the theory and pioneering experiments of electronic and heat transport at atomic- to nanometer length-scales. Advanced device functionalities enabled by recently discovered material systems will be covered. The students will learn how to exploit such phenomena for designing nanodevices and circuits to energy-efficiently implement neuromorphic algorithms for a sustainable future of information technologies.

**Lecture notes**
The presentation slides and further material will be provided every week.

**Prerequisites / notice**
Basic knowledge of solid state physics and semiconductors.

Information Systems for Engineers

**Abstract**
This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).
Objective

Do you want to be able to query your own data productively and efficiently in your future semester projects, bachelor's thesis, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This course teaches you how to do so as well as the dos and don'ts.

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.

2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).

3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.

4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality.

5. Explain what bad design is and why it matters.

6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".

7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.

8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.

9. Explain what data independence is all about and didn't age a bit since the 1970s.

10. Explain, in the big picture, how a relational database is physically implemented.

11. Know and deal with the natural syntax for relational data, CSV.

12. Explain the data cube model including slicing and dicing.

13. Store data cubes in a relational database.

14. Map cube queries to SQL.

15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook

Literature

- Lecture material (slides).

  (It is not required to buy the book, as the library has it)

Prerequisites / notice

For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logic
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving fostered

Social Competencies
Communication fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving fostered

Social Competencies
Communication fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking assessed

Electron Microscopy in Material Science

W 4 credits 2V+2U S. Gerstl, R. Erni, F. Gramm, A. Käch, F. Krumeich, K. Kunze

Abstract
A comprehensive understanding of the interaction of electrons and ions with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

Objective
A comprehensive understanding of the interaction of electrons and ions with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

Content
This course provides a general introduction into electron- and ion- microscopy of organic and inorganic materials. In the first part, the basics of transmission- and scanning electron microscopy are presented. The second part includes the most important aspects of specimen preparation, imaging and image processing. In the third part, focused ion-beam and atom probe microscopes are presented. Throughout the semester, various applications in materials science, solid state physics, structural biology, structural geology, and structural chemistry will be reported.

Lecture notes
will be distributed in English

Literature
Erni: Aberration-corrected imaging in transmission electron microscopy, Imperial College Press (2010, and 2nd ed. 2015)

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered

EM-Practical Course in Materials Science

W 2 credits 4P K. Kunze, S. Gerstl, F. Gramm, F. Krumeich, J. Reuteler

Abstract
Practical work on TEM, SEM, FIB and APT treatment of typical problems data analysis, writing of a report

Objective
Application of basic electron microscopic techniques to materials science problems

Literature
see lecture Electron Microscopy (327-0703-00L)

Prerequisites / notice
Attendance of lecture Electron Microscopy (327-0703-00L) is recommended. Maximum number of participants 15, work in groups of 3 people.

Microscopy Training SEM I - Introduction to SEM


Abstract
This introductory course on Scanning Electron Microscopy (SEM) emphasizes hands-on learning. Using ScopeM SEMs, students have the opportunity to study their own samples (or samples provided) and solve practical problems by applying knowledge acquired during the lectures. At the end of the course, students will be able to apply SEM for their (future) research projects.

Objective
- Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize microscope performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.
Content

During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications.

This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

Lectures:
- Introduction on Electron Microscopy and instrumentation
- electron sources, electron lenses and probe formation
- beam/specimen interaction, image formation, image contrast and imaging modes.
- sample preparation techniques for EM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

Practicals:
- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast (and image processing)
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Practice on real-world samples and report results

Lecture notes

Lecture notes will be distributed.

Literature


Prerequisites / notice

No mandatory prerequisites.

327-2126-00L Microscopy Training TEM I - Introduction to TEM

The number of participants is limited. In case of overbooking, the course will be repeated once. All registration will be recorded on the waiting list.

For PhD students, postdocs and others, a fee will be charged (https://scopem.ethz.ch/education/MTP.html).

All applicants must additionally register on this form: https://docs.google.com/forms/d/1xvD1HjPY3CB7XkZiNxfWFW7UV6EMJ9carEAQ2o/edit

The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

Abstract

The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

Objective

Understanding of
1. the set-up and individual components of a TEM
2. the basics of electron optics and image formation
3. the basics of electron beam – sample interactions
4. the contrast mechanism
5. various sample preparation techniques

Learning how to
1. align and operate a TEM
2. acquire data using different operation modes of a TEM instrument, i.e. Bright-field and Dark-field imaging
3. record electron diffraction patterns and index diffraction patterns
4. interpret TEM data

Content

Lectures:
- basics of electron optics and the TEM instrument set-up
- TEM imaging modes and image contrast
- STEM operation mode
- Sample preparation techniques for hard and soft materials

Practicals:
- Demo, practical demonstration of a TEM: instrument components, alignment, etc.
- Hands-on training for students: sample loading, instrument alignment and data acquisition.
- Sample preparation for different types of materials
- Practical work with TEMs
- Demonstration of advanced Transmission Electron Microscopy techniques

327-2210-00L Thin Films Technology - From Fundamentals to Oxide Electronics


Prerequisites / notice

No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.

327-2132-00L Multifunctional Ferroic Materials: Growth and Characterisation

This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

Lectures:
- Demonstration of advanced Transmission Electron Microscopy techniques
- Sample preparation techniques for hard and soft materials
- Practical work with TEMs
- Demonstration of advanced Transmission Electron Microscopy techniques

Practicals:
- Student participation on sample preparation techniques
- Practice on real-world samples and report results

Lecture notes

Lecture notes will be distributed.

Literature


Prerequisites / notice

No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.
In this course students will obtain an overarching view on thin film deposition techniques with a focus on epitaxial deposition processes. The main learning objectives are:

- Identification of most relevant deposition technique for a given application.
- Understanding of growth mechanism and growth modes.
- Understanding strategies for engineering the functionalities of the films using the deposition process.
- Selection of the most appropriate characterization technique.
- Understanding device concepts and fundamental limits in the technology relevant ultra-thin limit.
- Assessing the relevance of scientific literature dealing with complex oxide thin films.

A lab visit visit will be organized and students will participate to the design of thin films with atomic precision.

General description of the leading deposition routes including physical and chemical vapor deposition techniques (PVD and CVD) as well as so called “wet techniques” (e.g. spin coating and spray pyrolysis).

Growth modes and processes.

Part of the course discusses vacuum technologies.

Fundamental characterization techniques for application-relevant thin films as well as state of the art approaches for in situ and ex-situ determination of the structural, chemical and ferroic (ferromagnetic and ferroelectric) properties of films: (XRD for thin films, RHEED, EDX, scanning probe microscopy techniques, laser-optical characterization and many more)

Epitaxy for the advanced design and characterization of high quality thin films for energy efficient oxide electronics.

Types of ferroic order, multiferroics, multifunctional oxide materials, epitaxial strain related effects, oxide thin film based devices and examples.

Regular discussions on preselected scientific literature and mini-seminars will be organized.

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<th>Competencies</th>
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<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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<td>Concepts and Theories</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Project Management</td>
<td>Self-presentation and Social Influence</td>
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A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.

The main learning objectives are:

- Identification of most relevant deposition technique for a given application.
- Understanding of growth mechanism and growth modes.
- Understanding strategies for engineering the functionalities of the films using the deposition process.
- Selection of the most appropriate characterization technique.
- Understanding device concepts and fundamental limits in the technology relevant ultra-thin limit.
- Assessing the relevance of scientific literature dealing with complex oxide thin films.

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General description of the leading deposition routes including physical and chemical vapor deposition techniques (PVD and CVD) as well as so called “wet techniques” (e.g. spin coating and spray pyrolysis).

Growth modes and processes.

Part of the course discusses vacuum technologies.

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The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.

The main learning objectives are:
The course aims at enabling students to understand the key theoretical points of DNP and to design DNP experiments. Students will be able to:

- identify strengths and weaknesses of biomolecular DNP and how to design DNP experiments for particular applications
- understand the importance of different modeling approaches
- foster decision-making and problem-solving
- foster cooperation and teamwork
- foster communication

**Competencies**

- **Method-specific Competencies**
  - Problem-solving
  - Decision-making
  - Analytical Competencies

- **Social Competencies**
  - Communication
  - Cooperation and Teamwork

- **Personal Competencies**
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection

**Lecture notes**

A script which covers the topics will be accessible through the course Moodle.

**Prerequisites / notice**

Prerequisite: A basic knowledge of Magnetic Resonance, e.g. as covered in the Lecture Physical Chemistry IV, or the book “Spin Dynamics” by Malcolm Levitt.
Advanced Magnetic Resonance - Biological Magnetic Resonance

Abstract
The course is for advanced students and covers selected topics from magnetic resonance spectroscopy. It is concerned with inference of structure and dynamics of proteins and their complexes from data obtained by EPR and liquid-state NMR experiments. The special focus is on multi-state and ensemble modelling.

Objective
This course enables students to design experimental strategies for characterization of structure and dynamics of proteins whose flexibility is relevant for their function. Students understand the spin dynamics that encodes sidechain and backbone motion as well as distance information into signals measured by magnetic resonance experiments. They learn to solve the inverse problem of inferring dynamics parameters and distances from the experimental results. They acquire skills in modelling protein ensemble structure from constraints derived by analyzing magnetic resonance data. Students are aware of the complications introduced by the use of spin labels in such experiments and learn how to include such labels in modelling.

Content
- Nitroxide spin labels, their interaction with the environment, and influence of their dynamics on EPR line shapes
- Contributions to electron spin decoherence and ways to improve resolution in pulsed EPR
- Measurement of electron-electron dipole-dipole interaction and conversion of the primary data to distance distributions
- Modelling of spin labels by rotamer libraries
- Ensemble modelling with distance distributions
- Liquid-state NMR experiments for assessing protein structure and dynamics
- Assignment of NMR signals for proteins
- Theory of the nuclear Overhauser effect (NOE)
- Ensemble modelling with exact NOE constraints
- Multistate structure calculation and analysis
- Further constraints on protein structure and dynamics from NMR experiments

Lecture notes
A script, which covers the topics, will be accessible through the course Moodle

Prerequisites / notice
A basic knowledge of magnetic resonance, e.g. as covered in the lecture course Physical Chemistry IV or in the book "Spin Dynamics" by Malcolm Levitt

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-direction and Self-management: fostered

Advanced Magnetic Resonance - Solid State NMR

Abstract
Does not take place this semester.

Objective
The aim of the course is to familiarize the students with the basic concepts of modern high-resolution solid-state NMR. Starting from the mathematical description of spin dynamics, important building blocks for multi-dimensional experiments are discussed to allow students a better understanding of modern solid-state NMR experiments. Particular emphasis is given to achieving high spectral resolution.

Content
The basic principles of NMR in solids will be introduced. After the discussion of basic tools to describe NMR experiments, basic methods and experiments will be discussed, e.g., magic-angle spinning, cross polarization, decoupling, and recoupling experiments. Such basic building blocks allow a tailoring of the effective Hamiltonian to the needs of the experiment. These basic building blocks can then be combined in different ways to obtain spectra that contain the desired information.

Lecture notes
A script which covers the topics will be distributed in the lecture and will be accessible through the web page http://www.ssnmr.ethz.ch/education/

Prerequisites / notice
Prerequisite: A basic knowledge of NMR, e.g. as covered in the Lecture Physical Chemistry IV, or in the book by Malcolm Levitt.

Advanced Physical Chemistry: Statistical Thermodynamics

Abstract
Introduction to statistical mechanics and thermodynamics. Prediction of thermodynamic and kinetic properties from molecular data. Introduction to statistical mechanics and thermodynamics. Prediction of thermodynamic and kinetic properties from molecular data.

Objective

Lecture notes
See homepage of the lecture.

Prerequisites / notice
Chemical Thermodynamics, Reaction Kinetics, Molecular Quantum Mechanics and Spectroscopy; Mathematical Foundations (Analysis, Combinatorial Relations, Integral and Differential Calculus)

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

Social Competencies
- Communication: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed

Geophysics III

Abstract
This course builds on Geophysik I and Geophysik II, broadening the students' education in seismology, geodynamics and geodynamic theory, by considering various specific topics of particular interest.

Objective
To teach students the basics of observational seismology, earthquake source seismology, seismotectonics and the principle of seismic tomography, mantle convection over Earth history, structure of the oceanic and continental lithosphere, plate tectonics, hotspots, global heat flux, dynamo operation and magnetic field generation in Earth, planets, the Sun and stars and electromagnetism to probe the mantle.
Content
Observational seismology, earthquake source seismology, seismotectonics and the principle of seismic tomography. Mantle convection over Earth history, structure of the oceanic and continental lithosphere, plate tectonics, hotspots, global heat flux. Dynamo operation and magnetic field generation in Earth, planets, the Sun and stars; electromagnetism to probe the mantle.

651-4010-00L Planetary Sciences: a Physical Perspective

Abstract
This course aims to give a physical understanding of the formation, structure, dynamics and evolution of planetary bodies in our solar system and also apply it to ongoing discoveries regarding planets around other stars.

Objective
The goal of this course is to enable students to understand current knowledge and uncertainties regarding the formation, structure, dynamics and evolution of planets and moons in our solar system, as well as ongoing discoveries regarding planets around other stars. Students will practice making quantitative calculations relevant to various aspects of these topics through weekly homeworks.

The main topics covered are: Orbital dynamics and Tides, Solar heating and Energy transport, Planetary atmospheres, Planetary surfaces, Planetary interiors, Asteroids and Meteorites, Comets, Planetary rings, Magnetic fields and Magnetospheres, The Sun and Stars, Planetary formation, Exoplanets and Exobiology

Lecture notes
Slides and scripts will be posted on Moodle.

Literature
It is recommended but not mandatory to buy one of these books:

701-1257-00L European Climate Change

Abstract
The lecture provides an overview of climate change in Europe, from a physical and atmospheric science perspective. It covers the following topics:
• observational datasets, observation and detection of climate change;
• underlying physical processes and feedbacks;
• numerical and statistical approaches;
• currently available projections.

Objective
At the end of this course, participants should:
• understand the key physical processes shaping climate change in Europe;
• know about the methodologies used in climate change studies, encompassing observational, numerical, as well as statistical approaches;
• be familiar with relevant observational and modeling data sets;
• be able to tackle simple climate change questions using available data sets.

Content
Contents:
• global context
• observational data sets, analysis of climate trends and climate variability in Europe
• global and regional climate modeling
• statistical downscaling
• key aspects of European climate change: intensification of the water cycle, Polar and Mediterranean amplification, changes in extreme events, changes in hydrology and snow cover, topographic effects

Lecture notes
Slides and lecture notes will be made available at http://www.iac.ethz.ch/edu/courses/master/electives/european-climate-change.html

Prerequisites / notice
Participants should have a background in natural sciences, and have attended introductory lectures in atmospheric sciences or meteorology.

Proseminars and Semester Papers
Detailed information at: https://www.phys.ethz.ch/studies/master/semester-projects.html

Bachelor students in Physics who wish to register for a MSc Semester Project or Proseminar need to contact the study administration (studiensekretariat@phys.ethz.ch).

Number Title Type ECTS Hours Lecturers
402-0218-MSL Research Project W 8 credits 15A Supervisors

Abstract
Students conduct a small research project within a research group or carry out a guided self-study of original papers on a given theoretical topic. The results are submitted in a written report and an oral presentation.

Objective
Students are enabled to:
• expand their knowledge in a specific area of physics,
• conduct a project (a) in a research laboratory or (b) on a specific topic of theoretical physics,
• discuss their project results and conclusions in a team,
• present their findings in written and oral form.

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Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: fostered
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

402-0219-MSL Research Project II

To register, please contact the study administration at studies.physics@ethz.ch

Abstract
Students conduct a small research project within a research group or carry out a guided self-study of original papers on a given theoretical topic. The results are submitted in a written report and an oral presentation.

Objective
Students are enabled to:
- expand their knowledge in a specific area of physics,
- conduct a project (a) in a research laboratory or (b) on a specific topic of theoretical physics,
- discuss their project results and conclusions in a team,
- present their findings in written and oral form.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: fostered
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Science in Perspective

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-PHYS

Master's Thesis

Number Title Type ECTS Hours Lecturers
402-2000-00L Scientific Works in Physics O 0 credits D. Kienzler

Target audience:
Master students who cannot document to have received an adequate training in working scientifically.

Directive

Abstract
Literature Review: ETH-Library, Journals in Physics, Google Scholar; Thesis Structure: The IMRAD Model; Document Processing: LaTeX and BibTeX, Mathematical Writing, AVETH Survival Guide; ETH Guidelines for Integrity; Authorship Guidelines; ETH Citation Etiquettes; Declaration of Originality.

Objective
Basic standards for scientific works in physics: How to write a Master Thesis. What to know about research integrity.

402-0900-30L Master's Thesis O 30 credits 57D Supervisors

Only students who fulfill the following criteria are allowed to begin with their master's thesis:
- successful completion of the bachelor programme;
- fulfilling of any additional requirements necessary to gain admission to the master programme;
- have acquired at least 8 credits in the category Proseminars and Semester Papers.

Further information:
Abstract
The Master's thesis concludes the Master's programme and constitutes a full-time project of six-month duration aimed at advancing the skills and capabilities of students to work independently and creatively towards the solution of an individual research problem which has been agreed upon in advance.

Objective
Students are enabled to:
- solve a complex problem by applying theoretical and experimental methods and skills,
- articulate their beliefs and thoughts on a scientific subject, appreciate the positions of others and revisit their own positions based on new insights,
- contribute constructively to the projects of a diverse research team,
- actively participate in a scientific discourse on a specific area of physics and present positions based on scientific arguments.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
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- Self-awareness and Self-reflection
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<td>402-0530-00L</td>
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<td>C. D. Herzog, C. Becker, S. Müller</td>
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</tbody>
</table>

**Abstracts**

402-0396-00L: No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

402-0530-00L: Research colloquium

402-0620-00L: Current Topics in Accelerator Mass Spectrometry and Its Applications

227-0980-00L: Seminar on Biomedical Magnetic Resonance

227-1043-00L: Neuroinformatics - Colloquia (University of Zurich)

651-1581-00L: Seminar in Glaciology

402-0010-00L: Basics of Computing Environments for Scientists

**Objective**

402-0396-00L: No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

402-0530-00L: Students are able to understand modern experiments in the field of mesoscopic systems and nanostructures. They can present their own results, critically reflect published research in this field, explain both to an audience of physicists, and participate in a critical and constructive scientific discussion.

402-0620-00L: The seminar provides the participants an overview about newest trends and developments of accelerator mass spectrometry (AMS) and related applications. In their talks and subsequent discussions the participants learn intensively about the newest trends in the field of AMS thus attaining a broad knowledge on both, the physical principles and the applications of AMS, which goes far beyond the horizon of their own studies.

227-0980-00L: Current developments and problems of magnetic resonance imaging (MRI)

227-1043-00L: The colloquium in Neuroinformatics is a series of lectures given by invited experts. The lecture topics reflect the current themes in neurobiology and neuromorphic engineering that are relevant for our Institute.

651-1581-00L: Introduction to classic and modern literature of research in Glaciology. Active participation is expected and participants are mentored by PhD students of Glaciology.

402-0010-00L: Introduce IT services at D-PHYS and offer modules covering IT-related topics for scientists.

**Content**

402-0396-00L: Recent Research Highlights in Astrophysics (University of Zurich)

402-0530-00L: Mesoscopic Systems

402-0620-00L: Current Topics in Accelerator Mass Spectrometry and Its Applications

227-0980-00L: Seminar on Biomedical Magnetic Resonance

227-1043-00L: Neuroinformatics - Colloquia (University of Zurich)

651-1581-00L: Seminar in Glaciology

402-0010-00L: Basics of Computing Environments for Scientists

**Prerequisites / notice**

651-1581-00L: Active participation is expected with presence at the sessions. Only a limited number of participants can be accepted. One of the following courses should be taken as preparation:

- 651-3561-00L Kryosphäre
- 101-0289-00L Applied Glaciology
- 651-4101-00L Physics of Glaciers

402-0010-00L: Enrollment is only possible under https://www.lehrbetrieb.ethz.ch/laborpraktika

**Competencies**

651-1581-00L: Subject-specific Competencies

402-0010-00L: Adaptable and Flexible

**Adaptability and Flexibility**

Technical Competencies

Analytical Competencies

Decision-making

Media and Digital Technologies

Cooperation and Teamwork

Self-presentation and Social Influence

Sensitivity to Diversity

Negotiation

Personal Competencies

Adaptable and Flexible

Creative Thinking

Critical Thinking

Self-awareness and Self-reflection

**Conferences**

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

Mind the enrolment deadlines at UZH:


E-0 credits

1S

T. M. Ihn

E-0 credits

1S

M. Christl, S. Willett

E-0 credits

1S

K. P. Prüssmann, S. Kozerke, M. Weiger Senften

E-3 credits

2S

A. Bauder, M. Jacquemart

Z 0 credits

1V

C. D. Herzog, C. Becker, S. Müller

Autumn Semester 2024

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The "IT at D-PHYS" introduction provides a good understanding of how IT works at D-PHYS and presents an overview of the IT services and their providers. It is recommended for everyone joining the department.

The "IT and Information Security" crash course will address the most common threats you'll encounter when using the internet and teach you how to fend them off.

The remainder is structured into individual modules which can be attended separately. They give practical insights into everyday research-related IT challenges.

The "Linux Basics" modules offer an introduction to the Linux landscape and show how to work on the shell by using command line tools. The first part provides a basic understanding of Linux systems and their components. It introduces commands essential to working with local and remote machines. The second part focuses on more advanced tools and workflows and provides guidelines to scripting, automation and customization.

The "Python Ecosystem" modules present various aspects of the environment around Python. Without teaching the Python programming language itself, it aims at providing understanding of various concepts surrounding it. The first part focuses on getting ready to run code. It discusses the management of Python interpreters, packages and virtual environments. The second part presents tools for writing Python code and interacting with strings. From development environments (IDE, Jupyter), over code formatters and linters, to string formatting and parsing with regular expressions. The third part sits at the interface between Python code and external data files. We explain how to read or write files, discuss data types and file formats. We show how to handle configuration parameters and mention tools to automate the data analysis.

The "System Aspects module" deals with the hardware-related side of scientific computing. To get the best performance out of your scientific code, you have to be aware of the underlying hardware and adapt to it.

Use the dedicated web page https://www.lehrbetrieb.ethz.ch/laborpraktika to register. Enrolled students are eligible for an attestation of attendance after visiting at least 3 out of the 5 modules. Refer to https://compenv.phys.ethz.ch for the detailed contents.

### Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>406-0204-AAL</td>
<td>Electrodynamics</td>
<td>E-</td>
<td>7 credits</td>
<td>15R</td>
<td>N. Beisert</td>
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</table>

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

### Abstract


### Objective

Develop a physical understanding for static and dynamic phenomena related to moving charged objects and understand the structure of the classical field theory of electrodynamics (transverse versus longitudinal physics, invariances (Lorentz-, gauge-)). Appreciate the interrelation between electric, magnetic, and optical phenomena and the influence of media. Understand a set of classic electrodynamical phenomena and develop the ability to solve simple problems independently. Apply previously learned mathematical concepts (vector analysis, complete systems of functions, Green's functions, co- and contravariant coordinates, etc.). Prepare for quantum mechanics (eigenvalue problems, wave guides and cavities).

### Content

Classical field theory of electrodynamics: Derivation and discussion of Maxwell equations, starting from the static limit (electrostatics, magnetostatics, boundary value problems) in the vacuum and in media and subsequent generalization to the full dynamical case (Faraday's law, Ampere/Maxwell law; potentials and gauge invariance). Wave equation and solutions in full space, half-space (Snell's law), magnetostatics, boundary value problems) in the vacuum and in media and subsequent generalization to the full dynamical case (eigenvalue problems, wave guides and cavities).

### Literature

- J.D. Jackson, Classical Electrodynamics
- W.K.H Panovsky and M.Phillis, Classical electricity and magnetism
- A. Sommerfeld, Elektrodynamik, Optik (Vorlesungen über theoretische Physik)
- M. Born and E. Wolf, Principles of optics
- R. Feynman, R. Leighton, and M. Sands, The Feynman Lectures of Physics, Vol II

401-2673-AAL: Numerical Methods for CSE

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

### Abstract

The course gives an introduction into fundamental techniques and algorithms of numerical mathematics which play a central role in numerical simulations in science and technology. The course focuses on fundamental ideas and algorithmic aspects of numerical methods. The exercises involve actual implementation of numerical methods in C++.
Objective

* Knowledge of the fundamental algorithms in numerical mathematics
* Knowledge of the essential terms in numerical mathematics and the techniques used for the analysis of numerical algorithms
* Ability to choose the appropriate numerical method for concrete problems
* Ability to interpret numerical results
* Ability to implement numerical algorithms efficiently

Content

* Direct Methods for linear systems of equations
* Least Squares Techniques
* Data Interpolation and Fitting
* Filtering Algorithms
* Approximation of Functions
* Numerical Quadrature
* Iterative Methods for non-linear systems of equations

Lecture notes

Lecture materials (PDF documents and codes) will be made available to participants.

Literature


M. Hanke-Bourgeois "Grundlagen der Numerischen Mathematik und des wissenschaftlichen Rechnens", BG Teubner, 2002

P. Deuflhard and A. Hohmann, "Numerische Mathematik l", DeGruyter, 2002

M. Hanke-Bourgeois "Grundlagen der Numerischen Mathematik und des wissenschaftlichen Rechnens", BG Teubner, 2002

Prerequisites / notice

Solid knowledge about fundamental concepts and techniques from linear algebra & calculus as taught in the first year of science and engineering curricula.

The course will be accompanied by programming exercises in C++ relying on the template library EIGEN. Familiarity with C++, object oriented and generic programming is an advantage. Participants of the course are expected to learn C++ by themselves.

Physics Master - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<td>Compulsory</td>
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Key for Hours

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<td>G</td>
<td>lecture with exercise</td>
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<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
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</table>

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Quantitative Finance Master

see www.msfinance.ch/index.html?portrait/Curriculum.html

Students in the Joint Degree Master's Programme "Quantitative Finance" must book University of Zurich modules directly at the University of Zurich. Those modules are not listed here.

► Core

►► FIN (Finance)

For possible (additional) course offerings see www.msfinance.ch

►► MF (Mathematical Methods in Finance)

For possible additional course offerings see www.msfinance.ch

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tr>
<td>401-3913-01L</td>
<td>Mathematical Foundations for Finance</td>
<td>W</td>
<td>4</td>
<td>3V+2U</td>
<td>D. Possamaï</td>
</tr>
<tr>
<td>Abstract</td>
<td>First introduction to main modelling ideas and mathematical tools from mathematical finance</td>
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<tr>
<td>Objective</td>
<td>This course gives a first introduction to the main modelling ideas and mathematical tools from mathematical finance. It mainly aims at non-mathematicians who need an introduction to the main tools from stochastics used in mathematical finance. However, mathematicians who want to learn some basic modelling ideas and concepts for quantitative finance (before continuing with a more advanced course) may also find this of interest. The main emphasis will be on ideas, but important results will be given with (sometimes partial) proofs.</td>
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<td>Content</td>
<td>Topics to be covered include</td>
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<td></td>
<td>- financial market models in finite discrete time</td>
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<td>- absence of arbitrage and martingale measures</td>
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<td>- valuation and hedging in complete markets</td>
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<td>- basics about Brownian motion</td>
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<td>- stochastic integration</td>
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<td>- stochastic calculus: Itô's formula, Girsanov transformation, Itô's representation theorem</td>
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<td></td>
<td>Black-Scholes formula</td>
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<tr>
<td>Lecture notes</td>
<td>See information on course homepage</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Results and facts from probability theory as in the book &quot;Probability Essentials&quot; by J. Jacod and P. Protter will be used freely. Especially participants without a direct mathematics background are strongly advised to familiarise themselves with those tools before (or very quickly) during the course. (A possible alternative to the above English textbook are the (German) lecture notes for the standard course &quot;Wahrscheinlichkeitslehre&quot;). For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.</td>
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<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<td>- Concepts and Theories</td>
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<td>- Decision-making</td>
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<td>- Problem-solving</td>
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<td>Personal Competencies</td>
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<td></td>
<td>- Adaptability and Flexibility</td>
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<td>- Creative Thinking</td>
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<td>- Critical Thinking</td>
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<td>- Integrity and Work Ethics</td>
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► Elective

►► FIN (Finance)

For possible additional course offerings see www.msfinance.ch

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>401-4633-00L</td>
<td>Data Analytics in Organisations and Business</td>
<td>W</td>
<td>5</td>
<td>2V+1U</td>
<td>I. Flückiger</td>
</tr>
<tr>
<td>Abstract</td>
<td>This lecture covers organizations and businesses’ end-to-end data analytics process and deepens each process stage. It shows why a stage is needed and what actions are taken in each stage. It gives steps successfully applied in practice and loopholes when issues arise. Case studies from various industries will be presented for each stage.</td>
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<tr>
<td>Objective</td>
<td>This course aims to give the students an understanding of the whole data analytics life cycle in the business world. It shows the expectations of companies and how it is measured. It enables the student to manage successfully all the non-methodological aspects of a data analytics project which are the primary source of failure in end-to-end executions. The student will become familiar with the &quot;business language, and cultural aspects of organizations. It also gives an overview of the data analytics tool, platform, and methods ecosystem for successfully technical data analyses.</td>
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<tr>
<td>Content</td>
<td>1) Introduction</td>
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<td></td>
<td>2) Framing the business problem</td>
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<td>3) Framing the analytics problem</td>
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<td>4) Data</td>
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<td>5) Identification of problem-solving approaches and appropriate tools</td>
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<td>6) How to set up and validate models</td>
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<td>7) The deployment of a model</td>
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<td>8) Model lifecycle</td>
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<td></td>
<td>9) Operating models and roles</td>
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<td></td>
<td>10) Some words about soft skills needed by statistical and mathematical professionals</td>
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<tr>
<td>Lecture notes</td>
<td>The lecture's presentation slides will be provided.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Basic statistics and probability theory and regression</td>
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363-0711-00L| Accounting for Managers                      | W    | 3     | 2V         | H. Chen          |
| Abstract    | The course Accounting for Managers offers an introduction to financial and managerial accounting, especially for students who aspire for a career in business and management with a science or engineering background. |
Objective

After attending the class, you should be able to:
- understand the accounting system, the reporting process, and be able to prepare financial statements
- feel comfortable reading and using the information presented in companies' annual reports
- understand cost concepts and conduct cost analyses
- become familiar with several classic decisions using managerial accounting information
- comment on the current events related to these topics

Content

Accounting plays a critical role in the effective functioning of the financial market as well as the long-term success of a company. This course intends to provide an introduction to accounting for those who wish to pursue a career in business, and need the skills and knowledge to understand, analyze, and interpret accounting information to make informed decisions. The course is divided into two parts. In the first part, we focus on financial reporting and start with the basic accounting concepts and the accounting cycle, to learn how the financial system is set up in a company and how financial statements are prepared. We then delve deeper into each major account, and discuss how revenues and expenses are recognized, and how assets, liabilities, and equities are reported. In the second part, we focus on managerial accounting for internal managerial/operational decisions including fundamental topics such as cost behavior, cost estimation, CVP analyses, and relevant costing. We then cover budgeting and standard costing, which are important parts of accounting system in companies.

Prerequisites / notice

This course is a prerequisite for the course Financial Management.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
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</thead>
<tbody>
<tr>
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</table>

363-1081-00L Asset Liability Management and Treasury Risks

Abstract

Asset Liability Management (ALM) is key to the financial success of any corporation. The goal is to develop a comprehensive understanding of the nature of corporate balance sheet and off-balance sheet positions and related profits and losses, including identification and mitigation of undue risks taken. This course is geared towards preparing students to apply these concepts in practical settings.

Objective

The main learning objectives of this course are:
- develop a comprehensive understanding of the nature of corporate balance sheet and off-balance sheet positions and their respective contribution to profits and losses
- measure and assess exposures to risk factors such as interest and FX rates, equity and commodity prices, as well as liquidity events
- trading and hedging to mitigate undue risks incurred

Content

The course is organized around a series of case studies. We will first discuss and develop an understanding of the fundamentals on different aspects of the management and risk management of the balance sheet. Using real life case studies each concept will then be directly applied and tested. In-class discussions, presentations and one written assignment are used to facilitate active and interactive learning in a stimulating environment. During the case studies students will frequently work in small groups. Therefore, the number of participants is limited to 40.

The course focuses on the application of finance concepts to the financial management of corporations and is geared towards preparing students to apply these concepts in practical settings. Executives of all sectors are expected to have a sound understanding of the content covered. As such, the course is not exclusively targeted at students who are considering a career in the financial services sector. It also recommended for students who want to work in the finance, treasury or risk area of corporates. It is also suitable for students who want to work for a consultancy firm.

Literature

No single textbook covers the course, below we list some useful references. Further materials will be made available to students prior to the lectures


Prerequisites / notice

Participants should have a basic understanding of financial management, gained, for example, from prior undergraduate economics, business, or accounting studies.

Competencies

<table>
<thead>
<tr>
<th>Concept-specific Competencies</th>
<th>Concepts and Theories</th>
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MF (Mathematical Methods in Finance)

For possible additional course offerings see www.msfinance.ch

Number | Title | Type | ECTS | Hours |
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<td>401-3925-00L</td>
<td>Non-Life Insurance: Mathematics and Statistics</td>
<td>W</td>
<td>8 credits</td>
<td>4V+1U</td>
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</tbody>
</table>

Abstract

The lecture aims at providing a basis in non-life insurance mathematics which forms a core subject of actuarial science. It discusses collective risk modeling, individual claim size modeling, approximations for compound distributions, ruin theory, premium calculation principles, tariffication with generalized linear models and neural networks, credibility theory, claims reserving and solvency.

Objective

The student is familiar with the basics in non-life insurance mathematics and statistics. This includes the basic mathematical models for insurance liability modeling, pricing concepts, stochastic claims reserving models and ruin and solvency considerations.
Content
The following topics are treated:
- Collective Risk Modeling
- Claim Counts Models
- Individual Claim Size Modeling
- Censoring and Truncation
- Approximations for Compound Distributions
- Ruin Theory in Discrete Time
- Premium Calculation Principles
- Tarification
- Generalized Linear Models and Neural Networks
- Bayesian Models and Credibility Theory
- Claims Reserving
- Solvency Considerations

Lecture notes
M.V. Wüthrich, Non-Life Insurance: Mathematics & Statistics
http://ssrn.com/abstract=2319328

Literature
M.V. Wüthrich, M. Merz. Statistical Foundations of Actuarial Learning and its Applications

Prerequisites / notice
The exams ONLY take place during the official ETH examination period (no semester end exams), and only in person exams (i.e. no remote exams).

This course will be held in English and counts towards the diploma of “Aktuar SAV”. For the latter, see details under www.actuaries.ch.

<table>
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<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Media and Digital Technologies</th>
<th>Problem-solving</th>
<th>Project Management</th>
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<td>Method-specific</td>
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<td>Lectures notes:</td>
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401-4889-00L Mathematical Finance W 10 credits 4V+2U B. Acciaio

Abstract
Advanced course on mathematical finance:
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- additional topics

Objective
Advanced course on mathematical finance, presupposing good knowledge in probability theory and stochastic calculus (for continuous processes)

Content
This is an advanced course on mathematical finance for students with a good background in probability. We want to give an overview of main concepts, questions and approaches, and we do this mostly in continuous-time models.

Topics include
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- and probably others

Lecture notes
The course is based on different parts from different books as well as on original research literature.

Literature
While there are many textbooks on mathematical finance, none of them is ideal to cover the contents of this course. References include the following books:


Prerequisites / notice
Prerequisites are the standard courses
- Probability Theory (for which lecture notes are available)
- Brownian Motion and Stochastic Calculus (for which lecture notes are available)

Those students who already attended "Introduction to Mathematical Finance" will have an advantage in terms of ideas and concepts.

This course is the second of a sequence of two courses on mathematical finance. The first course "Introduction to Mathematical Finance" (MF I), 401-3888-00, focuses on models in finite discrete time. It is advisable that the course MF I is taken prior to the present course, MF II.

For an overview of courses offered in the area of mathematical finance, see https://www.math.ethz.ch/imsl/education/education-in-stochastic-finance/overview-of-courses.html.
Numerical Solution of Stochastic Ordinary Differential Equations

Abstract
This course is on the numerical approximations of stochastic ordinary differential equations (SDEs) driven by Brownian motions and Lévy processes. SDEs have several applications, for example in financial engineering. The contents cover stochastic processes, stochastic calculus, well-posedness results for SDEs, strong and weak approximations of SDEs, and simulation via Monte Carlo methods.

Objective
The aim of this course is to enable the students to carry out simulations and their mathematical convergence analysis for stochastic models originating from applications such as mathematical finance. For this the course teaches a decent knowledge of the different numerical methods, their underlying ideas, convergence properties and implementation issues.

Content
- Brownian motion and Lévy processes
- Stochastic integration and stochastic calculus
- Stochastic ordinary differential equations (SDEs)
- Numerical approximations of SDEs
- Stochastic simulation and Monte Carlo methods
- Applications to computational finance: Option valuation

Lecture notes
There will be English, typed lecture notes for registered participants in the course.

Literature

Prerequisites / notice
Mandatory:
- Probability and measure theory, basic numerical analysis and basics of MATLAB/Python programming.

a) mandatory courses:
- Measure - and Probability Theory I
- as covered in courses:
  - ETH 401-2283-00L Analysis III (Measure Theory)
  - UZH Kursmodul 10496 Hauptvorlesung: Mass- und Integrationstheorie

b) recommended courses:
- Stochastic Processes I

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered
Financial Risk Management in Social and Pension Insurance

W 4 credits 2V P. Blum

Abstract
Investment returns are an important source of funding for social and pension insurance, and financial risk is an important threat to stability. We study short-term and long-term financial risk and its interplay with other risk factors, and we develop methods for the measurement and management of financial risk and return in an asset/liability context with the goal of assuring sustainable funding.

Objective
Understand the basic asset-liability framework: essential principles and properties of social and pension insurance; cash flow matching, duration matching, valuation portfolio and loose coupling; the notion of financial risk; long-term vs. short-term risk; coherent measures of risk.

Understand the conditions for sustainable funding: derivation of required returns; interplay between return levels, contribution levels and other parameters; influence of guaranteed benefits.

Understand the notion of risk-taking capability: capital process as a random walk; measures of long-term risk and relation to capital; short-term solvency vs. long-term stability; effect of embedded options and guarantees; interplay between required return and risk-taking capability.

Be able to study empirical properties of financial assets: the Normal hypothesis and the deviations from it; statistical tools for investigating relevant risk and return properties of financial assets; time aggregation properties; be able to conduct analysis of real data for the most important asset classes.

Understand and be able to carry out portfolio construction: the concept of diversification; limitations to diversification; correlation breakdown; incorporation of constraints; sensitivities and shortcomings of optimized portfolios.

Understand and interpret the asset-liability interplay; the optimized portfolio in the asset-liability framework; short-term risk vs. long-term risk; the influence of constraints; feasible and non-feasible solutions; practical considerations.

Understand and be able to address essential problems in asset / liability management, e.g. optimal risk / return positioning, optimal discount rate, target value for funding ratio or turnaround issues.

Have an overall view: see the big picture of what asset returns can and cannot contribute to social security; be aware of the most relevant outcomes; know the role of the actuary in the financial risk management process.

For pension insurance and other forms of social insurance, investment returns are an important source of funding. In order to earn these returns, substantial financial risks must be taken, and these risks represent an important threat to financial stability, in the long term and in the short term.

Risk and return of financial assets cannot be separated from one another and, hence, asset management and risk management cannot be separated either. Managing financial risk in social and pension insurance is, therefore, the task of reconciling the contradictory dimensions of

1. Required return for a sustainable funding of the institution,
2. Risk-taking capability of the institution,
3. Returns available from financial assets in the market,
4. Risks incurred by investing in these assets.

This task must be accomplished under a number of constraints. Financial risk management in social insurance also means reconciling the long time horizon of the promised insurance benefits with the short time horizon of financial markets and financial risk.

It is not the goal of this lecture to provide the students with any cookbook recipes that can readily be applied without further reflection. The goal is rather to enable the students to develop their own understanding of the problems and possible solutions associated with the management of financial risks in social and pension insurance.

To this end, a rigorous intellectual framework will be developed and a powerful set of mathematical tools from the fields of actuarial mathematics and quantitative risk management will be applied. When analyzing the properties of financial assets, an empirical viewpoint will be taken using statistical tools and considering real-world data.

Extensive handouts will be provided. Moreover, practical examples and data sets in Excel will be made available.

Solid base knowledge of probability and statistics is indispensable. Specialized concepts from financial and insurance mathematics as well as quantitative risk management will be introduced in the lecture as needed, but some prior knowledge in some of these areas would be an advantage.

This course counts towards the diploma of "Aktuar SAV".

The exams ONLY take place during the official ETH examination period.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Life Insurance Mathematics
W 4 credits 2V M. Koller

Abstract
The classical life insurance model is presented together with the important insurance types (insurance on one and two lives, term and endowment insurance and disability). Besides that the most important terms such as mathematical reserves are introduced and calculated. The profit and loss account and the balance sheet of a life insurance company is explained and illustrated.

Machine Learning in Finance and Insurance
W 5 credits 2V+1U P. Cheridito
Abstract
This course introduces machine learning methods that can be used in finance and insurance applications.

Objective
The goal is to learn methods from machine learning that can be used in financial and insurance applications.

Content
Linear, polynomial, logistic, ridge and lasso regression, dimension reduction methods, singular value decomposition, kernel methods, support vector machines, classification and regression trees, random forests, XGBoost, neural networks, stochastic gradient descent, autoencoders, graph neural networks, transformers, credit analytics, pricing, hedging, insurance claim prediction.

Lecture notes
Course material is available on https://people.math.ethz.ch/~patrickc/mlfi

Literature

Prerequisites / notice
The course requires basic knowledge in analysis, linear algebra, probability theory and statistics.

Competencies
- Subject-specific Competencies: Concepts and Theories, Techniques and Technologies, Analytical Competencies, Problem-solving, Project Management.
- Social Competencies: Adaptability and Flexibility, Creative Thinking, Critical Thinking, Integrity and Work Ethics, Self-direction and Self-management.
- Personal Competencies: Adaptability and Flexibility, Creative Thinking, Critical Thinking, Integrity and Work Ethics, Self-direction and Self-management.

401-3931-00L Responsible Machine Learning with Insurance Applications
W 4 credits 2G M. Mayer, C. Lorentzen-Geiser

Abstract
This lecture covers important aspects of applying supervised machine learning models in a responsible way, based on sound statistical theory. The focus is on model interpretability, calibration (bias) assessment, and proper model comparison. The methods are illustrated with actuarial datasets.

Objective
The student is familiar with the main tools of model interpretability, calibration assessment, and model comparison and knows how to apply supervised machine learning in a responsible way.

Content
- Overview of supervised machine learning (statistical learning theory, GLMs, tree based methods, and neural nets; cross-validation)
- Model interpretability methods (partial dependence plots, measures of variable importance, and SHAP)
- Bias/calibration assessment with identification functions
- Model comparison with consistent scoring functions
- Working with dependent observations and further topics

Prerequisites / notice
This course will be held in English and counts towards the diploma of "Aktuar SAV". For the latter, see details under www.actuaries.ch.

Competencies
- Subject-specific Competencies: Concepts and Theories, Techniques and Technologies, Analytical Competencies.
- Method-specific Competencies: fostered
- Personal Competencies: fostered

401-5820-00L Seminar in Computational Finance for CSE
W 4 credits 2S J. Teichmann

Prerequisites / notice
Requirements: sound understanding of stochastic concepts and of concepts of mathematical Finance, ability to implement econometric or simulation routines in Python.

Competencies
- Subject-specific Competencies: Concepts and Theories, Techniques and Technologies, Analytical Competencies.
- Personal Competencies: Negotiation, Adaptability and Flexibility, Creative Thinking, Critical Thinking, Integrity and Work Ethics, Self-awareness and Self-reflection, Self-direction and Self-management.
### Quantitative Finance Master - Key for Type

<table>
<thead>
<tr>
<th>Letter</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</table>

### Key for Hours

<table>
<thead>
<tr>
<th>Letter</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

### ECTS

- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Quantum Engineering Master

Core Courses

A minimum of 24 credits must be obtained from core courses during the MSc QE, course selection is subject to the tutor's agreement.

Quantum Technology Lab

This core course is a prerequisite for participation in the QuanTech Labs of the second and third semester.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
</table>

Abstract

In this course students will be exposed to different topics of quantum engineering and develop ideas for possible projects. Based on presentations by ETH labs participating in the MSc QE program and with the assistance of a mentor students will work in groups to develop concrete plans for a quantum experiment.

Objective

Acquire a broad overview of quantum engineering activities at ETH and develop own ideas about future quantum engineering projects.

Engineering Core Courses

These core courses target students with a physics background and all those who need additional engineering foundations.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0103-00L</td>
<td>Control Systems</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>F. Dörfler</td>
</tr>
</tbody>
</table>

Abstract

Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Objective

Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Content


Literature


Prerequisites / notice

MATLAB is used for system analysis and simulation.

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0116-00L</td>
<td>VLSI 1: HDL Based Design for FPGAs</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>F. K. Gürkaynak</td>
</tr>
</tbody>
</table>

Abstract

This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Objective

Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

Content

This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modelling.
- Organization and configuration of commercial-field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog.
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Lecture notes

Textbook and all further documents in English.

Literature


Prerequisites / notice

Prerequisites:
Basics of digital circuits.

Examination:
In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details:
https://lis-students.ee.ethz.ch/lectures/vlsi-1/
<table>
<thead>
<tr>
<th>227-0166-00L</th>
<th>Analog Integrated Circuits</th>
<th>W</th>
<th>6 credits</th>
<th>4G</th>
<th>T. Jang</th>
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<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems. The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors. The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Handouts of presented slides. No script but an accompanying textbook is recommended.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>Behzad Razavi, Design of Analog CMOS Integrated Circuits (Irwin Electronics &amp; Computer Engineering) 1st or 2nd edition, McGraw-Hill Education</td>
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<table>
<thead>
<tr>
<th>227-0301-00L</th>
<th>Optical Communication Fundamentals</th>
<th>W</th>
<th>6 credits</th>
<th>2V+1U+1P</th>
<th>J. Leuthold</th>
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</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.</td>
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<td><strong>Objective</strong></td>
<td>An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the important elements will be passed on. Students attending the lecture will further get engaged in critical discussion on societal, economical and environmental aspects related to the on-going exponential growth in the field of communications.</td>
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<tr>
<td><strong>Content</strong></td>
<td>* Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.</td>
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<td>* Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.</td>
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<td>* Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.</td>
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<td>* Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Lecture notes are handed out.</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>* Chapter 7: Optical Amplifiers : Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.</td>
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</tbody>
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<table>
<thead>
<tr>
<th>227-0417-00L</th>
<th>Information Theory I</th>
<th>W</th>
<th>6 credits</th>
<th>4G</th>
<th>A. Lapidoth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equipartition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The fundamentals of Information Theory including Shannon’s source coding and channel coding theorems</td>
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<tr>
<td><strong>Content</strong></td>
<td>The entropy rate of a source, Typical sequences, the asymptotic equipartition property, the source coding theorem, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity</td>
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<tr>
<td><strong>Literature</strong></td>
<td>T.M. Cover and J. Thomas, Elements of Information Theory (second edition)</td>
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</tbody>
</table>

### Physics Core Courses

These core courses target students with an engineering background and all those who need additional physics foundations.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>402-0205-00L</td>
<td>Quantum Mechanics I</td>
<td>W</td>
<td>8 credits</td>
<td>3V+2U</td>
<td>A. Messiah, M. Krstic Marinkovic</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Quantum BSc students with programme regulations 2016 need to register for “402-0205-10L Quantummechanik I”</td>
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</tr>
<tr>
<td><strong>Content</strong></td>
<td>Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems. The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradoxon and Bell's inequality); Perturbation theory.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Auk Moodle</td>
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</tbody>
</table>
**Quantum Physics for Non-Physicists**

**402-0209-00L**

**Abstract**
This is an introduction to the physics of quantum mechanics following an information-theoretical approach. We start from the basic postulates, study the behaviour of quantum systems from a single spin to entangled particles in space, and connect the learnings to groundbreaking experiments from the past and the present. This course is well-suited for students with little background in physics.

**Objective**
This course teaches the basics of quantum physics, and complements courses in quantum computation and information theory. Students are equipped with tools to tackle complex quantum mechanical problems and foundational questions. The course covers approximately the same content as QM1, but from an information-driven perspective.

**Content**
Quantum formalism, from qubits to particles in space; Time and dynamics for quantum systems; Problems in 1D; Uncertainty and open systems; Spin; Problems in 3D; Non-locality and foundational aspects of quantum theory

**Lecture notes**
Lecture notes will be provided.

**Literature**
Quantum Processes Systems, and Information, by Benjamin Schumacher and Michael Westmoreland, available at [https://www.cambridge.org/core/books/quantum-processes-systems-and-information/4E459E64E1EE7121CA2321435FAECC8A](https://www.cambridge.org/core/books/quantum-processes-systems-and-information/4E459E64E1EE7121CA2321435FAECC8A)

**Prerequisites / notice**
This course is aimed at non-physicists, and in particular at students with a background in computer science, mathematics or engineering. Basic linear algebra and calculus knowledge is required (equivalent to first-year courses). Physics knowledge is not required. Physicists and students from a different background than outlined above are welcome at their own risk.

Note that while we follow an information-theoretical approach, this is not a course on quantum information theory or quantum computing. It therefore complements those courses offered at ETH Zurich.

This course can be taken in parallel to Quantum Information Processing I & II.

**Competencies**

---

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: assessed

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**Introduction to Solid State Physics**

**402-0255-00L**

**Abstract**
The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, electronic properties of insulators, metals, semiconductors, transport properties, and magnetism.

**Objective**
Introduction to Solid State Physics.

**Content**
The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, thermal properties of insulators; metals (classical and quantum mechanical description of electronic states, thermal and transport properties of metals); semiconductors (bandstructure and n/p-type doping); magnetism.

**Lecture notes**
The script will be available on moodle.
Subject-specific Competencies fostered

A. Imamoglu

Analytical Competencies assessed

Text-books:

- Quantum Information Processing II: Implementations
- Quantum Computation and Quantum Information
- Concepts and Theories

This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics covered include the quantum nature of light, semi-classical and quantum mechanical description of light-matter interaction, laser manipulation of atoms and ions, optomechanics and quantum computation.

Objective
The course aims to provide the knowledge necessary for pursuing research in the field of Quantum Optics. Fundamental concepts and techniques of Quantum Optics will be linked to modern experimental research. During the course the students should acquire the capability to understand currently published research in the field.

Content
This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics that are covered include:

- coherence properties of light
- quantum nature of light: statistics and non-classical states of light
- light matter interaction: density matrix formalism and Bloch equations
- quantum description of light matter interaction: the Jaynes-Cummings model, photon blockade
- laser manipulation of atoms and ions: laser cooling and trapping, atom interferometry,
- further topics: Rydberg atoms, optomechanics, quantum computing, complex quantum systems.

Lecture notes
Selected book chapters will be distributed.

Literature

G. Gryenberg, A. Aspect and C. Fabre, Introduction to Quantum Optics
R. Loudon, The Quantum Theory of Light
Atomic Physics, Christopher J. Foot
Advances in Atomic Physics, Claude Cohen-Tannoudji and David Guéry-Odelin
C. Cohen-Tannoudji et al., Atom-Photon-Interactions
M. Scully and M.S. Zubairy, Quantum Optics
Y. Yamamoto and A. Imamoglu, Mesoscopic Quantum Optics

Competencies

Concepts and Theories assessed

Concepts and Theories

Techniques and Technologies assessed

Techniques and Technologies

Analytical Competencies assessed

Analytical Competencies

Decision-making assessed

Decision-making

Problem-solving assessed

Problem-solving

Creative Thinking assessed

Creative Thinking

Critical Thinking assessed

Critical Thinking

Integrity and Work Ethics fostered

Integrity and Work Ethics

Personal Competencies fostered

Personal Competencies

Method-specific Competencies fostered

Method-specific Competencies

Social Competencies fostered

Social Competencies

Cooperation and Teamwork fostered

Cooperation and Teamwork

Creative Thinking assessed

Creative Thinking

Critical Thinking fostered

Critical Thinking

Method-specific Competencies

Quantum Optics W 10 credits 3V+2U A. Imamoglu

Quantum Optics

Quantum Optics

402-0442-00L

10 credits

10 credits

A. Imamoglu

This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics covered include:

- coherence properties of light
- quantum nature of light: statistics and non-classical states of light
- light matter interaction: density matrix formalism and Bloch equations
- quantum description of light matter interaction: the Jaynes-Cummings model, photon blockade
- laser manipulation of atoms and ions: laser cooling and trapping, atom interferometry,
- further topics: Rydberg atoms, optomechanics, quantum computing, complex quantum systems.

Lecture notes
Selected book chapters will be distributed.

Literature

G. Gryenberg, A. Aspect and C. Fabre, Introduction to Quantum Optics
R. Loudon, The Quantum Theory of Light
Atomic Physics, Christopher J. Foot
Advances in Atomic Physics, Claude Cohen-Tannoudji and David Guéry-Odelin
C. Cohen-Tannoudji et al., Atom-Photon-Interactions
M. Scully and M.S. Zubairy, Quantum Optics
Y. Yamamoto and A. Imamoglu, Mesoscopic Quantum Optics

Competencies

Concepts and Theories assessed

Concepts and Theories

Techniques and Technologies assessed

Techniques and Technologies

Analytical Competencies assessed

Analytical Competencies

Decision-making assessed

Decision-making

Problem-solving assessed

Problem-solving

Creative Thinking assessed

Creative Thinking

Critical Thinking assessed

Critical Thinking

Integrity and Work Ethics fostered

Integrity and Work Ethics

Personal Competencies fostered

Personal Competencies

Method-specific Competencies fostered

Method-specific Competencies

Social Competencies fostered

Social Competencies

Cooperation and Teamwork fostered

Cooperation and Teamwork

Creative Thinking assessed

Creative Thinking

Critical Thinking fostered

Critical Thinking

Method-specific Competencies

Quantum Information Processing I: Concepts W 5 credits 2V+1U J. Renes

Quantum Information Processing I: Concepts

Quantum Information Processing I: Concepts

402-0448-01L

5 credits

5 credits

J. Renes

This course will cover the key concepts and formalism of quantum information processing. Topics include quantum algorithms, quantum error correction, quantum cryptography, and quantum metrology, with an emphasis on the power of quantum information processing beyond that of classical information processing. The formalism of quantum states, measurements, and channels is developed in detail.

Objective
By the end of the course students are able to explain the basic mathematical formalism of quantum mechanics and apply it to quantum information processing problems. They are able to adapt and apply these concepts and methods to analyze and discuss quantum algorithms and other quantum information-processing protocols.

Content
The topics covered in the course will include quantum circuits, gate decomposition and universal sets of gates, efficiency of quantum circuits, quantum algorithms (Shor, Grover, Deutsch-Josza,...), stabilizer-based quantum error correction, fault-tolerant designs, the BB84 quantum key distribution protocol, and simple methods of quantum metrology.

Lecture notes
Will be provided.

Literature

Quantum Computation and Quantum Information
Michael Nielsen and Isaac Chuang
Cambridge University Press

Prerequisites / notice
A good understanding of finite dimensional linear algebra is recommended.

Competencies

Concepts and Theories assessed

Concepts and Theories

Techniques and Technologies assessed

Techniques and Technologies

Analytical Competencies assessed

Analytical Competencies

Decision-making assessed

Decision-making

Problem-solving assessed

Problem-solving

Creative Thinking assessed

Creative Thinking

Critical Thinking fostered

Critical Thinking

Integrity and Work Ethics fostered

Integrity and Work Ethics

Personal Competencies fostered

Personal Competencies

Method-specific Competencies

Quantum Information Processing II: Implementations W 5 credits 2V+1U A. Wallraff, J.-C. Besse

Quantum Information Processing II: Implementations

Quantum Information Processing II: Implementations

402-0448-02L

5 credits

5 credits

A. Wallraff, J.-C. Besse

This experimental part QIP II together with the theory part

402-0448-02L

Quantum Information Processing II: Implementations

Quantum Information Processing II: Implementations

Autumn Semester 2024
Statistical Physics

- Quantum bits
- Coherent Control
- Measurement
- Decoherence
- QIP with Ions
- Superconducting Circuits
- Photons
- NMR
- Rydberg atoms
- NV-centers
- Quantum dots

Lecture notes
Lecture notes course material be made available at www.qudev.ethz.ch and on the Moodle platform for the course. More details to follow.

Literature
Quantum Computation and Quantum Information
Michael Nielsen and Isaac Chuang
Cambridge University Press

Prerequisites / notice
The class will be taught in English language.

Basic knowledge of concepts of quantum physics and quantum systems, e.g from courses such as Physics III, Quantum Mechanics I and II or courses on topics such as atomic physics, solid state physics, quantum electronics are considered helpful.

More information on this class can be found on the web site www.qudev.ethz.ch

402-0861-00L Statistical Physics

402-0861-00L Statistical Physics

W 10 credits 4V+2U

M. Sigrist

Abstract
This lecture covers the concepts of classical and quantum statistical physics. Several techniques such as second quantization formalism for fermions, bosons, photons and phonons as well as mean field theory and self-consistent field approximation. These are used to discuss phase transitions, critical phenomena and superfluidity.

Objective
This lecture gives an introduction in the basic concepts and applications of statistical physics for the general use in physics and, in particular, as a preparation for the theoretical solid state physics.

Content
Kinetic approach to statistical physics: H-theorem, detailed balance and equilibrium conditions.

Classical statistical physics: microcanonical ensembles, canonical ensembles and grandcanonical ensembles, applications to simple systems.

Quantum statistical physics: density matrix, ensembles, Fermi gas, Bose gas (Bose-Einstein condensation), photons and phonons.

Identical quantum particles: many body wave functions, second quantization formalism, equation of motion, correlation functions, selected applications, e.g. Bose-Einstein condensate and coherent state, phonons in elastic media and melting.

One-dimensional interacting systems.

Phase transitions: mean field approach to Ising model, Gaussian transformation, Ginzburg-Landau theory (Ginzburg criterion), self-consistent field approach, critical phenomena, Peierls' arguments on long-range order.


Lecture notes
Lecture notes available in English.

Literature
No specific book is used for the course. Relevant literature will be given in the course.

Prerequisites / notice
Knowledge in basic thermodynamics and quantum mechanics.

Competencies

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
  - Analytical Competencies
  - Problem-solving
  - Adaptability and Flexibility
  - Creative Thinking

- Method-specific Competencies
  - assessed
  - fostered

- Personal Competencies
  - assessed
  - fostered

 Courses

- Statistical Physics
  - W 10 credits 4V+2U
  - M. Sigrist
  - Introduction to statistical physics. Several techniques such as second quantization formalism for fermions, bosons, photons and phonons as well as mean field theory and self-consistent field approximation. These are used to discuss phase transitions, critical phenomena and superfluidity.
  - The class will be taught in English language.
  - More information on this class can be found on the web site www.qudev.ethz.ch

Autumn Semester 2024

Electives
This is a selection of courses particularly suitable for the MSc QE. In agreement with the tutor, students may choose other courses from the ETH course catalogue.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0053-00L</td>
<td>High-Frequency Design</td>
<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>C. Bolognesi, T. Popovic</td>
</tr>
<tr>
<td></td>
<td>Techniques</td>
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</table>

Abstract
Introduction to the basics of high-frequency circuit design techniques used in the realization of high-bandwidth communication systems and devices. Modern society depends on increasingly large data masses that need to be transmitted/processed as rapidly as possible: higher carrier frequencies allow wider bandwidth channels which enable higher data transmission rates.

Objective
Familiarize students with the essential tools and principles exploited in the high-frequency design. Introduction to circuit simulation. Introduction to amplifier design.

Content
Introduction to wireless, radio spectrum. Review of vectors and complex numbers, AC circuit analysis, matching networks, distributed circuit design, transmission lines and transmission line equations, reflection coefficients, the Smith Chart and its software, voltage standing wave ratio (VSWR), skin effect, matrix analysis, scattering parameters, electromagnetic fields and waves, amplifier design. Hands-on experience with measurement equipment.

Concepts and Theories

Techniques and Technologies

Assessed

Analytical Competencies

Problem-solving

Assessed

Communication

Cooperation and Teamwork

Assessed

Creative Thinking

Critical Thinking

Assessed

Discrete-Time and Statistical Signal Processing

W 6 credits 4G

H.-A. Loeliger

The course is about some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.

Solid State Electronics and Optics

W 6 credits 4G

N. Yazdani, V. Wood

"Solid State Electronics" is an introductory condensed matter physics course covering crystal structure, electron models, classification of metals, semiconductors, and insulators, band structure engineering, thermal and electronic transport in solids, magnetoresistance, and optical properties of solids.

Data Conversion System Design

W 6 credits 2V+2U

T. Burger, G. Cervelli, R. Reutemann

This course provides a thorough treatment of integrated data conversion systems from system level specifications and trade-offs, over architecture choice down to circuit implementation.

Semiconductor Devices: Physical Bases and Simulation

W 4 credits 3G

A. Schenk, C. R. Roman

It is highly recommended to attend the course "Analog Integrated Circuits" of Prof. T. Jang as a preparation for this course.
Abstract
The course addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical simulation. Necessary basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided. Computer simulations of the most important devices and of interesting physical effects supplement the lectures.

Objective
The course aims at the understanding of the principle physics of modern semiconductor devices, of the foundations in the physical modeling of transport and its numerical simulation. During the course also basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided.

Content
The main topics are: transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model, hydrodynamic model), physical characterization of silicon (intrinsinc properties, scattering processes), mobility of cold and hot carriers, recombination (Shockley-Read-Hall statistics, Auger recombination), impact ionization, metal-semiconductor contact, metal-insulator-semiconductor structure, and heterojunctions. The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

Lecture notes
The script (in book style) can be downloaded from: https://tis-students.ee.ethz.ch/lectures/227-0225-00L/notice

Literature
The script (in book style) is sufficient. Further reading will be recommended in the lecture.

Literature

Prerequisites

227-0166-00L Analog Integrated Circuits

Abstract
This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies.

Objective
Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

Content
The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.

Lecture notes
Handouts of presented slides. No script but an accompanying textbook is recommended.

Literature

227-0225-00L Linear System Theory

Abstract
The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.

Objective
Students should be able to formulate fundamental results in linear system theory to analyze and control linear dynamical systems.

Content
- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

Lecture notes
Available on the course Moodle platform.

Prerequisites
Sufficient mathematical maturity, in particular in linear algebra, analysis.

Competencies
Subject-specific Competencies

Method-specific Competencies

Personal Competencies

227-0311-00L Qubits, Electrons, Photons

Abstract
In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis).

Objective
Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics. Starting from the axioms of quantum mechanics, we will derive the fascinating theory describing spin and qubits, electron transitions and transfer, photons and LASER: quantum mechanics is different because it mocks our daily Euclidean intuition!

In this way, students will work out a robust quantum mechanics (theoretical!!!) basis which will help them in their advanced studies of the following masters: EET (batteries), Biomedical Engineering (NMR, bioelectronics), Quantum Engineering, Micro- and Nanosystems.

Content
- Lagrangian and Hamiltonian: Symmetries and Poisson Brackets
- Postulates of GM: Hilbert Spaces and Operators
- Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator
- Density Operator
- Spin: Qubits, Bloch Equations, and NMR
- Entanglement
- Symmetries and Corresponding Operators
- Schrödinger’s Wave Mechanics: Electrons in a Periodic Potential and Energy Bands
- Harmonic Oscillator: Creation and Annihilation Operators
- Identical Particles: Bosons and Fermions
- Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER
- Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener
No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM, while corresponding videos of the previous years are available in Moodle !!!


Supplementary material will be uploaded in Moodle.

+ (as rigorous and profound presentation of the mathematical framework) G. Dell’Antonio, "Lectures on the Mathematics of Quantum Mechanics I", 2015, Springer

+ (as account of those formidable years) G. Gamow, "Thirty Years that Shook Physics", 1985, Dover Publications Inc.

The course has been intentionally conceived to be self-consistent with respect to QM for those master students not having encountered it in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) QM introduction course like the D-ITET "Physics II".

A solid base of Analysis I & II as well as of Linear Algebra is really helpful.

Suitable for Master Students as well as Doctoral Students.

This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers.

This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers. The way the exam is done allows for the different interests of the two groups.

The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during the whole term to analyze circuits on a system level (analog continuous-time, analog discrete-time, mixed-signal and digital) and understand how signals propagate through them. The theory and CMOS implementation of active Filters is then discussed in detail using the example of gm-C filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators follows. The link to the practical design of circuits and systems is done with an overview over different quality measures and figures of merit used in scientific literature and datasheets. Finally, an introduction to discrete-time and mixed-domain filters and circuits is given, including sensor read-out amplifiers, correlated double sampling, and chopping, and an introduction to sigma-delta A/D and D/A conversion on a system level.

This lecture does not go down to the details of transistor implementations. The lecture "227-0166-00L Analog Integrated Circuits" complements This lecture very well in that respect.

The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the technical content.

Details: https://people.ee.ethz.ch/~haschmid/asfwiki/

The graph methods are also supported with teaching videos: https://tube.switch.ch/channels/d206c96c?order=episodes , and a Python-based open-source tool to manipulate graphs is available on https://github.com/hanspi42/signalflowgrapher

Some material is protected by password; students from ETHZ who are interested can write to haschmid@ethz.ch to ask for the password even if they do not attend the lecture.

Prerequisites / notice

Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.

Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria ...) and of the main properties of linear systems is necessary.
The lecture will treat the following chapters:

- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation
- Adaptable and Flexible
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

The reference book for the lecture is "Quantum Cascade Lasers" by Jerome Faist, published by Oxford University Press.

The goal of this lecture is to explore both the rich physics as well as the application of these system for sources and detectors. In fact, devices based on intersubband transitions are now unlocking large area of the electromagnetic spectrum.

**Prerequisites / notice**
1. Electrodynamics
2. Physics 1,2
3. Introduction to quantum mechanics

The lecture will treat the following chapters:

- Introduction: intersubband optoelectronics as an example of quantum engineering
- Technological aspects
- Electronic states in semiconductor quantum wells
- Intersubband absorption and scattering processes
- Mid-IR and THz ISB Detectors
- Mid-infrared and THz photonics: waveguides, resonators, metamaterials
- Quantum Cascade lasers:
  - Mid-IR QCLs
  - THz QCLs (direct and non-linear generation)
- Further electronic confinement: interlevel Qdot transitions and magnetic field effects
- Strong light-matter coupling in Mid-IR and THz range

**Literature**
Mostly the original articles, other useful reading can be found in:
- E. Rosencher and B. Vinter, Optoelectronics, Cambridge Univ. Press
- G. Bastard, Wave mechanics applied to semiconductor heterostructures, Halsted press

**Competencies**

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
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<td></td>
<td>Decision-making</td>
<td>Media and Digital Technologies</td>
<td>Project Management</td>
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<td>Media and Digital Technologies</td>
<td>Problem-solving</td>
<td>Leadership and Responsibility</td>
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<td></td>
<td>Problem-solving</td>
<td>Negotiation</td>
<td>Self-direction and Self-management</td>
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</tbody>
</table>

**Prerequisites / notice**

- A basic knowledge of solid-state physics and of quantum electronics.

**Literature**

- G. Scalari, Intersubband Optoelectronics, W 6 credits 2V+1U 4 credits 2V+1U 6 credits
- M. Frimmer, Quantum Measurements and Optomechanics, W 4 credits

**Abstract**

The lecture will treat the following chapters:

- Introduction: intersubband optoelectronics as an example of quantum engineering
- Technological aspects
- Electronic states in semiconductor quantum wells
- Intersubband absorption and scattering processes
- Mid-IR and THz ISB Detectors
- Mid-infrared and THz photonics: waveguides, resonators, metamaterials
- Quantum Cascade lasers:
  - Mid-IR QCLs
  - THz QCLs (direct and non-linear generation)
- Further electronic confinement: interlevel Qdot transitions and magnetic field effects
- Strong light-matter coupling in Mid-IR and THz range

**Prerequisites / notice**

- G. Scalari, Intersubband Optoelectronics, W 6 credits 2V+1U 4 credits 2V+1U 6 credits
- M. Frimmer, Quantum Measurements and Optomechanics, W 4 credits
<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Prerequisites / Notice</th>
</tr>
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<tbody>
<tr>
<td>252-0836-00L</td>
<td>Computer Science II</td>
<td>4</td>
<td>Understanding design, analysis and implementation of fundamental algorithms and data structures, including graph theory and graph problems. It also introduces generic and parallel programming.</td>
</tr>
<tr>
<td>201-0563-01L</td>
<td>Dynamic Programming and Optimal Control</td>
<td>4</td>
<td>Covers the fundamental concepts of Dynamic Programming &amp; Optimal Control.</td>
</tr>
<tr>
<td>227-0663-00L</td>
<td>Nano-Optics</td>
<td>6</td>
<td>Nano-Optics is the study of light-matter interaction at the sub-wavelength scale. Nano-optics embraces topics such as plasmonics, optical antennas, optical trapping and manipulation, and high/super-resolution imaging and spectroscopy.</td>
</tr>
</tbody>
</table>

**Objective**
- Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real-world data.
- The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

**Content**
- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory
- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
- Learning Dynamical Systems
- Non-parametric density estimation
- Learning Dynamical Systems

**Literature**
- The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.
- Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

**Prerequisites / Notice**
- PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2115 of 2653

Lecture notes
All material (slides, lecture recordings, examples, exercises, etc.) will be published on the course website.

Prerequisites / notice
Prerequisite: Computer Science I

Abstract
This course gives an introduction into the fundamentals of semiconductor materials. The main focus is on state-of-the-art fabrication and characterization methods. The course will be continued in the spring term with a focus on applications.

Objective
Basic knowledge of semiconductor physics and technology. Application of this knowledge for state-of-the-art semiconductor device processing

Content
1. Fundamentals of Solid State Physics
   1.1 Semiconductor materials
   1.2 Band structures
   1.3 Carrier statistics in intrinsic and doped semiconductors
   1.4 p-n junctions
   1.5 Low-dimensional structures
2. Bulk Material growth of Semiconductors
   2.1 Czochalski method
   2.2 Floating zone method
   2.3 High pressure synthesis
3. Semiconductor Epitaxy
   3.1 Fundamentals of Epitaxy
   3.2 Molecular Beam Epitaxy (MBE)
   3.3 Metal-Organic Chemical Vapor Deposition (MOCVD)
   3.4 Liquid Phase Epitaxy (LPE)
4. In situ characterization
   4.1 Pressure and temperature
   4.2 Reflectometry
   4.3 Ellipsometry and RAS
   4.4 LEED, AES, XPS
   4.5 STM, AFM
5. The invention of the transistor - Christmas lecture

Lecture notes
https://moodle-app2.let.ethz.ch/course/view.php?id=20749

Prerequisites / notice
The "compulsory performance element" of this lecture is a short presentation of a research paper complementing the lecture topics. Several topics and corresponding papers will be offered on the moodle page of this lecture.
Introduction to ultrafast laser physics with an outlook into cutting edge research topics such as attosecond science and coherent ultrafast sources from THz to X-rays.

Understanding of basic physics and technology for pursuing research in ultrafast laser science. How are ultrashort laser pulses generated, how do they interact with matter, how can we measure these shortest man-made events and how can we use them to time-resolve ultrafast processes in nature? Fundamental concepts and techniques will be linked to a selection of hot topics in current research and applications.

The aim of the lecture is to deepen and broaden the knowledge about current research in the field of quantum optics. In addition, it will also foster the assessment of an arXiv paper in the style of a referee report.

The interactive part of the lecture will include presentations of recent papers, panel discussions of recent papers and the writing of a critical assessment of an arXiv paper in the style of a referee report.
### Dissipative Quantum Systems

- **Compilants**
  - Subject-specific Competencies
  - Concepts and Theories
  - Social Competencies
  - Communication
  - Personal Competencies
  - Creative Thinking
- **Course Details**
  - Course Code: 402-0444-00L
  - Title: Dissipative Quantum Systems
  - Credits: 6
  - Weekly Hours: 2V+1U
  - Instructor: A. Imamoglu
- **Abstract**
  - This course builds up on the material covered in the Quantum Optics course. The emphasis will be on quantum optics in condensed-matter systems.
- **Objective**
  - The purpose of the course is to provide knowledge necessary for pursuing advanced research in the field of Quantum Optics in condensed matter systems. Fundamental concepts and techniques of Quantum Optics will be linked to experimental research in systems such as quantum dots, exciton-polaritons, quantum Hall fluids and graphene-like materials.
- **Content**
- **Lecture notes**
  - Lecture notes will be provided.
- **Literature**
  - C. Cohen-Tannoudji et al., Atom-Photon-Interactions (recommended)
  - Y. Yamamoto and A. Imamoglu, Mesoscopic Quantum Optics (recommended)
  - A collection of review articles (will be pointed out during the lecture)
- **Prerequisites**
  - Masters level quantum optics knowledge
  - Subject-specific Competencies
    - Concepts and Theories
    - Analytical Competencies
    - Problem-solving
    - Cooperation and Teamwork
    - Creative Thinking
    - Critical Thinking

### Quantum Technologies for Searches of New Physics

- **Compilants**
  - Subject-specific Competencies
  - Concepts and Theories
  - Method-specific Competencies
  - Analytical Competencies
  - Problem-solving
  - Social Competencies
  - Cooperation and Teamwork
  - Personal Competencies
  - Creative Thinking
- **Course Details**
  - Course Code: 402-0457-00L
  - Title: Quantum Technologies for Searches of New Physics
  - Credits: 6
  - Weekly Hours: 2V+1U
  - Instructor: P. Crivelli
- **Abstract**
  - Recent years have witnessed incredible progress in the development of new quantum technologies driven by their application in quantum information, metrology, high precision spectroscopy and quantum sensing. This course will present how these emerging technologies are powerful tools to address open questions of the Standard Model in a complementary way to what is done at the high energy frontier.
- **Objective**
  - The aim of the course is to equip students of different backgrounds with a solid base to follow this rapidly developing and exciting multidisciplinary field.
- **Content**
  - The first lectures will be dedicated to review the open questions of the Standard Model and the different Beyond Standard Model extensions which can be probed with quantum technologies. This will include searches for dark sector, dark matter, axion and axion-like particles, new gauge bosons (e.g. Dark photons) and extra short-range forces.
- **Prerequisites**
  - The preceding attendance of introductory particle physics, quantum mechanics and quantum electronics courses at the bachelor level is recommended.
  - Subject-specific Competencies
    - Concepst and Theories
    - Analytical Competencies
    - Problem-solving
    - Social Competencies
    - Cooperation and Teamwork
    - Personal Competencies
    - Creative Thinking

### Light-Matter Interaction in Semiconductors: Physics and Applications

- **Compilants**
  - Subject-specific Competencies
  - Concepts and Theories
  - Social Competencies
  - Creative Thinking
- **Course Details**
  - Course Code: 402-0464-00L
  - Title: Light-Matter Interaction in Semiconductors: Physics and Applications
  - Credits: 8
  - Weekly Hours: 2V+2U
  - Instructor: T. Smolenski, A. Dikopoltsev
- **Abstract**
  - The course presents fundamental aspects of light-matter interaction in semiconductor materials, from basic research topics to opto-electronic devices.
- **Objective**
  - The rich physics of the optical properties of semiconductors, as well as the advanced processing available on these materials, enabled numerous applications as well as the realization of new physical concepts. In this course, we will learn the principles of light-matter interaction in semiconductors for single and multiple particle excitations, and cover opto-electronic applications based on these principles.
- **Content**
  - Fundamental concepts and techniques of Quantum Optics will be linked to experimental research in systems such as quantum dots, exciton-polaritons, quantum Hall fluids and graphene-like materials.
- **Prerequisites**
  - Prerequisites: Quantum Mechanics II, Introduction to Solid State Physics, Quantum Electronics

### Nanomaterials for Photonic Devices

- **Compilants**
  - Social Competencies
  - Communication
  - Personal Competencies
  - Creative Thinking
- **Course Details**
  - Course Code: 402-0468-15L
  - Title: Nanomaterials for Photonic Devices
  - Credits: 6
  - Weekly Hours: 2V+1U
  - Instructor: R. Grange, E. Baillie, R. Chapman, V. Falcone, A. Morandi
- **Abstract**
  - The lecture describes various nanomaterials (semiconductor, metal, dielectric, carbon-based...) for photonic applications (optoelectronics, plasmonics, photonic integrated circuits, ordered and disordered structures...). It starts with concepts of light-matter interactions, fabrication and characterization, the description of the properties and the state-of-the-art applications and devices.
- **Objective**
  - The students will acquire theoretical and experimental knowledge about the different types of nanomaterials (semiconductors, metals, dielectric, carbon-based, ...) and their uses as building blocks for advanced applications in photonics (optoelectronics, plasmonics, photonic crystal, ...). Together with the exercises, the students will learn (1) to read, summarize and discuss scientific articles related to the lecture, (2) to estimate order of magnitudes with calculations using the theory seen during the lecture, (3) to prepare a short oral presentation and report about one topic related to the lecture, and (4) to imagine an original photonic device.
1. Introduction to nanophotonics
2. Wave physics for nanophotonics
3. Characterization of nanomaterials
4. Semiconductors
5. Nonlinear crystals
6. Photonic integrated circuits
7. Optical quantum devices
8. Plasmonics
9. Metasurfaces
10. Graphene & 2D Materials
11. Nanocomposites

Lecture notes
Slides and book chapter will be available for downloading

Literature
References will be given during the lecture

Prerequisites / notice
Basics of solid-state physics (i.e. energy bands) can help

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Decision-making fostered

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Leadership and Responsibility fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

402-0469-67L Classical and Quantum Parametric Phenomena W 6 credits 3G A. Eichler, A. Grimm

Abstract
There are numerous physical phenomena that rely on time-dependent Hamiltonians (or parametric driving) to amplify, cool, squeeze or couple resonating systems. In this course, we will introduce parametric phenomena in different fields of physics, ranging from classical engineering ideas to devices proposed for quantum computing.

Objective
This course is intended for
- Experimentalists who desire to gain a solid theoretical understanding of nonlinear driven-dissipative systems,
- Theorists looking to enter a topical new field,
- Any scientist interested to learn what lies beyond the harmonic resonator.

In the course, the students will grasp the ubiquitous nature of parametric phenomena and apply it to both classical and quantum systems. The students will understand both the theoretical foundations leading to the parametric drive as well as the experimental aspect related to the realizations of the effect. Each student will analyze an independent system using the tools acquired in the course and will present his/her insights to the class.

Content
This course will provide a general framework for understanding and linking various phenomena, ranging from the child-on-a-swing problem to quantum-limited amplifiers, to optical frequency combs, and to optomechanical sensors used in the LIGO experiment. The course will combine theoretical lectures and the study of important experiments through literature.

The students will receive an extended lecture summary as well as numerous Python scripts, including some that are base on the QuTiP library. These tools will enable them to apply analytical and numerical methods to a wide range of systems beyond the duration of the course.

Lecture notes
A full script will be available in the form of chapters from a dedicated book ("Classical and Quantum Parametric Phenomena").

Prerequisites / notice
The students should be familiar with wave mechanics as well as second quantization. Following the course requires a laptop with Python installed to run Jupyter notebooks, including the QuTiP library.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management assessed

402-0492-00L Experimental Techniques in Quantum and Electro-Optics W 6 credits 2V+1U

Abstract
We will cover experimental issues in making measurements in modern physics experiments. The primary challenge in any measurement is achieving good signal to noise. We will cover areas such as optical propagation, electronics, noise limits and feedback control. Methods for stabilizing frequencies and intensities of laser systems will also be described.
Objective
I aim to give an in depth understanding of experimental issues for students wishing to work on experimental science. The methods covered are widely applicable in modern physics, since light and electronics are the primary methods by which measurements are made across the field.

Content
The course will cover a number of different areas of experimental physics, including
- Optical elements and propagation
- Electronics and Electronic Noise
- Optical Detection
- Control Theory

Examples from a modern quantum information laboratory will be discussed and illustrated through active devices in the lecture.

Abstract
This course tackles the fundamental question of why only a few materials exhibit magnetism in Nature. The origin of atomic magnetic moments and the key mechanisms that govern their interactions are justified starting from fundamental principles. In addition, the influence of thermal fluctuations on magnetic ordering is discussed as well as the formalism to describe magnetic resonance phenomena.

Objective
By the end of this course, students will develop the ability to utilize quantum mechanics concepts to estimate the strength of atomic magnetic moments and understand their reciprocal interactions. They will gain proficiency in interpreting experimental measurements on model systems in terms of material composition and an appropriate, phenomenological spin Hamiltonian. For instance, students will be able to recognize whether the magnetic hysteresis observed in some samples arises from slow dynamics or from a phase transition. Lastly, they will be capable of interpreting the occurrence of abrupt transitions or the emergence of characteristic length scales as resulting from the interplay between competing interactions. Altogether, students will acquire the basic knowledge needed to develop a research project in the field of magnetism or to attend effectively more advanced courses on this topic.

Content
The lecture “Introduction to Magnetism” aims at letting students familiarize themselves with the basic principles of quantum and statistical physics that determine the behavior of real magnets. Understanding why only a few materials are magnetic at finite temperature will be the leitmotiv of the course. We will see that defining in a formal way what “being magnetic” means is essential to address this question properly. Theoretical concepts will be applied to a few selected nano-sized magnets, which will serve as clean reference systems.

Topics:
- Magnetism in atoms (quantum-mechanical origin of atomic magnetic moments, intra-atomic exchange interaction)
- Magnetism in solids (mechanisms producing inter-atomic exchange interaction in solids, crystal field)
- Magnetic order at finite temperatures (Ising, XY, and Heisenberg models, low-dimensional magnetism)
- Spin precession and relaxation (Larmor precession, resonance phenomena, quantum tunneling, Bloch equation, superparamagnetism)

Lecture notes
Learning material will be made available through Moodle and through the ETH JupyterHub.

Prerequisites / notice
Students are assumed to possess a basic background knowledge in quantum mechanics, solid-state and statistical physics as well as classical electromagnetism.

Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: fostered
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Media and Digital Technologies: fostered
  - Problem-solving: fostered
- Personal Competencies
  - Creative Thinking: fostered
  - Critical Thinking: assessed
  - Self-direction and Self-management: fostered

Abstract
The course covers the foundations of semiconductor nanostructures, e.g., materials, band structures, bandgap engineering and doping, field-effect transistors. The physics of the quantum Hall effect and of common nanostructures based on two-dimensional electron gases will be discussed, i.e., quantum point contacts, Aharonov-Bohm rings and quantum dots.

Objective
At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:
1. The integer quantum Hall effect
2. Conductance quantization in quantum point contacts
3. the Aharonov-Bohm effect
4. Coulomb blockade in quantum dots

Content
1. Introduction and overview
2. Semiconductor crystals: Fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k-p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

Lecture notes

Literature
In addition to the lecture notes, the following supplementary books can be recommended:

Prerequisites / notice
The lecture is suitable for all physics students, students of Quantum Engineering, and students of Micro- and Nanosystems beyond the bachelor of science degree. Basic knowledge of solid state physics is a prerequisite. Very ambitious students in the third year of Physics may be able to follow. The lecture can be chosen as part of the PhD-program. The course is taught in English.
Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Media and Digital Technologies assessed
- Problem-solving fostered

Social Competencies
- Communication fostered
- Self-presentation and Social Influence assessed
- Sensitivity to Diversity fostered

Personal Competencies
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-direction and Self-management fostered

Advanced Quantum Algorithms (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: PHY582

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

Abstract
The course treats selected families of quantum algorithms, currently the best candidates to achieve a practical quantum advantage over classical computation in physics, chemistry, optimization, sampling and machine learning. Starting from the basics, quantum algorithms are introduced and their feasibility to solve real-world problems in science and industry is critically discussed.

Objective
The course aims to provide a balanced outlook of this transformative technology, discussing strengths and possible limitations of all discussed algorithms, especially in the context of concrete today and future hardware implementation. After the course, students will have a clear understanding of the state-of-the-art of this field (i.e., the applications and algorithms amenable to quantum speedup, types of hardware, and quantum software). The course content is devised to provide first-hand experience with quantum algorithms and stimulate critical thinking. The course will be instrumental for the student's career development in quantum technology and computational science, in academia or industry.

Content
Course content:
- Quantum gates and circuits basics
- Quantum annealing
- Hamiltonian simulations (Trotter, LCU, circuit decompositions)
- Mapping fermionic, bosonic operators to qubits
- Quantum phase estimation and applications
- Variational quantum algorithms (VQE, QAOA)
- Algorithms for sampling and search (Amplitude amplification, estimation, quantum walks, quantum enhanced Markov chains)
- Selected Quantum Machine learning algorithms
- Prospects for quantum advantage

Lecture notes
Lecture notes covering in detail all the course content will be provided.

Literature
- My lecture notes and references therein which are open-access will be more than enough to follow.
- For an introduction to quantum computing and information it could be useful to read specific chapters of Nielsen and Chuang book.

Prerequisites / notice
The course is designed to be self-contained concerning the basics: i.e. the definition of quantum gates and circuits. Prior knowledge in quantum information science is beneficial but not required. Knowledge of basic statistical mechanics and quantum mechanics is required, specifically: linear algebra, spin operators, many-body wavefunctions, Hamiltonians in second quantisation formalism.

Semester Project

Number Title Type ECTS Hours Lecturers
227-1871-00L Semester Project O 12 credits 20A Supervisors

Abstract
Semester projects are designed to train the students for independent scientific work. A project uses the student's technical and social skills acquired during the master's program. The semester project comprises 280 hours of work and is supervised by a professor.

Objective
see above

Prerequisites / notice
Supervisor must be a professor at D-ITET or associated, see https://www.ee.ethz.ch/studies/main-master/projects-and-master-thesis.html

Internship

Number Title Type ECTS Hours Lecturers
227-1873-00L Internship in Industry W 12 credits external organisers

Abstract
The main objective of the (minimum) 12-week (full-time) internship in industry is to expose master's students to the industrial work environment. During this period, students can be involved in on-going projects at the company. Projects in academic institutions are subject to agreement of the programme direction.

Objective
see above

227-1873-10L QuanTech Workshops W 12 credits 2P G. Raino, M. Frimmer
Abstract
The QuanTech Workshops are a project-oriented learning environment in the context of quantum technology. Students work in teams, consisting of engineers and physicists, and jointly tackle a quantum engineering project. During the preceding course "Case Studies: Application of Quantum Technologies", students develop project proposals. Successful proposals will be realized in a QuanTech Workshop.

Objective
Students practice development, planning, and execution of a project in the quantum engineering domain. By working in close collaboration with senior scientists and professors from the two departments D-ITET and D-PHYS, the goal is to provide solutions for pressing challenges in in the field of quantum technologies.

Prerequisites / notice
Attendance of "227-1831-10L Case Studies: Applications of Quantum Technology" and successful "QuanTech Workshop" proposal.

Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-1800-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>68D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Admission only if ALL of the following apply:

a) bachelor program successfully completed;
b) acquired (if applicable) all credits from additional requirements for admission to master program;
c) successfully completed the semester project.

Note: the conditions above are not applicable to incoming exchange students.

Registration in mystudies required!
Supervisor must be a professor at D-ITET or D-PHYS, see http://master-qi.ethz.ch/education/master-project.html.

Abstract
The Master Program finishes with a 6-months Master Thesis which is directed by a Professor of the Department or a Professor of another Department who is associated with the D-ITET. Students gain the ability to conduct independent scientific research on a specific research problem.

Objective
see above

Prerequisites / notice
Supervisor must be a professor at D-ITET or associated, see https://www.ee.ethz.ch/studies/main-master/projects-and-master-thesis.html

Science in Perspective

Only courses offered under "GESS Science in Perspective" count in this category. See "Offered in" tab in course view. For more information, please refer to https://gess.ethz.ch/en/studies/science-in-perspective/SiP-FAQs.html

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-ITET

Quantum Engineering Master - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
<td></td>
<td>European Credit Transfer and Accumulation System</td>
</tr>
</tbody>
</table>

Special students and undergraduates need special permission from the lecturers.
### Geospatial Engineering Bachelor

**Basic Courses**

#### First Year Examinations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0241-00L</td>
<td>Analysis I</td>
<td>O</td>
<td>7</td>
<td>4V+2U</td>
<td>M. Akveld, G.-I. Ionita</td>
</tr>
</tbody>
</table>

**Abstract**  
Mathematical tools for the engineer

**Objective**  
Mathematics as a tool to solve engineering problems. Basic mathematical knowledge for engineers. Mathematical formulation of technical and scientific problems.

**Content**  
Complex numbers. Calculus for functions of one variable with applications. Simple Mathematical models in engineering.

**Lecture notes**  
Wird auf der Vorlesungshomepage zu Verfügung gestellt.

**Literature**  


Urs Stammbach, "Analysis III" (erhältlich im ETH Store); https://people.math.ethz.ch/~stammb/analysisskript.html

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0141-00L</td>
<td>Linear Algebra</td>
<td>O</td>
<td>5</td>
<td>4V+1U</td>
<td>M. Akka Ginosar, R. Prohaska</td>
</tr>
</tbody>
</table>

**Abstract**  
Introduction to Linear Algebra

**Objective**  
Basic knowledge of linear algebra as a tool for solving engineering problems. Understanding of abstract mathematical formulation of technical and scientific problems. Together with Analysis we develop the basic mathematical knowledge for an engineer.

**Content**  
Introduction and linear systems of equations, matrices, quadratic matrices, determinants and traces, general vector spaces, linear mappings, bases, change of basis, diagonalization, eigenvalues and eigenvectors, orthogonal transformations, scalar-product, inner product spaces.

**Lecture notes**  
The lecturer will provide course notes.

**Literature**  
K. Nipp, D. Stoffer, Lineare Algebra, VdF Hochschulverlag ETH

G. Strang, Lineare Algebra, Springer


G. Strang, Lineare Algebra, Springer


Eric Matthes

Python Crash Course

A Hands-On, Project-Based Introduction to Programming

Wes McKinney

Python for Data Analysis

Data wrangling with pandas, NumPy & Jupyter, 3rd Edition

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0845-00L</td>
<td>Computer Science I</td>
<td>O</td>
<td>5</td>
<td>2V+2U</td>
<td>M. Lüthi, A. Streich</td>
</tr>
</tbody>
</table>

**Abstract**  
The course covers the basic concepts of computer programming.

**Objective**  
Basic understanding of programming concepts. Students will be able to write and read simple programs and to modify existing programs. In the course "Computer Science I", the competency of programming is taught, applied and examined. Furthermore modeling is taught and applied.

**Content**  
variables, types, control structures, functions, scoping, recursion, object-oriented programming. The programming language is Python.

**Lecture notes**  
The slides and lecture notes will be made available for download on the course website.

**Literature**  
Learn to Code by Solving Problems

A Python Programming Primer

Daniel Zingaro

Python Crash Course

A Hands-On, Project-Based Introduction to Programming

Eric Matthes

Python for Data Analysis

Data wrangling with pandas, NumPy & Jupyter, 3rd Edition

Wes McKinney

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0313-00L</td>
<td>Spatial Planning and Landscape Development</td>
<td>O</td>
<td>5</td>
<td>4G</td>
<td>G. Debrunner, S. Hauller, D. Jerjen</td>
</tr>
</tbody>
</table>

**Abstract**  
The lecture introduces the main-features of Swiss spatial planning. Core subjects are e.g., spatial planning as a federal responsibility, spatial planning instruments (federal, cantonal, municipal), as well as systematic problem solving techniques and methodologies of spatial planning. The lecture is complemented with in-depth topics and comparative international examples.

**Objective**  
Die Studierenden kennen die Grundzüge der Schweizer Raumplanung, ihre wichtigsten Instrumente auf nationaler, kantonaler, regionaler und kommunaler Ebene und systematische Problemlösungsverfahren. Sie können das vermittelte theoretische Wissen direkt an konkreten, praxisorientierten Übungsaufgaben umsetzen.

Klaus Dürrenberger

- Grundzüge der Raumplanung und ihre wichtigsten Instrumente kennenlernen
- Erarbeiten der Fähigkeit, räumliche Probleme zu erkennen und Problemlösungsverfahren auf diese anzuwenden
- Planung und Landnutzungsmanagement als interaktiven und aktionsbezogenen Prozess kennenlernen und anwenden
- Verstehen der mit Ressourcen und Boden verbundenen Potentiale, Nutzungen und Prozesse
- Das vermittelte theoretische Wissen direkt an konkreten, praxisorientierten Fallbeispielen umsetzen können
The lecture covers the fundamentals of (Swiss) spatial planning and landscape development:

- What is spatial planning (Definitions and Backgrounds)
- Actual current developments, trends in spatial planning
- Space planning principles: historical development and legal obligations of the Swiss spatial planning
- Spatial planning as a state function – Spatial Planning Policy in Switzerland
- Instruments of spatial planning at national, cantonal, regional and municipal levels (e.g. cadastral and concepts, legal planning, planning, focusing planning, cost-benefit analysis)
- Problem-solving methods in spatial planning - system technical aspects
- Thematic planning: Development planning for the future; Climate-adapted spatial planning; Property and cooperative planning; Spatial development

The focus of the lecture lies on spatial planning policy at the federal level, the cantons and municipalities, and on the policy-relevant aspects of spatial planning instruments. The lecture will be given in a direct manner, with a Zürcher Spatial Planning Commission as a guest speaker. In the framework of teaching, a study trip to a Zürcher urban development project will be conducted as a practical task.

Lecture notes


Further information at http://www.karto.ethz.ch/studium/lehrangebot.html

103-0214-00L Cartography Fundamentals O 5 credits 4G L. Hurni

Abstract

Basic knowledge about communication with spatial information by using plans and maps, about the most important design rules and production methods for map graphics.

Objective

Acquire basic knowledge about communication with spatial information by using plans and maps, about the most important design rules and production methods for map graphics. Ability to assess existing products with respect to their content-related and design quality. Ability to design proper plans and well-designed legends for basic maps.

Content

Definitions "map" and "cartography"; map types, current tasks and situation of cartography, map history, spatial reference systems, map projections, map conception and workflow planning, map design, analog and digital map production technology, prepress technology, printing technology, topographic maps, map critics.

Lecture notes

Will be distributed module by module.

Prerequisites / notice

Further information at http://www.karto.ethz.ch/studium/lehrangebot.html

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2123 of 2653
Ecology and Soil Science

**Abstract**
The lecture deals with ecological and pedological basics, especially from an engineering and spatial planning perspective. Students learn about soil properties, genesis, ecosystem functions and cycles. Soil changes due to natural and human intervention, the resulting soil degradation and functional restrictions as well as soil protection and management are taught.

**Objective**
- Students know the basic concepts of soil science and ecology.
- Students can explain soil properties, soil ecosystems and material cycles.
- Students can understand, calculate, analyze and assess the effects of human activities on soils and their functions.
- Students can understand and apply engineering and spatial planning approaches to soil protection and management.

**Content**
Basics of soil science & ecology: Basic terms, definition of soil, soil functions, soil formation, soil composition, soil types and key parameters, connection between soil and ecology,

Soil use & hazards: Soil compaction, erosion, material pollution of the soil, water balance changes & disturbances

Soil protection & management: soil recultivation and soil monitoring, soil in the city, soil and spatial planning, soil monitoring and the role of the federal government

**Lecture notes**
Lecture notes and slides (in German) can be found on the Moodle page of the course.

**Literature**


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**Additional Basic Courses**
No offer in Autumn Semester.

**Compulsory Courses**

**Examination Block 1**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>401-0243-00L</td>
<td>Analysis III</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>M. Akka Ginosar</td>
</tr>
</tbody>
</table>

**Abstract**
We will model and solve scientific problems with partial differential equations. Differential equations which are important in applications will be classified and solved. Elliptic, parabolic and hyperbolic differential equations will be treated. The following mathematical tools will be introduced: Laplace and Fourier transforms, Fourier series, separation of variables, methods of characteristics.

**Objective**
Learning to model scientific problems using partial differential equations and developing a good command of the mathematical methods that can be applied to them. Knowing the formulation of important problems in science and engineering with a view toward civil engineering (when possible). Understanding the properties of the different types of partial differential equations arising in science and in engineering.

**Content**
Study of the Heat equation general diffusion/parabolic problems using the following tools through Separation of variables as an introduction to Fourier Series.

Systematic treatment of the complex and real Fourier Series

Study of the wave equation and general hyperbolic problems using Fourier Series, D'Alembert solution and the method of characteristics.

Laplace transform and it's uses to differential equations

Study of the Laplace equation and general elliptic problems using similar tools and generalizations of Fourier series.

Application of Laplace transform for beam theory will be discussed.

Time permitting, we will introduce the Fourier transform.

**Lecture notes**
Lecture notes will be provided

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large part of the material follow certain chapters of the following first two books quite closely.


The course material is taken from the following sources:

Stanley J. Farlow - Partial Differential Equations for Scientists and Engineers


Prerequisites / notice

Analysis I and II, insbesondere, gewöhnliche Differentialgleichungen.

103-0233-10L Fundamentals of GIS O 6 credits 5G M. Raubal

Abstract

Fundamentals of geographic information systems: spatial data modeling; metrics & topology; vector, raster and network data; thematic data; spatial statistics; system architectures; data quality; spatial queries and analysis; geovisualisation; spatial databases; labs with GIS software

Objective

Knowing theoretical aspects of geographic information regarding data acquisition, representation, analysis and visualisation. Knowing the fundamentals of geoinformation technologies for the realization, application and operation of geographic information systems in engineering projects.

Content

- Einführung GIS & GIScience
- Konzeptionelles Modell & Datenschema
- Vektorgeometrie & Topologie
- Rastergeometrie und -algebra
- Netzwerke
- Thematische Daten
- Räumliche Statistik
- Systemarchitekturen & Interoperabilität
- Datenqualität, Unsicherheiten & Metadaten
- Räumliche Abfragen und Analysen
- Präsentation raumbezogener Daten
- Geodatenbanken

Lecture notes Vorlesungspräsentationen werden digital zur Verfügung gestellt.

Literature


Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies

- Self-presentation and Social Influence

Personal Competencies

- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

103-0187-02L Satellite Geodesy O 4 credits 3G M. Aichinger-Rosenberger

Abstract


Objective

- Sicherheit im Umgang mit Koordinaten-, Referenz- und Zeitsystemen
- Grundlegendes Verständnis der Berechnung von Satellitenbahnen
- Grundlegendes Verständnis der geodätischen Weltraumverfahren und deren Stärken und Schwächen
- Kenntnis der wichtigsten Prozesse, die für Änderungen in der Geometrie, der Rotation und dem Schwerefeld der Erde verantwortlich sind.
- Erkennen der Anwendungsmöglichkeiten der Satellitengeodäsie für interdisziplinäre Aufgaben (System Erde).

Content

- Koordinatensysteme, Transformationen
- Referenz- und Zeitsysteme
- Grundlagen Satellitenbahnen
- Weltraumverfahren: VLBI, SLR, DORIS, Altimetrie
- Schwerefeldmmissionen
- Kombination der Weltraumverfahren zur Bestimmung der Geometrie, Orientierung sowie des Schwerefeldes der Erde
- Interdisziplinäre Anwendungen (Meteorologie, Klimatologie, Hydrologie, etc.)

Introduction to Law

This class introduces students into basic features of the legal system. Fundamental issues of constitutional law, administrative law, private law and the law of the EU are covered. The focus is on legal problems related to space. Active participation is expected in short interactive sequences.

Objective

Students are able to identify basic structures of the legal system. They understand selected topics of public and private law. They are able to apply the fundamentals in more advanced law classes and to recognize the relevance of law in their own field.

Literature


Prerequisites / notice

Sie brauchen keine Vorkenntnisse, um dem Kurs zu folgen.

Competencies

Subject-specific Competencies:
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies:
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed

Personal Competencies:
- Critical Thinking: fostered
- Self-awareness and Self-reflection: fostered

<table>
<thead>
<tr>
<th>Subject:</th>
<th>Code:</th>
<th>Credits:</th>
<th>Prerequisites:</th>
<th>Literature:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economics</td>
<td>351-1158-00L</td>
<td>3 credits</td>
<td>2G</td>
<td>U. Renold, T. Bolli, P. McDonald, F. Pusterla, A. Zubovic</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Fostered</td>
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</tbody>
</table>

Abstract

This course introduces basic economic concepts and theories. Beginning with microeconomics, the course starts with the topics of supply and demand, markets, and behavioral economics before moving on to the key macroeconomic concepts of national accounts, the labor market, trade, and monetary policy.

Objective

After successful completion of the course you will be able to:
- Describe the basic micro- and macroeconomic problems and theories.
- Introduce economic reasoning appropriately to a given topic.
- Evaluate economic measures.

Content

Households, firms, supply and demand: How are household preferences and consumption patterns formed? How does a household react to price changes? How are goods prices formed? At what prices are companies willing to offer goods? How do we make economic decisions?

Market failure: What is “perfect competition” and how does a competitive market work? Are monopolies always a bad thing? How can the state influence the market?

Labour market: How do supply and demand work in the labour market? What influences unemployment?

National accounts: How big is the Swiss economy?

Foreign trade: Why do countries trade with each other? What are the consequences for the domestic market?

Money and inflation: What exactly is money? How does money creation work and what happens when there is too much (or too little) money on the market?

Students will be asked to apply these concepts to issues in their own field of study and to current issues in society. This goal will be achieved through participation in exercises, class discussions and reading material from current media. By the end of the course, students should be able to apply economic analysis confidently and independently.

Lecture notes

no script available

Data: 15.06.2024 12:39

Autumn Semester 2024
The economic environment of today's companies is characterized by high cost pressure, declining margins, intensified international competition, rising customer requirements and increasingly strict regulations. Strategic and operational decisions at all management levels are becoming more and more complex due to the increasing amount of data, interrelationships, conditions and target criteria to be considered. Often it is no longer possible to solve operational tasks with experience and common sense alone and to adequately estimate the consequences of decisions without software support.

Quantitative models and methods of operations research and operations management offer decision support for complex problems. Mathematical optimization models are used to precisely formulate operational decision problems so that they can subsequently be analyzed and optimized using suitable solution methods. A large number of quantitative real-world problems can be formulated and solved in this general framework. Applications of operations research comprise, for instance, decision problems in production planning, supply chain management, transportation networks, machine and workforce scheduling, blending of components, telecommunication network design, airline fleet assignment and revenue management.

This course offers an introduction to operations research, emphasizing basic methodologies and underlying mathematical structures. The following topics are covered in detail:

- Introductions to system modeling and operations research
- Linear models and the importance of linear programming
- Duality theory in linear programming and shadow prices
- Integer programming
- Dynamic optimization (under uncertainty) and applications in inventory management.

A printed script will be made available.

Any standard textbook in Operations Research is a useful complement to the course.

Undergraduate calculus, linear algebra, probability and statistics are a prerequisite.

The course includes an introduction to specialized project management software as well as agile project management concepts.
Objective
Projects are not only the base of work in modern enterprises, but also the primary type of cooperation with customers. Students of ETH will often work in or manage projects in the course of their career. Good project management knowledge is not only a guarantee for individual, but also for company-wide success.

The goal of this course is to give a detailed introduction into project management. The students should learn to plan and execute a project.

Content
Project planning (aims, appointments, capacities, efforts and costs), project organization, scheduling and risk analysis, project execution, supervision and control, project evaluation and documentation, conflict management, multinational project management, IT support as well as agile project management methods such as SCRUM.

Lecture notes
No. The lecture slides and other additional material will be available for download from Moodle a week before each class.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
</tr>
<tr>
<td>Techniques and Technologies</td>
<td>Decision-making</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
</tr>
<tr>
<td></td>
<td>Project Management</td>
</tr>
</tbody>
</table>

Social Competencies

- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Objective

The world’s growing population, changing demographics, and changing climate pose formidable challenges to humanity’s ability to live sustainably. Ensuring that humanity can live sustainably requires accommodating Earth’s growing and changing population through the provision and operation of a sustainable and resilient built environment. This requires ensuring excellent decision-making as to how the built environment is constructed and modified.

The objective of this course is to ensure the best possible decision making when engineering sustainable systems, i.e., ones that meet the needs of stakeholders in the short, medium and long term. In this course, you will learn the main principles of Systems Engineering that can help you from the first idea that a system may not meet expectations, to the quantitative and qualitative evaluation of possible system modifications. Additionally, the course includes an introduction to the use of operations research methods in the determination of optimal solutions in complex systems.

More specifically upon completion of the course, you will have gained insight into:

- how to structure the large amount of information that is often associated with attempting to modify complex systems
- how to set goals and define constraints in the engineering of complex systems
- how to generate possible solutions to complex problems in ways that limit exceedingly narrow thinking
- how to compare multiple possible solutions over time with differences in the temporal distribution of costs and benefits and uncertainty as to what might happen in the future
- how to assess values of benefits to stakeholders that are not in monetary units
- how to assess whether it is worth obtaining more information in determining optimal solution
- how to take a step back from the numbers and qualitatively evaluate the possible solutions in light of the bigger picture
- the basics of operations research and how it can be used to determine optimal solutions to complex problems, including linear, integer and network programming, dealing with multiple objectives and conducting sensitivity analyses.

Content

1. Introduction – An introduction to System Engineering, a way of thinking that helps to engineer sustainable systems, i.e., ones that meet the needs of stakeholders in the short, medium and long terms. A high-level overview of the main principles of System Engineering. The expectations of your efforts throughout the semester.
2. Situation analysis – How to structure the large amount of information that is often associated with attempting to modify complex systems.
3. Goals and constraints – How to set goals and constraints to identify the best solutions as clearly as possible.
4. Generation of possible solutions – How to generate possible solutions to problems, considering multiple stakeholders.
5. The principles of net-benefit maximization and a series of methods that range from qualitative and approximate to quantitative and exact, including pairwise comparison, elimination, weighting, and expected value.
6. The idea behind the supply and demand curves and revealed preference methods.
7. The concept of equivalence, including the time value of money, interest, life times and terminal values.
8. The relationship between net-benefit and the benefit-cost ratio. How incremental cost benefit analysis can be used to determine the maximum net benefit. Internal rates of return.
9. How to consider multiple possible futures and use simple rules to help pick optimal solutions and to determine the value of more information.
10. Once quantitative analysis is used it becomes possible to use operations research methods to analyse large numbers of possible solutions. Linear programming and the simplex method.
11. How sensitivity analysis is conducted using linear programming.
12. How to use operations research to solve problems that consist of discrete values, as well as how to exploit the structure of networks to find optimal solutions to network problems.
13. How to set up and solve problems when there are multiple objectives.

Lecture notes

- The lecture materials consist of a script, the slides, example calculations in Excel, Moodle quizzes, and exercises.
- The lecture materials will be distributed via Moodle before each lecture.
Appropriate literature in addition to the lecture materials will be handed out when required via Moodle.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Leadership and Responsibility: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### Elective Blocks

#### Geodesy and Satellite Navigation

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0139-00L</td>
<td>Geodetic Data Analysis</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Schartner</td>
</tr>
<tr>
<td>Abstract</td>
<td>The lecture provides knowledge about the analysis of geodetic time series and their modeling as stochastic processes. Besides, Fourier analysis is also discussed in detail, and basic concepts for parameter estimation, significance, and quality control are laid out. Finally, Monte Carlo simulations are discussed as well.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>After completing the course, participants should have the necessary knowledge to analyze geodetic time series and decompose them into their components. They will also be able to perform hypothesis tests and apply Monte Carlo simulations.</td>
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</tr>
</tbody>
</table>
| Content      | - Time series analysis (component decomposition, stochastic processes, parametric and non-parametric methods, regression models, significance tests)  
- Fourier analysis (discrete/continuous, sampling frequency, frequency resolution, aliasing, leakage effects, window functions)  
- Recapitulation of basics from statistics and probability calculations (density and distribution functions, random variables, correlation, hypothesis tests)  
- Monte Carlo simulations |      |        |       |                                |
| Lecture notes| English script and slides are provided. |      |        |       |                                |
| Literature   | Literaturquellen werden während des Kurses bekannt gegeben. |      |        |       |                                |
| Prerequisites / notice | Linear algebra, basics in statistics and probability theory, parameter estimation |      |        |       |                                |

#### Global Satellite Navigation Systems

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>103-0135-01L</td>
<td>Global Satellite Navigation Systems</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td>M. Aichinger-Rosenberger</td>
</tr>
</tbody>
</table>
| Objective    | • Erkennen von Anwendungsmöglichkeiten von GNSS in der Vermessung, Positionierung, Navigation, GIS, im Geomonitoring und in den Erd- und Umweltwissenschaften  
• Verstehen der wichtigsten Fehlerquellen und der unterschiedlichen Beobachtungsverfahren  
• Erkennen von Anwendungsmöglichkeiten von GNSS in der Vermessung, Positionierung, Navigation, GIS, im Geomonitoring und in den Erd- und Umweltwissenschaften |      |        |       |                                |
| Content      | • Überblick über die verschiedenen GNSS (GPS, GLONASS, Galileo, Beidou, QZSS und INRSS)  
• Systemkomponenten, Signalstruktur, Referenz- und Zentrenbeobachtungsgleichungen für Pseudorange- und Phasenmessungen der GNSS  
• Bildung von Differenzen und Linearkombinationen der ursprünglichen Beobachtungen  
• Fehlerquellen: Satellitenbahnen und -uhren, troposphärische und ionosphärische Refraktion, Antennenphasenzentren, relativistische Einflüsse, Mehrwegeffekte und Messrauschen  
• Einblick in die Bedeutung der speziellen und allgemeinen Relativitätstheorie für die GNSS  
• Auswertestrategien und Beobachtungsverfahren sowie Methoden zur Lösung der Phasenmehrdeutigkeiten  
• Referenzstationsnetze und Dienste  
• Viele Anwendungsbeispiele  
• Praktische und rechnerische Übungen für die Erfassung und Auswertung der GNSS-Messungen |      |        |       |                                |
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking assessed

Digitalisation and 3D Modelling

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
Advanced topics in geodetic metrology with focus on approaches to 3d modelling of local real world environments with higher accuracy.

Objective
By the end of this course, the students are able to create digital 3d models of the real world covering areas with an extension up to several 100 m with accuracies in the mm- to cm-level range. They can select the appropriate geodetic instruments or terrestrial laser scanners, plan and carry out the required working steps, test the equipment before use, and describe the quality of the results. They know a broad spectrum of visualization options and can assess their respective suitability for various application cases.

Content
- Overview: 3D Modelling from planning of data acquisition to visualization of the results
- Modern geodetic instruments
- Atmospheric effects
- Measurement techniques for high accuracy
- Introduction to terrestrial laser scanning
- Test and calibration of measurement instruments
- Point cloud processing; preprocessing, registration & georeferencing
- 3d modelling and visualization of objects, VR/AR/MR

Lecture notes
The slides and documents for enhanced study and further reading will be provided online.

Literature

Prerequisites / notice
The course is carried out in German. Basic knowledge of geodetic metrology is required as a prerequisite, corresponding to the learning objectives and content of the course Geodätische Messtechnik GZ. Besides lectures and data processing, the course also comprises extensive practical exercises in the field.

GIS and Cartography

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0717-00L</td>
<td>Geoinformation Technologies and Analysis</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>M. Raubal</td>
</tr>
</tbody>
</table>

Abstract
Geoinformationstechnologien und -analysen für Fortgeschrittene: Mobile GIS; Web-GIS & Geo-Web-Services; Spatial Big Data; Zeitliche Aspekte in GIS; Analyse von Bewegungsdaten; Benutzerschnittstellen
Übungen: Web-GIS-Semesterprojekt in Gruppenarbeit - die Übungen finden auf Englisch statt!

Objective

Content
- Mobile GIS
- Web-GIS & Geo-Web-Services
- Spatial Big Data
- Zeitliche Aspekte in GIS
- Analyse von Bewegungsdaten
- Benutzerschnittstellen

Lecture notes
Vorlesungspräsentationen werden digital zur Verfügung gestellt.

Literature

Prerequisites / notice
GIS GZ
### Spatial and Environmental Planning

#### Number 103-0325-02L
**Title**: Integrated Spatial Planning in Cities and Districts  
**Type**: W  
**ECTS**: 6 credits  
**Hours**: 4G  
**Lecturers**: G. Di Carlo Alvarez, F. Günther, R. Streit

#### Abstract
Methodische und instrumentelle Grundlagen der Raumentwicklung werden aus integrierter Sicht (Städtebau, Freiraum, Verkehr) vermittelt und von den Studierenden konkret in einem Zürcher Stadtquartier als Semesterübung angewendet.

#### Objective
- Ein Repertoire an hilfreichen Werkzeugen sowie Denkmuster aus der Raumplanung kennen
- Quartiere eigenständig zu erkunden, Potentiale sowie Risiken der Raumentwicklung zu erkennen und zu dokumentieren
- Eigene Räumliche Entwicklungskonzepte zu entwerfen und zu präsentieren
- Massnahmen für Schlüsselgebiete zu konkretisieren, u.a. hinsichtlich Zeitplanung, Organisation und Kosten

#### Content
Die Vorlesung vermittelt methodische und instrumentelle Grundlagen zu planerischen Denkmustern und Repertoire sowie Hilfestellungen für Entwerfen, Argumentieren und Entscheiden.


Die Semesterübung erfolgt als Gruppenarbeit und wird der Note der Vorlesung angerechnet. Während der Vorlesungszeit sind mehrere Termine für die Gruppenarbeit, Werkstattgespräche und die Präsentation von (Zwischen-)Ergebnissen vorgesehen.

#### Lecture notes
Vorlesungsfolien und Unterlagen werden auf Moodle hochgeladen.

### Traffic Systems

#### Number 101-0415-01L
**Title**: Public Transport and Railways  
**Type**: W  
**ECTS**: 3 credits  
**Hours**: 2G  
**Lecturers**: F. Corman

#### Abstract
Fundamentals of public and collective transport, in its different forms. Categorization of performance dimensions of public transport systems, and their implications to their design and operations.

#### Objective
- Teachs the basic principles of public transport network and topology design, to understand the main characteristics and differences of public transport networks, based on buses, railways, or other technologies.
- Teaches students to recognize the interactions between the infrastructure design and the production processes, and various performance criteria based on various perspective and stakeholders.
- At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate different choices of technologies to suitable cases; optimize the use of resources in public transport.
Content

- **Fundamentals:** Infrastructures and vehicle technologies of public transport systems; interaction between track and vehicles; passengers and goods as infrastructure users; management and financing of networks.
- **Infrastructure:** Planning processes and decision levels in network development and infrastructure planning, planning of topologies; tracks and roadways, station infrastructures; Fundamentals of the infrastructure design for lines; track geometries; switches and crossings.
- **Vehicles:** Classification, design and suitability for different goals.
- **Network design:** design dilemmas, conceptual models for passenger transport on long distance, urban regional transport.
- **Operations:** Passenger/Supply requirements for line operations; timetabling, measures of realized operations, capacity.

Lecture notes

Slides, in English, are made available some days before each lecture.

Literature

Reference material books are provided in German and English (list disseminated at lecture), plus Skript Bahinfrastuktur; System- und Netzplanung.

Competencies

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: fostered

- **Social Competencies**
  - Communication: fostered
  - Cooperation and Teamwork: fostered
  - Customer Orientation: fostered
  - Leadership and Responsibility: fostered
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered
  - Negotiation: fostered

- **Personal Competencies**
  - Adaptability and Flexibility: fostered
  - Creative Thinking: fostered
  - Critical Thinking: fostered
  - Integrity and Work Ethics: fostered
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

### Network Infrastructure

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
----------- | -------- | -------- | -------- | -------- | ------------
103-0532-00L | **Introduction to Power Grid Infrastructure** | W | 2 credits | 3G | T. Schultz, P. Bühlmann, S. Hedtke

*Abstract*

In this lecture, the basics for the construction and operation of power grids are explained. The focus is on the components of the grid, from generation to transport and consumption.

*Objective*

The lecture covers:

- an overview of how the power grid is constructed and which components it requires.
- an understanding of the advantages and disadvantages of the different technologies and systems (e.g. cable and overhead lines or AC and DC voltage).
- an overview of the challenges and opportunities presented by external influences and new technologies.

*Content*

Electricity is one of the most important forms of energy used by modern society. The availability of electricity has an immense impact on our daily lives and is an essential prerequisite for economic and social development. Electricity is used in almost all aspects of daily life due to its high flexibility of use. From lighting and cooling homes and offices, to running factories and machinery, and powering electric vehicles, electricity is a major driver of modern society.

The goal of this course is to provide an understanding of electricity as a form of energy, its generation, transmission and use. To this end, the necessary systems and components as well as their interaction in one of the largest technical systems in the world, the interconnected power grid, will be presented.

This includes in particular:

- Electricity as a form of energy
- Electricity generation and storage
- Loads
- Transmission components (overhead lines, cables, substations)
- Protection technology
- Grid operation
- HVDC and power electronics for the power grids of the future
- Energy transition and current challenges

*Prerequisites / notice*

Enrolment only for students in Geospatial Engineering.

*Competencies*

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Problem-solving: assessed
  - Project Management: fostered

- **Personal Competencies**
  - Creative Thinking: assessed
  - Critical Thinking: assessed

### Electives

**Electives ETH Zurich**

Course Catalogue of ETH Zurich
Recommended Electives of Bachelor Degree Programme

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0241-00L</td>
<td>Cartography Lab</td>
<td>W</td>
<td>6 credits</td>
<td>13S</td>
<td>L. Hurni</td>
</tr>
</tbody>
</table>

**Abstract**
Independent semester work in cartography

**Objective**
Independent semester work in cartography

**Content**
Choice of theme upon individual agreement

**Prerequisites / notice**
Cartography Fundamentals

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

- **Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management

- **Social Competencies**
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Sensitivity to Diversity

- **Personal Competencies**
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

- **Method-specific Competencies**
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management

- **Social Competencies**
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Sensitivity to Diversity

- **Personal Competencies**
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  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

**Science in Perspective**

**Science in Perspective**

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-BAUG

**Language Courses**

see Science in Perspective: Language Courses ETH/UZH

**Bachelor’s Thesis**

see Science in Perspective: Language Courses ETH/UZH

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0006-10L</td>
<td>Bachelor’s Thesis</td>
<td>O</td>
<td>10 credits</td>
<td>21D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

**Abstract**
The Bachelor Programme concludes with the Bachelor Thesis. This project is supervised by a professor. Writing up the Bachelor Thesis encourages students to show independence and to produce structured work.

**Objective**
Encourages students to show independence, to produce scientifically structured work and to apply engineering working methods.

**Content**
The contents base upon the fundamentals of the Bachelor Programme. Students can choose from different subjects and tasks. The thesis consists of both a written report and an oral presentation.

**Geospatial Engineering Bachelor - Key for Type**

- **O** Compulsory
- **W** Eligible for credits and recommended
- **W** Eligible for credits
- **E-** Recommended, not eligible for credits
- **Z** Courses outside the curriculum
- **Dr** Suitable for doctorate

**Key for Hours**

- **V** lecture
- **G** lecture with exercise
- **U** exercise
- **S** seminar
- **K** colloquium
- **P** practical/laboratory course
- **A** independent project
- **D** diploma thesis
- **R** revision course / private study

**ECTS**
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Spatial Development and Infrastructure Systems Master

Master Studies (Programme Regulations 2021)

Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>101-0467-01L</td>
<td>Transport Systems</td>
<td>O</td>
<td>6</td>
<td>4G</td>
<td>E. Heinen, L. Ambühli, B. Martin Iradi</td>
</tr>
<tr>
<td></td>
<td>Only for master students, otherwise a special permission by the lecturers is required.</td>
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<tr>
<td></td>
<td>Abstract</td>
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<tr>
<td></td>
<td>History, impact and principles of the design and operation of transport systems</td>
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<td>Objective</td>
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<td></td>
<td>Introduction of the basic principles of the design and operation of transport systems (road, rail, air) and of the essential pathways of their impacts (investment, generalised costs, accessibilities, external effects), referring to relatively constant, and factors with substantial future uncertainty, in the past and expected evolution of transport systems.</td>
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<tr>
<td></td>
<td>Content</td>
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<tr>
<td></td>
<td>Transport systems and land use; network design; fundamental model of mobility behaviour; costs and benefits of mobility; transport history</td>
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|                                      |                                      |      |      |       |                                              |
| Lecture notes                        | Lecturer notes and slides as well as hints to further literature will be given during the course. |      |      |       |                                              |
| Prerequisites / notice               | Obligatory lecture for students of the first semester of MSc Spatial development and Infrastructure Systems. |      |      |       |                                              |
| Competencies                         | Subject-specific Competencies         |      |      |       |                                              |
|                                      | Concepts and Theories                 |      |      |       | assessed                                     |
|                                      | Techniques and Technologies           |      |      |       | assessed                                     |
| Method-specific Competencies         | Analytical Competencies               |      |      |       | assessed                                     |
|                                      | Decision-making                      |      |      |       | fostered                                      |
|                                      | Problem-solving                      |      |      |       | fostered                                      |
| Social Competencies                  | Communication                        |      |      |       | fostered                                      |
|                                      | Cooperation and Teamwork              |      |      |       | fostered                                      |

<table>
<thead>
<tr>
<th>103-0317-00L</th>
<th>Spatial Planning and Development</th>
<th>O</th>
<th>3</th>
<th>2G</th>
<th>D. Kaufmann, A. Kutenbrouwer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Only for master students, otherwise a special permission by the lecturer is required.</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>The course deals with theoretical, methodological and practical foundations around the understanding and production of urban space. It discusses theoretical planning frameworks, and tasks of spatial planning at various scales, addresses current and future challenges of spatial development and reviews approaches for a sustainable development in Switzerland and beyond.</td>
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<td>Objective</td>
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<td>The overall aim of the course is to raise students' awareness and curiosity about the aspects that guide and shape our environment. Through lectures, readings, discussions, and exercises, the course seeks to achieve this goal by accumulating crucial notions from both theoretical and practice-based examples, and applying such knowledge into tasks of spatial planning. At the end of this course, students should feel empowered to critically engage with the teaching topic from a variety of approaches. By taking up the lecture, the students should be able to to analyse, interpret and reflect complex cross-scale tasks of spatial development and transformation, and to use their theoretical, methodical and professional knowledge to tackle them.</td>
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<td></td>
<td>Content</td>
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<td></td>
<td>Spatial development as a discipline deals with the development, (trans)formation, and arrangement of our urban environment. We simultaneously perceive and contribute to its transformation, making space the result of manifold intended and unintended changes. To mediate between different demands, interests and interventions of multiple actors, a forward-looking, evidence-based, and action-oriented planning is necessary. As guidance for future action, (spatial) planning has to be committed to the sustainable handling as well as just allocation of resources, in particular of the non-replicable resource land. The course focuses on both theoretical concepts and practice-oriented approaches to gain knowledge and be equipped to address current issues in spatial planning and development. This is mirrored in the course’s structure made of both of lectures and exercises. The lecture series introduces necessary key concepts and covers the following main topics: - Drivers of spatial development, inward development, core tasks and current challenges for (spatial) planners. - Interplay of formal and informal planning instruments across scales and actors. - Differentiation urban typologies, their characteristics and challenges - Types of spatial analysis and key figures - Planning approaches and the (political) steering of spatial development. - Types of processes and participation in spatial development. - Approaches for planning complex urban situations - Concepts for sustainable development</td>
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<tr>
<td></td>
<td>Lecture notes</td>
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<td>A course will be set up on Moodle for the provision of lectures and documents, to upload group deliverables and to ask questions in a discussion Forum. All documents provided are exclusively available for use within this course.</td>
</tr>
</tbody>
</table>
### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>assessed</td>
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<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Project Management</td>
<td>fostered</td>
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<td>Social Competencies</td>
<td>Cooperation and Teamwork</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
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</tbody>
</table>

### Abstract

#### Landscape Planning and Environmental Systems

In this course, students learn about methods for the identification and measurement of landscape characteristics, as well as measures and policies for landscape planning. Landscape planning is put into the context of environmental systems (soil, water, air, climate, flora and fauna) and discussed with regard to socio-political questions of the future.

#### Objective

The aims of this course are:

1. To illustrate the concept of landscape planning, the economic relevance of landscape and nature in the context of the environmental systems (soil, water, air, climate, flora and fauna);
2. To show landscape planning as an integral information system for the coordination of different instruments by illustrating the aims, methods, instruments and their functions in landscape planning.
3. To show the importance of ecosystem services.
4. To learn basics about nature and landscape: Analysis and assessment of the complex interactions between landscape elements, effects of current and future land use (ecosystem goods and services, landscape functions).
5. To identify and measure the characteristics of landscape.
6. Learn how to use spatial data in landscape planning.

#### Content

In this course, the following topics are discussed:
- Definition of the concept of landscape
- Relevance of landscape planning
- Landscape metrics
- Landscape change
- Methods, instruments and aims of landscape planning (policy)
- Socio-political questions of the future
- Environmental systems, ecological connectivity
- Ecosystem services
- Urban landscape services
- Practice of landscape planning
- Use of GIS in landscape planning

#### Lecture notes

No script. The documentation, consisting of presentation slides are partly handed out and are provided for download on Moodle.

#### Prerequisites / notice

The contents of the course will be illustrated in the associated course 103-0347-01 U (Landscape Planning and Environmental Systems (GIS Exercises)) or in Project LAND within the Experimental and Computer Lab (for Environmental Engineers). A combination of courses is recommended.

### Competencies

<table>
<thead>
<tr>
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<th>Concepts and Theories</th>
<th>assessed</th>
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<td>Communication</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Personal Competencies</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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</tbody>
</table>

### Abstract

#### Basics of RE&IS

The course Basics of RE&IS provides essential skills and knowledge for the Master's degree program in Spatial Development & Infrastructure Systems. Students will know the basics of scientific writing with complementary use of human and artificial intelligence. Students will learn how to search for scientific literature, create graphs, and give a presentation while writing a literature review.

#### Objective

The overall objective is to equip students with the necessary skills and knowledge to effectively conduct academic writing, specifically focused on writing a review article, and to introduce them to the use of Generative AI in enhancing their research and writing process. By the end of the course, students should be able to independently:
- search for and evaluate high-quality sources on their chosen topic and use citation management software.
- organize their writing and construct a scientific text, paragraph, and sentence structure using coherent and complete arguments and clear, concise, and specific language.
- understand citation styles and subject conventions, apply references to the chosen reference system, and properly cite all types of sources.
- determine appropriate types of graphs to represent data and create and evaluate effective graphical representations of data.
- present results systematically and persuasively using a consistent, informative slide deck with engaging and accurate visualizations; speak clearly and confidently using effective words, voice, and body language; know how to practice and deliver the presentation.
- review and provide appropriate feedback on peer work, use AI tools to assist in various stages of the writing process, and critically reflect on originality declarations, plagiarism, etc.
Involving chairs are:

Christian Sailer, education developer at the D-BAUG, has a special focus on interdisciplinary competencies in teaching at the D-BAUG. He therefore takes the lead of this course in collaboration with RE&IS chairs, who periodically alternate among themselves.

Lecture notes

All documents relevant for the course (slides, literature, further links, etc.) are provided centrally via the Moodle platform.

Literature


Wittkower, K.W. (2016) Style Guide for Student Dissertations, IVT, ETH Zürich, Zürich (available as download under learning materials)


ETH (2017) Citation etiquette: How to handle the intellectual property of others, ETH, ETH Zürich, Zürich (last retrieved 29.11.2017)


Content

This course explains how ideas for infrastructure emerge from strategic planning (macro scale), are taken up in the planning of systems (meso scale) and progress to approval through project evaluation (micro scale). It also provides infrastructure planners with principles for the appraisal of possible projects with and without the explicit valuing of costs and benefits.

More specifically, upon completion of the course students will understand:

- how ideas for infrastructure are generated at a strategic level, are interpreted in the development of system plans and reach concrete project proposals
- how project ideas emerge from system plans and are iteratively developed and appraised until approval
- the principles of system modelling and system modelling over time in appraising and defending infrastructure proposals
- the advantages and disadvantages of explicitly evaluating the costs and benefits in the appraisal of infrastructure proposals and the advantages and disadvantages of not evaluating the costs and benefits in the appraisal of infrastructure proposals.

This course provide infrastructure planners with an understanding of how ideas for infrastructure emerge from strategic planning (macro scale), are taken up in the planning of systems (meso scale) and progress to approval through project evaluation (micro scale). It also provides infrastructure planners with principles for the appraisal of possible projects with and without the explicit valuing of costs and benefits.

The course consists of 5 lectures, 4 help sessions and 4 presentation / evaluation sessions. The two hour weekly lecture period is used as follows:

1-Introduction: Strategic planning to project appraisals – This lecture provides an introduction to the course and an explanation of how the impetus for infrastructure modifications emerge from strategic planning and evolve to the appraisal and approval of specific infrastructure projects. The requirements for successful completion of the course are discussed.

2-Project appraisals: Case for change to approval – This lecture explains how project ideas are generated from system plans and iteratively evolve to become an appraised project.

3-Modelling how a system works and doesn't work - This lecture explain the principles of how to model a system to facilitate the appraisal of the project.

4-Modelling how systems evolve over time - This lecture explains how to model how systems evolve over time using Monte Carlo simulations and both system changes and planner decisions triggered by system changes.

5-Appraising potential projects with/without cost benefit analysis - This lecture explains two way of appraising projects. The first can be used when it is possible to explicitly estimate the costs and benefits of the proposed modifications. The second can be used when it is not possible to explicitly estimate costs and benefits of the proposed modifications.

6-10-Help sessions – We use the lecture periods to answer any questions you might have on your project. Your project is due on Friday of week 9.

11-14-Project presentations – In these lecture periods each group will be asked to present their project and be asked to field questions from the lecturers and fellow students. The presentations will be graded by the lecturers. Fellow students will give their impressions of the presentations and ability of the group to answer the questions.

Lecture notes

The course uses a combination of qualitative and quantitative approaches. The quantitative analysis required in the project requires at least the use of Excel. Some students, however, prefer to use Python or R.

- The lecture materials consist of handouts, the slides, and example calculations in Excel.
- The lecture materials will be distributed via Moodle two days before each lecture.

Literature

Appropriate literature will be handed out when required via Moodle.

Prerequisites / notice

This course has no prerequisites.

101-0509-10L Infrastructure Planning O 3 credits 2G B. T. Adey

Abstract

This course explains how ideas for infrastructure emerge from strategic planning (macro scale), are taken up in the planning of systems (meso scale) and progress to approval through project evaluation (micro scale). It also provides infrastructure planners with principles for the appraisal of possible projects with and without the explicit valuing of costs and benefits.

Objective

Infrastructure planners ensure our built environment optimally meets our future needs. This is challenging, as the built environment is a large and complex system, which interacts extensively with the natural environment. Additionally, there is considerable uncertainty with respect to the expectations of the built environment in the future, due to the uncertain environment in which we live, e.g. changing technologies and the changing climate. It is in the face of this complexity and uncertainty that infrastructure planners need to help develop strategic goals, and propose and defend specific potential infrastructure improvements and to a large and diverse set of stakeholders.

Content

The course provides an introduction to the course and an explanation of how the insights for infrastructure modifications emerge from strategic planning and evolve to the appraisal and approval of specific infrastructure projects. The requirements for successful completion of the course are discussed.

2-Project appraisals: Case for change to approval – This lecture explains how project ideas are generated from system plans and iteratively evolve to become an appraised project.

3-Modelling how a system works and doesn’t work - This lecture explains the principles of how to model a system to facilitate the appraisal of the project.

4-Modelling how systems evolve over time - This lecture explains how to model how systems evolve over time using Monte Carlo simulations and both system changes and planner decisions triggered by system changes.

5-Appraising potential projects with/without cost benefit analysis - This lecture explains two ways of appraising projects. The first can be used when it is possible to explicitly estimate the costs and benefits of the proposed modifications. The second can be used when it is not possible to explicitly estimate costs and benefits of the proposed modifications.

6-10-Help sessions – We use the lecture periods to answer any questions you might have on your project. Your project is due on Friday of week 9.

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Lecture notes

The course uses a combination of qualitative and quantitative approaches. The quantitative analysis required in the project requires at least the use of Excel. Some students, however, prefer to use Python or R.

- The lecture materials consist of handouts, the slides, and example calculations in Excel.
- The lecture materials will be distributed via Moodle two days before each lecture.

Literature

Appropriate literature will be handed out when required via Moodle.

Prerequisites / notice

This course has no prerequisites.
Introduction to the Programming Language R

Abstract

R is one of the most popular programming languages in science and practice for data analysis, modelling and visualisation. In this course, you will learn the basics of R and some common applications of R, such as making plots, regression analysis and working with spatial data. The weekly computer labs start with a short lecture followed by exercises that have to be handed in to pass the course.

Objective

The overall objective of this course is to provide an introduction to the programming language R and to build confidence to apply R in other courses. More specifically, the objectives are:

- Understand how to import and export data, and how to work with the most important types of R-objects (e.g. vectors, data frames, matrices and lists).
- Learn how to create meaningful and visually attractive graphics and apply this knowledge to several datasets.
- Learn how to apply several types of important functions (e.g. for- and while-loops, if-else statements, data manipulation).
- Understand descriptive statistics and regression analysis and apply this knowledge to analyse several datasets.
- Understand the possibilities of analysing and plotting spatial data.
- Learn how to write own functions.

Content

The course has a strong focus on "learning by doing". During the weekly computer lab sessions, students will be given an introduction to the programming language R. Each lab session will start with a short introductory lecture, after which students work through the script and complete the exercises. During the lab sessions, the lecturers will be available to answer individual questions. The main topics that will be covered in the lab sessions are:

- importing and exporting data
- types of R-objects
- data scraping
- plotting data
- descriptive statistics
- data manipulation
- conditionals and loops
- regression analysis
- plotting and analysing spatial data
- writing own functions

In the 7th and 14th week of the course, students have the time to finish the exercises that should be handed in at the end of those weeks.

Lecture notes

A script with theory, examples and exercises will be handed out at the beginning of the course. Data for the exercises will be made available via Moodle.

Literature


Prerequisites / notice

No prior knowledge of R or any other programming language is required for this course.
Abstract
System of swiss planning law, Constitutional and statutory provisions, Space planning and fundamental rights, Instruments, Application, legal protection, enforcement, Practical training.

Objective
Basic understanding of nature and function of space planning from a legal point of view. Basic knowledge of space planning instruments, relationship between space planning and constitutional law (especially property rights), solving of practical cases.

Content

Lecture notes
Haller, Walter/Karlen, Peter, Raumplanung-, Bau- und Umweltrecht, 3.A., Zürich 1999
Hänni, Peter, Planungs-, Bau- und besonderes Umweltschutzrecht, 7.A., Bern 2021

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Social Competencies
Communication assessed
Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

103-0327-00L History of Spatial Planning W 3 credits 2V M. Koll-Schretzenmayr
Abstract
The course examines the patterns of cleavage, conflict, convergence of interest, and consensus that have influenced spatial planning.

Objective
This course aims to provide students with knowledge of the historical background to understand the current spatial structure and to face the current challenges in spatial planning. Social, cultural, and economic forces will be analyzed for the roles they have played in shaping the landscapes and cityscapes and the answers spatial planning had to spatial development. The course focuses on the history of planning ideas, paradigms and approaches. A link is made to current challenges in spatial planning. Students will critically discuss the challenges spatial planning is facing today.

Lecture notes
Handouts will be available.

Literature
Daniel Kurz: Die Disziplinierung der Stadt - Moderner Städtebau in Zürich 1900 bis 1940. gta Verlag 2008

103-0569-00L European Aspects of Spatial Development W 3 credits 2G A. Peric Momcilovic
Abstract
Following the insight into historical perspective and contemporary models of governance and planning, the course focuses on the international dimension of spatial planning in Europe. This includes a discussion of how European spatial policy is made and by whom, how planners can participate in such process and how they can address transnational challenges of spatial development cooperatively.

Objective
Keeping the general aim of exploring the European dimension of spatial planning in mind, the specific course learning objectives are as follows:
- to interpret the history of spatial planning at the transnational scale
- to understand and explain the content of the European spatial policy agenda
- to describe and analyse the role of territorial cooperation in making European spatial development patterns and planning procedures
- to discuss the changing role of planners and evaluate the ways of their engagement in European spatial policy-making

Content
- European spatial policy agenda: introduction and basic directives
- governance models
- planning models; collaborative planning model (main concepts & critics)
- post-positivist approach to spatial planning
- transnational spatial planning in Europe; questioning the European spatial planning; spatial development trends in Europe
- EU as a political system: EU institutions & non-EU actors
- planning families in Europe; the European spatial planning agenda
- spatial planning strategies and programmes on territorial cooperation
- the notion of planning culture and planning system; planning cultures in Europe
- basic characteristics of planning systems in Europe
- the relevance of European transnational cooperation for spatial planning
- European transnational initiatives

Lecture notes
The documents for the lecture will be provided at the moodle.
**Literature**


**Recommended literature**

- Governance models:

- Planning models:

**EU as a political context:**


**Territorial cooperation in Europe:**


**Planning families and cultures:**


**Planning systems in Europe:**


**Prerequisites / notice**

- Only for master students, otherwise a special permission by the lecturer is required.

**Competencies**

- Subject-specific Competencies: Concepts and Theories
- Techniques and Technologies
- Method-specific Competencies: Analytical Competencies
- Decision-making
- Social Competencies: Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Negotiation
- Personal Competencies: Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

**Abstract**

The course content of the lecture Landscape Planning and Environmental Systems (103-0347-00 V) will be illustrated in practical GIS exercises (e.g. habitat modelling, land use change, ecosystem services, connectivity).

**Objective**

- Practical application of theory from the lectures
- Quantitative assessment and evaluation of landscape characteristics
- Developing landscape planning measures for practical case studies

**Content**

- Applications of GIS in landscape planning
- Landscape analysis
- Landscape structural metrics
- Modelling habitats and land use change
- Calculating urban ecosystem services
- Ecological connectivity

**Lecture notes**

A script and presentation slides for each exercise will be provided on Moodle.

**Literature**

Will be named in the lecture.

**Prerequisites / notice**

Basic GIS skills are strongly recommended.
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### Foundations of Ecosystem Management

**W 5 credits 3G J. Ghazoul, A. Giger Dray**

**Abstract**
This course introduces the broad variety of conflicts that arise in projects focusing on sustainable management of natural resources. It explores case studies of ecosystem management approaches and considers their practicability, their achievements and possible barriers to their uptake.

**Objective**

Students should be able to:

1. propose appropriate and realistic solutions to ecosystem management problems that integrate ecological, economic and social dimensions across relevant temporal and spatial scales;
2. identify important stakeholders, their needs and interests, and the main conflicts that exist among them in the context of land and resource management.

**Content**

Traditional management systems focus on extraction of natural resources, and their manipulation and governance. However, traditional management has frequently resulted in catastrophic failures such as, for example, the collapse of fish stocks and biodiversity loss. These failures have stimulated the development of alternative ecosystem management approaches that emphasise the functionality of human-dominated systems. Inherent to such approaches are system-wide perspectives and a focus on ecological processes and services, multiple spatial and temporal scales, as well as the need to incorporate diverse stakeholder interests in decision making. Thus, ecosystem management is the science and practice of managing natural resources, biodiversity and ecological processes, to meet multiple demands of society. It can be local, regional or global in scope, and addresses critical issues in developed and developing countries relating to economic and environmental security and sustainability.

This course provides an introduction to ecosystem management, and in particular the importance of integrating ecology into management systems to meet multiple societal demands. The course explores the extent to which human-managed terrestrial systems depend on underlying ecological processes, and the consequences of degradation of these processes for human welfare and environmental well-being. Building upon a theoretical foundation, the course will tackle issues in resource ecology and management, notably forests, agriculture and wild resources within the broader context of sustainability, biodiversity conservation and poverty alleviation or economic development. Case studies from tropical and temperate regions will be used to explore these issues. Dealing with ecological and economic uncertainty, and how this affects decision making, will be discussed. Strategies for conservation and management of terrestrial ecosystems will give consideration to landscape ecology, protected area systems, and community management, paying particular attention to alternative livelihood options and marketing strategies of common pool resources.

**Literature**


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### Ecological Assessment and Evaluation

**W 3 credits 3G F. Knaus**

**Abstract**

The course provides methods and tools for ecological evaluations dealing with nature conservation or landscape planning. It covers census methods, ecological criteria, indicators, indices and critically appraises objectivity and accuracy of the available methods, tools and procedures. Birds and plants are used as main example guiding through different case studies.
The lectures in the fall semester course “History and Theory of Gardens and Landscape Architecture” provide an overview of the cultural causes, contexts and consequences. Handouts and a bibliography will be provided.

The course provides the basics and tools for an in-depth understanding of the discipline of landscape architecture and its far-reaching interconnections with architecture, urban planning, ecology and other spatial and nature-related sciences. The aim is to adopt landscape perspectives in planning and design processes and to critically reflect on one’s own projects within a specific context.

Students learn about historical developments and their topicality and learn “from history”. Design contexts are presented on the basis of examples. Students develop a basis for ways of thinking and action for current landscape architectural challenges.

The lectures in the fall semester course “History and Theory of Gardens and Landscape Architecture” provide an overview of the cultural history of nature, the landscape and the garden from its origins to the present day. An in-depth understanding of change as well as the design strategies and characteristics of the most important epochs and their current relevance will be discussed.

Bachelor students: The knowledge taught in the lecture and the exam-relevant literature provided by the lecturer serve as the basis for exam preparation. The course is designed as an annual program. As the written session exam tests knowledge from both the Landscape Architecture I and II lecture series, it is strongly recommended that you attend the course over two semesters.

The examination topics will be announced shortly before the end of the semester. The lecturer will provide texts on the examination topics as pdf files for download. These serve to deepen understanding of the lecture.

Mobility students or students from other departments: Students who only attend the lecture for one semester complete the lecture with an end-of-semester oral examination. Here too, the lecturer provides literature relevant to the examination as a download.

Students registered for the exam will receive further information on the exam procedure by email shortly before the end of the semester.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Project Management

Communication

Cooperation and Teamwork

Negotiation

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Self-direction and Self-management

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Adapted
Objective

This course has the aim of deepening students' knowledge of the environmental assessment methodologies and their various applications. In particular, students completing the course should have the
- Ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors
- Knowledge about the current state of the scientific discussion and new research developments
- Ability to properly plan, conduct and interpret environmental assessment studies
- Knowledge of how to use LCA as a decision support tool for companies, public authorities, and consumers

Content

- Inventory developments, transparency, data quality, data completeness, and data exchange formats
- Allocation (multioutput processes and recycling)
- Hybrid LCA methods.
- Consequential and marginal analysis
- Recent development in impact assessment
- Spatial differentiation in Life Cycle Assessment
- Workplace and indoor exposure in Risk and Life Cycle Assessment
- Uncertainty analysis
- Subjectivity in environmental assessments
- Multicriteria analysis
- Case Studies

Lecture notes

No script. Lecture slides and literature will be made available on Moodle.

Literature

No specific literature will be required. However, students are encouraged to read a range of textbooks and journals to support their learning.

Prerequisites / notice

Basic knowledge of environmental assessment tools is a prerequisite for this class. Students that have not done classwork in this topic before are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. 2016: Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5.2)).

Competition

Computational Methods for Geospatial Analysis

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Analytical Competencies
Media and Digital Technologies
Problem-solving

Personal Competencies

Critical Thinking

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Analytical Competencies
Decision-making
Problem-solving

Personal Competencies

Critical Thinking

Social Science Research for Urban Planning & Urban Studies: Quantitative & Qualitative Methods

Objective

This course explores research designs and methods as tools in urban planning and urban studies. Students will actively engage with quantitative and qualitative methods. A focus lies on active learning from examples that apply the discussed methods. In the end, students can create coherent research designs by formulating relevant research questions and assessing and discussing suitable methods.

Specific objectives:

- Know and critically assess urban research methods
- Select, investigate, and learn to apply urban research methods
- Interpret and discuss urban research projects by evaluating the applied research methods
- Create coherent research designs

Competencies

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Analytical Competencies
Decision-making
Problem-solving

Social Competencies

Communication
Cooperation and Teamwork
Self-presentation and Social Influence
Sensitivity to Diversity

Personal Competencies

Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Topography

The elective course "Topography" in the Autumn Semester 2023 builds on a long standing specialization in the spatial exploration of the landscape. We will embark the participants on a terrain that we shape through our own thoughts and actions, adopting different perceptual perspectives, supported by examples from art, literature, technology and history.
This elective course gives architecture students the opportunity to further develop their perception of space through a site-specific approach in the field of landscape architecture. The students will learn to use 3D point cloud technology and other spatial sensing technologies in order to analyze complex urban landscape and develop new ways of editing and representing these intertwined spaces.

Students will document and analyze a case-study site to reveal its topological potentials and sensory qualities. This understanding will be gained through point cloud modeling and audiovisual composition. In particular, we will develop a new, comprehensive sectional model of a topologically interesting site situation. Students will become acquainted to working with point cloud models produced with laser-scanning. Through a series of steps, they will learn how a laser-scanning survey is conducted, how the raw data is processed, how point cloud models are assembled, what qualities these models can provide to analyze, explore and represent space as an audiovisual experience. Collected samples from the field will be assembled and built into an interactive application in the «Landscape Visualization and Modelling Lab». All software required is open source and can also be installed on private laptops, facilitating work from home if necessary.

Semester performance will be assessed on the basis of a written group assignment on extended urbanization (approximately 10 pages, in groups of four). For the assignment - describe and analyse an example of extended urbanization in a geography of your choice. The example may be from Switzerland or from any other region of the planet. Based on scientific literature and other data, conduct a critical analysis of the chosen case study, and discuss the consequences of urbanization of this area for its people and the environment. Develop a possible urban strategy for alternative inclusive development. Summarize your findings through a A3-sized poster.

Methods of Urban Research: Extended Urbanisation

While architects, planners, and urban designers have engaged with the city, the analysis of urbanising territories ‘beyond the city’ have been a blind spot. This lecture series attempts to close this gap by discussing with researchers who will present methods, experiences and findings from a great variety of territories of extended urbanisation.

The lecture series “Methods of Urban Research: Extended Urbanisation” presents the methodology of sociological analysis of territories of extended urbanisation. These territories, which have traditionally been beyond the sensorium of architecture and urban design professions provide important terrains for urban practice. The lecture series will bring together researchers that have been part of a long-standing research project on territories of extended urbanisation. They will present a kaleidoscopic overview of the diverse methods and insights into international research on urbanisation processes in large metropolises and in territories characterized by extended urbanisation. Most of the presented case studies are published in the brand new book "Extended Urbanisation: Tracing Planetary Struggles". Semester performance will be assessed on the basis of a written group assignment on extended urbanization (approximately 10 pages, in groups of four). For the assignment - describe and analyse an example of extended urbanization in a geography of your choice. The example may be from Switzerland or from any other region of the planet. Based on scientific literature and other data, conduct a critical analysis of the chosen case study, and discuss the consequences of urbanization of this area for its people and the environment. Develop a possible urban strategy for alternative inclusive development. Summarize your findings through a A3-sized poster.

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Objective

Public transport is a key driver for making our cities more livable, clean and accessible, providing safe, and sustainable travel options for millions of people around the globe. Proper planning of public transport system also ensures that the system is competitive in terms of speed and cost. Public transport is a crucial asset, whose social, economic and environmental benefits extend beyond those who use it regularly; it reduces the amount of cars and road infrastructure in cities; reduces injuries and fatalities associated to car accidents, and gives transport accessibility to very large demographic groups.

Goal of the class is to understand the main characteristics and differences of public transport networks.

Their various performance criteria based on various perspective and stakeholders. The most relevant decision making problems in a planning tactical and operational point of view

At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate possible improvements to existing networks of public transport and the management of those networks; optimize the use of resources in public transport.

General structure:

general introduction of transport, modes, technologies, system design and line planning for different situations, mathematical models for design and line planning timetabling and tactical planning, and related mathematical approaches operations, and quantitative support to operational problems, evaluation of public transport systems.

Content

Basics for line transport systems and networks
Passenger/Supply requirements for line operations
Objectives of system and network planning, from different perspectives and users, design dilemmas
Conceptual concepts for passenger transport: long-distance, urban transport, regional, local transport
Planning process, from demand evaluation to line planning to timetables to operations
Matching demand and modes
Line planning techniques
Timetabling principles
Allocation of resources
Management of operations
Measures of realized operations
Improvements of existing services

Lecture notes

Lecture slides are provided.

Literature

Ceder, Avi: Public Transit Planning and Operation, CRC Press, 2015, ISBN 978-1466563919 (English)


Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management fostered

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Customer Orientation assessed
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

151-0227-00L Basics of Air Transport (Aviation I) W 4 credits 3G P. Wild

Abstract

In general the course explains the main principles of air transport and elaborates on simple interdisciplinary topics. Working on broad 14 different topics like aerodynamics, manufacturers, airport operations, business aviation, business models etc. the students get a good overview in air transportation. The program is taught in English and we provide 11 different experts/lecturers.

Objective

The goal is to understand and explain basics, principles and contexts of the broader air transport industry.
Further, we provide the tools for starting a career in the air transport industry. The knowledge may also be used for other modes of transport. Ideal foundation for Aviation II - Management of Air Transport.

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## Content

Weekly: 1h independent preparation; 2h lectures and 1 h training with an expert in the respective field

**Concept:** This course will be taught as Aviation I. A subsequent course - Aviation II - covers the "Management of Air Transport".

Content: Transport as part of the overall transportation scheme; Aerodynamics; Aircraft (A/C) Designs & Structures; A/C Operations; Aviation Law; Maintenance & Manufacturers; Airport Operations & Planning; Aviation Security; ATC & Airspace; Air Freight; General Aviation; Business Jet Operations; Business models within Airline Industry; Military Aviation.

Technological visit: This course includes a guided tour at Zurich Airport and Dubendorf Airfield (baggage sorting system, apron, Tower & Radar Simulator at Skyguide Dubendorf).

**Lecture notes**
Preparation materials & slides are provided prior to each class

**Literature**
Literature will be provided by the lecturers, respectively there will be additional Information upon registration (normally available in Moodle)

The lecture is planned as class teaching.

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<td>Media and Digital Technologies</td>
<td>Customer Orientation</td>
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<td></td>
<td>assessed</td>
<td>Problem-solving</td>
<td>Leadership and Responsibility</td>
<td>assessed</td>
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<td></td>
<td>assessed</td>
<td>Project Management</td>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
</tr>
</tbody>
</table>

**E. Heinen**

**A. Kouvelas**

### 101-0417-00L Transport Planning Methods

**W 6 credits**

**4G**

**E. Heinen**

**Abstract**
The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis.

**Objective**
- Knowledge and understanding of statistical methods and algorithms commonly used in transport planning
- Comprehend the reasoning and capabilities of transport models
- Ability to independently develop a transport model able to solve / answer planning problem
- Getting familiar with cost-benefit analysis as a decision-making supporting tool

**Content**
The course provides the necessary knowledge to develop models supporting the solution of given planning problems and also introduces cost-benefit analysis as a decision-making tool. Examples of such planning problems are the estimation of traffic volumes, prediction of estimated utilization of new public transport lines, and evaluation of effects (e.g. change in emissions of a city) triggered by building new infrastructure and changes to operational regulations.

To cope with that, the problem is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis. Interim lab session take place regularly to guide and support students with the applied part of the course.

**Lecture notes**
Moodle platform (enrollment needed)

**Literature**

### 101-0437-00L Traffic Engineering

**W 6 credits**

**4G**

**A. Kouvelas**

**Abstract**
Fundamentals of traffic flow theory and control.

**Objective**
The objective of this course is to fully understand the fundamentals of traffic flow theory in order to effectively manage traffic operations. By the end of this course students should be able to apply basic techniques to model different aspects of urban and inter-urban traffic performance, including congestion.

**Content**
Introduction to fundamentals of traffic flow theory and control. Includes understanding of traffic data collection and processing techniques, as well as data analysis, traffic modeling, and methodologies for traffic control.

**Lecture notes**
The lecture notes and additional handouts will be provided during the lectures.

**Literature**
Additional literature recommendations will be provided during the lectures.

**Prerequisites / notice**
Verkehr III - Road Transport Systems 6th Sem. BSc (101-0415-00L)
Special permission from the instructor can be requested if the student has not taken Verkehr III

### 227-0523-00L Railway Systems I

**W 6 credits**

**4G**

**M. Meyer**

**Abstract**
Fundamentals of traffic flow theory and control.

**Objective**
The objective of this course is to fully understand the fundamentals of traffic flow theory in order to effectively manage traffic operations. By the end of this course students should be able to apply basic techniques to model different aspects of urban and inter-urban traffic performance, including congestion.

**Content**
Introduction to fundamentals of traffic flow theory and control. Includes understanding of traffic data collection and processing techniques, as well as data analysis, traffic modeling, and methodologies for traffic control.

**Lecture notes**
The lecture notes and additional handouts will be provided during the lectures.

**Literature**
Additional literature recommendations will be provided during the lectures.

**Prerequisites / notice**
Verkehr III - Road Transport Systems 6th Sem. BSc (101-0415-00L)
Special permission from the instructor can be requested if the student has not taken Verkehr III
Abstract
Basic characteristics of railway vehicles and their interfaces with the railway infrastructure:
- Transportation tasks and vehicle types
- Running dynamics
- Mechanical part of rail vehicles
- Brakes
- Traction chain and auxiliary supply
- Railway power supply
- Signaling systems
- Standards
- Availability and safety
- Traffic control and maintenance

Objective
- Overview of the technical characteristics of railway systems
- Know-how about the design and construction principles of rail vehicles
- Interrelationship between different fields of engineering sciences (mechanics, electro and information technology, transport systems)
- Understanding tasks and opportunities of engineers working in an environment which has strong economical and political boundaries
- Insight into the activities of the railway vehicle industry and railway operators in Switzerland
- Motivation of young engineers to start a career in the railway industry or with railway operators

Content
EST I (Herbstsemester) - Begriffen, Grundlagen, Merkmale

1 Einführung:
1.1 Geschichte und Struktur des Bahnsystems
1.2 Fahrdynamik

2 Vollbahnfahrzeuge:
2.1 Mechanik: Kasten, Drehgestelle, Lauftechnik, Adhäsion
2.2 Bremsen
2.3 Traktionsantriebssysteme
2.4 Hilfsbetriebe und Komfortanlagen
2.5 Steuerung und Regelung

3 Infrastruktur:
3.1 Fahrweg
3.2 Bahnstromversorgung
3.3 Sicherungsanlagen

4 Betrieb:
4.1 Interoperabilität, Normen und Zulassung
4.2 RAMS, LCC
4.3 Anwendungsbeispiele

Voraussichtlich ein oder zwei Gastreferate

Lecture notes
Abgabe der Unterlagen (gegen eine Schutzgebühr) zu Beginn des Semesters. Rechtzeitig eingeschriebene Teilnehmer können die Unterlagen auf Wunsch und gegen eine Zusatzgebühr auch in Farbe beziehen.

Prerequisites / notice
Dozent: Dr. Markus Meyer, Emkamatik GmbH

Voraussichtlich ein oder zwei Gastvorträge von anderen Referenten.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed

Personal Competencies
Critical Thinking assessed

Urban Systems and Transportation W 3 credits 2G M. Köthenbürger, G. Loumeau

Abstract
This course is an introduction to urban and regional economics. It focuses on the formation and development of urban systems, and highlight how transport infrastructure investments can affect the location, size and composition of such systems.

Objective
The main objective of this course is to provide students with some basic tools to analyze the fundamental economic forces at play in urban systems (i.e., agglomeration and congestion forces), and the role of transport networks in shaping the structure of these systems. Why do urban areas grow or decline? How do transport networks affect the location of individuals and firms? Does the location of a firm determine its productivity? Can transport infrastructure investments reduce economic disparities? These are some of the questions that students should be able to answer after having completed the course.
The course is organized in four parts. I start with the key observation that economic activity (both in terms of population density and productivity) is unevenly distributed in space. For instance, the share of the population living in urban centers is increasing globally, from 16% in 1900 and 50% in 2000 to about 68% by the year 2050 (UN, World Economic Prospects, 2014). The goal of the first part is then to understand the economic forces at play behind these trends, looking at the effects within and across urban areas. I will also discuss how natural or man-made geographical characteristics (e.g., rivers, mountains, borders, etc.) affect the development of such urban systems.

In the second part, I discuss the planning and pricing of transport networks, moving from simple local models to more complex transport models at a global scale. The key aspects include: the first and second best road pricing, the public provision of transport networks and the demographic effects of transport networks.

In the third part, I combine the previous two parts and analyze the interaction between urban systems and transportation. Thereby, the main focus is to understand the economic mechanisms that can lead to a general equilibrium of all actors involved. However, as the study of the historical development of urban systems and transport networks provides interesting insights, I will discuss how their interaction in the past shapes today’s economic geography.

Finally, I broaden the scope of the course and explore related topics. There will be a particular emphasis on the relation between urban systems and fiscal federalism as well as environmental policies. Both aspects are important determinants of the contemporary developments of urban systems, and as such deserve our attention.

In general, this class focuses on the latest research developments in urban and regional economics, though it does not require prior knowledge in this field. It pays particular attention to economic approaches, which are based on theoretical frameworks with strong micro-foundations and allow for precise policy recommendations.

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Critical Thinking</td>
</tr>
<tr>
<td>assessed</td>
<td>assessed</td>
<td>fostered</td>
<td>fostered</td>
</tr>
</tbody>
</table>

### Content

1. Car following models
2. Lane change models
3. Calibration and validation methodology

Specific tasks for the project will include:

1. Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed.
2. Calibrating and validating the simulation model.
3. Redesigning/extending the model to improve the traffic performance through Aimsun and with/without programming in Python or C++.

The course will be based on a project that each group of students will build (design, calibrate, analyze and present) across the semester. A mid-term and final presentation of the work will be asked from each group of students.

The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.

### Literature

Course slides will be made available to students prior to each class.

### Lecture notes

Course slides will be made available to students.

### Prerequisites / notice

Students need to know some basic road transport concepts. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Cooperation and Teamwork</td>
<td>Creative Thinking</td>
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<tr>
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</tbody>
</table>

### Abstract

This course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based simulation models' current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in groups.
This course provides an introduction to agent-based models for transportation policy analysis. Four essential topics are covered:

1) Introduction of agent-based modeling and its comparison to the traditional state of practice modeling
2) Introduction of MATSim, an open-source agent-based model, developed at ETH Zurich and TU Berlin, and its various parts
3) Setting up an agent-based model simulation, where different statistical methods used in the process will be introduced and explained.
4) Conducting a transport policy study. The case study will be performed in groups and will include a paper-like report.

During the course, outside lecturers will give several lectures on using MATSim in practice (i.e., SBB).

### Literature

MATSim


### Prerequisites / notice
There are no strict preconditions regarding which lectures the students should have previously attended. However, experience with at least one high-level programming language (Java, R, Python, or other) is recommended.

For those without object-oriented programming experience, a crash course 101-0491-10 Basics of Java and Best Practices for Scientific Computing before the start of HS is recommended.

### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
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<th>Social Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
<td>Analytical Competencies</td>
<td>Cooperation and Teamwork</td>
</tr>
<tr>
<td>fostered</td>
<td>Problem-solving</td>
<td>fostered</td>
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<tr>
<td>assessed</td>
<td>Project Management</td>
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<td></td>
<td></td>
<td>Critical Thinking</td>
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<tr>
<td>assessed</td>
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</table>

### Literature

- Further literature: will be presented during the course

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**Major in Network Infrastructure**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>101-0492-00L</td>
<td>Microscopic Modelling and Simulation of Traffic Operations</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Makridis</td>
</tr>
</tbody>
</table>

The course introduces basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies. The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.
Objective
The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a real traffic network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication. Simulations will be implemented in Aimsun software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario.

Upon completion of the course, the students will:
- Understand the basic models used in microsimulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.).
- Design a road transport network inside the simulation software.
- Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network.
- Understand how to design a complete study, implement and validate it for planning purposes, e.g. creating a new road infrastructure.
- Make valid and concrete engineering proposals based on the simulation model and alternative scenarios.

Content
In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun. Microscopic modelling and simulation concepts will include:
1) Car following models
2) Lane change models
3) Calibration and validation methodology
Specific tasks for the project will include:
1) Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed.
2) Calibrating and validating the simulation model.
3) Redesigning/ extending the model to improve the traffic performance through Aimsun and with/without programming in Python or C++.

The course will be based on a project that each group of students will build (design, calibrate, analyze and presentation) across the semester. A mid-term and final presentation of the work will be asked from each group of students. It consists of weekly 2-hour lectures. The students work in pairs on a group project that completes in the end of the semester. The modelling software used is Aimsun and lectures (theory and hands on experience) are taking place in a computer room.

The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.

Lecture notes
- The lecture notes and additional handouts will be provided before the lectures.

Literature
- Additional literature recommendations will be provided at the lectures.
- Maintenance strategies, fundamentals of track maintenance and related methods
- 6 - Track maintenance
- Track diagnostics and forecast
- Goals, methods, procedures
- 5 - Diagnostics, maintenance strategies
- Track diagnostics and forecast
- 6 - Track maintenance
- Maintenance strategies, fundamentals of track maintenance and related methods
- Swisstopo (2004). The Access to the data is granted for the students of the course. Additional literature recommended will be presented during the course.

101-0469-00L Road Safety

Objective
Imparting knowledge base about road safety and the event of accident, presenting possibilities to increase road safety

Content
- Accident origin, collection of road accidents, statistical (descriptive and multivariate, accident prediction models) and geographical analysis of road accidents, risk analysis and rehabilitation measures, road safety instruments for infrastructure with focus on road safety audit, Swiss and international transport policy

Literature

Further literature will be presented during the course.

101-0419-02L Railway Infrastructures 2

Objective
- Railway technology; interaction between track and vehicles; stress; track construction including features of railway bridges and tunnels; starting up; track diagnostics and forecast; track maintenance and related methods

Content
- 1 - Railway technology
- Track, power supply / catenaries, information technology, safety / interlockings / dispatching
- 2 - Interaction
- Interaction between track and vehicles, vehicle dynamics
- 3 - Railway Track
- Stress; track construction including special features of railway bridges and tunnels
- 4 - Starting up
- Goals, methods, procedures
- 5 - Diagnostics, maintenance strategies
- Track diagnostics and forecast
- 6 - Track maintenance
- Maintenance strategies, fundamentals of track maintenance and related methods

Lecture notes
- The slides will be made available.

Literature
- A list with related technical literature will be handed out.
Prerequisites / notice
Prerequisite: 101-0419-01 Railway Infrastructures 1 (FS)

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving fostered

Social Competencies
Customer Orientation assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics assessed

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Major Courses for all Majors

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>363-0541-00L</td>
<td>Economic Dynamics and Complexity</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td>F. Schweitzer, L. Verginer</td>
</tr>
</tbody>
</table>

Abstract
What causes economic business cycles? How are limited resources, competition, and cooperation reflected in growth dynamics? To answer such questions, we combine macroeconomic models and methods of nonlinear dynamics. We study the role of bifurcations and control parameters for dynamic stability. Feedback cycles and coupled dynamics are reasons for limited predictability, instability and chaos.

Objective
successful participant of the course is able to:
- understand the importance of different modeling approaches
- formalize and solve one- and two-dimensional nonlinear models
- identify critical conditions for stability and dynamic transitions
- analyze macroeconomic models of business cycles, supply and demand
- apply formal concepts to model economic growth and competition

Content
System theory sees the economy as a complex adaptive system. What does this mean for economic modeling?
We focus on two sources of complexity: (a) nonlinear dynamics, which is captured in this course, “Economic Dynamics and Complexity” and (b) collective interactions, which is captured in the course “Agent-Based Modeling of Economic Systems” (in Spring).

Our approach to economic dynamics combines insights from different disciplines: macroeconomics studying business cycles and growth, system dynamics rooted general system theory and cybernetics, and nonlinear dynamics using applied mathematics.

We start with a comparison of different modeling approaches, to highlight the problems and challenges of system modeling. The subsequent lectures then introduce different one- and two-dimensional nonlinear models with applications in economics, such as models of supply and demand, business cycles, growth and competition.
Emphasis is on the formal analysis of these models using methods from applied mathematics and tools for solving coupled differential equations.

Weekly self-study tasks are used to apply the concepts introduced in the lectures. We practice how to solve nonlinear models formally and numerically and how to interpret the results.

Lecture notes
The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.

Prerequisites / notice
Students should be familiar with nonlinear differential equations and should have basic programming skills. All necessary details to solve nonlinear models will be provided in the course. The course will not build on mathematical proofs, optimization, statistics, efficient numerical computation and other specialized skills.

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>103-0020-00L</td>
<td>Interdisciplinary Project</td>
<td>O</td>
<td>16 credits</td>
<td>34A</td>
<td>A. Grêt-Regamey</td>
</tr>
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</table>

Abstract
The Interdisciplinary Project Activity (IPA) forms the key feature of the MSc RE&IS. Students work on an interdisciplinary task from the field of spatial development and infrastructure systems in a real-life application. The interdisciplinary cooperation and strong communication skills are crucial skills required in practice to communicate with and between relevant actors and other stakeholders.

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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2150 of 2653
Upon completion of the Interdisciplinary Project Activity, students will have gained experience in:

1) Investigating and understanding the project area as well as identifying, evaluating and formulating the current challenges and relevant topics within that area.

2) Creating, designing, developing and evaluating an overall integrated strategy for an urban area with relevant interventions as well as an in-depth study of either a focus area or focus topic within the given urban area.

3) Organising, structuring and fostering teamwork within an interdisciplinary group of 4-5 students in self-responsibility.

4) Applying previously learnt interdisciplinary methodological and theoretical skills from different fields to create solutions to real-world challenges as well as arguing for the solutions’ suitability.

5) Evaluating and choosing effective ways of presenting and communicating information (e.g., text, statistics, images, etc.), ideas, and recommendations throughout the whole semester.

6) Understanding, developing, strengthening, and critically self-evaluating their disciplinary position and role in planning urban development.

Students apply the full range of their previously learned theoretical and methodological skills to solve the task together in their project team. Working closely with representatives of the case study area (e.g. officials, the wider public, different experts and decision-makers), as well as other experts, through site visits, and through individual mentoring by the six RE&IS chairs, students work in a stimulating and motivating environment to solve real-world spatial challenges. The case study area changes every year.

- The semester is structured through an intermediate and final presentation, bilateral discussions with the chairs involved as well as individual group mentoring. During these meetings, the work status has to be communicated and presented with appropriate means. The status of the work is discussed with the professors, assistants and possibly external experts.

- The project begins with a site visit of the project area at the beginning of the semester and the identification as well as precise formulation of the challenges and opportunities observed within the project area.

- The students work on a complex, rather rough task and define their exact objective independently on the basis of the as-is analysis. In the overall strategy, the future development direction for the project area is then determined and interventions are formulated to steer the development in this direction. Within a focus area or focus topic, students further develop their project and deepen their overall strategy. The students test and evaluate the impact of selected interventions and finally reflect on their project, summarize the most important findings and make a recommendation formulated to decision-makers.

- The project gets developed in an interdisciplinary group of students. The internal structuring of the group and distribution of work is to be organised by the students themselves.

- The choice of software for the project development is up to the students. The software used could be applicable to data analysis, information processing, image production and word processing, e.g., the Adobe programs such as InDesign, Illustrator or Photoshop, GIS software, the Microsoft programs such as Word, PowerPoint or Excel as well as CAD, R, Python etc.

Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>103-0010-10L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>20</td>
<td>43D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Only for Spatial Development and Infrastructure Systems MSc, Programme Regulations 2021.

Before starting the Master's thesis, students must have a. obtained the Bachelor's degree; 
  b. fulfilled all specified admission conditions, if any; 
  c. acquired at least 90 credits in the Master's programme, including the required credits for compulsory courses and for interdisciplinary project work.

The Master Programme concludes with the Master Thesis, which has to be done in one of the chosen Majors and has to be completed within 16 weeks. The Master Thesis is supervised by a professor and shall attest the students ability to work independently and to produce scientifically structured work.

The topics of the Master Thesis are published by the professors. The Topic can be set also in consultation between the student and the professor.
*Major in Spatial and Landscape Development*

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>052-0801-00L</td>
<td>Global History of Urban Design I</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>T. Avermaete</td>
</tr>
</tbody>
</table>

**Abstract**

This course focuses on the history of the design of cities, as well as on the ideas, processes and actors that engender and lead their development and transformation. The history of urban design will be approached as a cross-cultural field of knowledge that integrates scientific, economic and technical innovation as well as social and cultural advances.

**Objective**

The lectures deal mainly with the definition of urban design as an independent discipline, which maintains connections with other disciplines (politics, sociology, geography) that are concerned with the transformation of the city. The aim is to make students conversant with the multiple theories, concepts and approaches of urban design as they were articulated throughout time in a variety of cultural contexts, thus offering a theoretical framework for students’ future design work.

**Content**

In the first semester the genesis of the objects of study, the city, urban culture and urban design, are introduced and situated within their intellectual, cultural and political contexts:

01. The History and Theory of the City as Project
02. Of Rituals, Water and Mud: The Urban Revolution in Mesopotamia and the Indus
03. The Idea of the Polis: Rome, Greece and Beyond
04: The Long Middle Ages and their Counterparts: From the Towns of Tuscany to Delhi
05: Between Ideal and Laboratory: Of Middle Eastern Grids and European Renaissance Principles
06: Of Absolutism and Enlightenment: Baroque, Defense and Colonization
07: The City of Labor: Company Towns as Cross-Cultural Phenomenon
08: Garden Cities of Tomorrow: From the Global North to the Global South and Back Again
09: Civilized Wilderness and City Beautiful: The Park Movement of Olmsted and The Urban Plans of Burnham
10: The Extension of the European City: From the Viennese Ringstrasse to Amsterdam Zuid

**Lecture notes**

Prior to each lecture a chapter of the reader (Skript) will be made available through the webpage of the Chair. These chapters will provide an introduction to the lecture, the basic visual references of each lecture, key dates and events, as well as references to the compulsory and additional reading.

**Literature**

There are three books that will function as main reference literature throughout the course:


These books will be reserved for consultation in the ETH Baubibliothek, and will not be available for individual loans.

A list of further recommended literature will be found within each chapter of the reader (Skript).

**Prerequisites / notice**

Students are required to familiarize themselves with the conventions of architectural drawing (reading and analyzing plans at various scales).

**Competencies**

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>Analytical Competencies</th>
<th>Project Management</th>
<th>Communication</th>
<th>Cooperation and Teamwork</th>
<th>Leadership and Responsibility</th>
<th>Self-presentation and Social Influence</th>
<th>Sensitivity to Diversity</th>
<th>Negotiation</th>
<th>Creative Thinking</th>
<th>Critical Thinking</th>
<th>Integrity and Work Ethics</th>
<th>assessed</th>
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<th>assessed</th>
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<th>assessed</th>
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*Major in Transport Systems and Behaviour*

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<td>363-0445-00L</td>
<td>Production and Operations Management</td>
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**Abstract**

This core course provides insights into the basic theories, principles, concepts, and techniques used to design, analyze, and improve the operational capabilities of an organization.

**Objective**

This course provides students with a broad theoretical basis for understanding, designing, analyzing, and improving manufacturing operations. After completing this course:

1. Students can apply key concepts of POM to detail an operations strategy.
2. Students can do simple forecasting of demand and plan the needed capacity to meet it.
3. Students can conduct process mapping analysis, use it to design and improve processes and layouts, and elaborate on the limitations of the chosen method.
4. Students can choose IT, OT, and automation technology for manufacturing applications.
5. Students can design information flows, manage master data, and use it to plan and control a factory.
6. Students can design material flows in and beyond factories.
7. Students can design performance management systems.
8. Students can select and use problem-solving tools to improve quality and productivity.
9. Additional skills: Students acquire experience in teamwork.
The course covers the most fundamental strategic and tactical concepts in production and operations management (POM).

Production and Operations Management (POM) is at the heart of any business. It is concerned with the business processes that transform input into output and deliver products and services to customers. Factory management is an important part of POM, but it is much more than what takes place inside the production facilities of companies like ABB, Boeing, BMW, LEGO, Nestlé, Roche, TESLA, and Toyota. Did you know that the largest portion of assets and employees in most organizations are engaged in the operations function? Although this course focuses on manufacturing, all types of organizations depend on their operational capabilities. With the ongoing globalization and digitization of manufacturing, POM has won a deserved status for providing a competitive advantage.

This course covers the following topics: Introduction to POM, Manufacturing strategy, Forecasting and capacity, Process design, Layout, Industry 4.0, Information flow, Material flow, Logistics/SCM, Performance management, Performance improvement, Quality management, and Maintenance.

This course is administered via Moodle. The course is designed around five elements:

2. Video lectures. Short video lectures presenting basic POM concepts.
3. Class lectures. Deep-dives with case examples on select topics.
4. FactoryVR group assignment. FactoryVR allows students to visit factories virtually.
5. Quizzes. A few quizzes during the semester help students check their progress and prepare for the written exam.

Suggested literature is provided in the syllabus.

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101-0491-00L  
Agent Based Modeling in Transportation  
W 6 credits  
4G M. Balac, G. O. Kagho  

Abstract
This course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based simulation models' current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in groups.

Objective
At the end of the course, the students should:
- have an understanding of agent-based modeling
- have an understanding of MATSim
- have an understanding of the process needed to set up an agent-based study
- have practical experience of using MATSim to perform transportation studies

Content
This course provides an introduction to agent-based models for transportation policy analysis. Four essential topics are covered:

1) Introduction of agent-based modeling and its comparison to the traditional state of practice modeling
2) Introduction of MATSim, an open-source agent-based model, developed at ETH Zurich and TU Berlin, and its various parts
3) Setting up an agent-based model simulation, where different statistical methods used in the process will be introduced and explained. Here the open-source eqasim framework used at ETH Zurich to set up agent-based models will be introduced
4) Conducting a transport policy study. The case study will be performed in groups and will include a paper-like report.

During the course, outside lecturers will give several lectures on using MATSim in practice (i.e., SBB).

Agent-based modeling in general
MATSim

Additional relevant readings, primarily scientific articles, will be recommended throughout the course.

Prerequisites / notice
There are no strict preconditions regarding which lectures the students should have previously attended. However, experience with at least one high-level programming language (Java, R, Python, or other) is recommended.

For those without object-oriented programming experience, a crash course 101-0491-10 Basics of Java and Best Practices for Scientific Computing before the start of HS is recommended.
### Road Safety

**Abstract**
The collection and the methods of statistical and geographical analysis of road accidents are important fundamentals of this course. Safety aspects in design of urban roads are discussed and measures for improving the safety situation are presented. Procedures of infrastructure safety management for administrations and police are another topic.

**Objective**
Imparting knowledge base about road safety and the event of accident, presenting possibilities to increase road safety

**Content**
Accident origin, collection of road accidents, statistical (descriptive and multivariate, accident prediction models) and geographical analysis of road accidents, risk analysis and rehabilitation measures, road safety instruments for infrastructure with focus on road safety audit, Swiss and international transport policy

**Literature**

Further literature: will be presented during the course

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### Microscopic Modelling and Simulation of Traffic Operations

**Abstract**
The course introduces basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies. The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.

**Objective**
The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a real traffic network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication.

Simulations will be implemented in Aimsun software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario.

Upon completion of the course, the students will:
- Understand the basic models used in multimicrosimulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.).
- Design a road transport network inside the simulation software.
- Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network.
- Understand how to design a complete study, implement and validate it for planning purposes, e.g. creating a new road infrastructure.
- Make valid and concrete engineering proposals based on the simulation model and alternative scenarios.

**Content**
In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun.

Microscopic modelling and simulation concepts will include:
1) Car following models
2) Lane change models
3) Calibration and validation methodology

Specific tasks for the project will include:
1) Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed.
2) Calibrating and validating the simulation model.
3) Redesigning/Extending the model to improve the traffic performance through Aimsun and with/without programming in Python or C++.

The course will be based on a project that each group of students will build (design, calibrate, analyze and presentation) across the semester. A mid-term and final presentation of the work will be asked from each group of students.

It consists of weekly 2-hour lectures. The students work in pairs on a group project that completes in the end of the semester. The modelling software used is Aimsun and lectures (theory and hands-on experience) are taking place in a computer room.

The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.

**Lecture notes**
The lecture notes and additional handouts will be provided before the lectures.

**Literature**
Additional literature recommendations will be provided at the lectures.

**Prerequisites**
Students need to know some basic road transport concepts. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.

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### Introduction to Mathematical Optimization

**Abstract**
Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering.

**Objective**
The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.

**Content**
Topics covered in this course include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.

**Literature**
Information about relevant literature will be given in the lecture.

**Prerequisites**
This course is meant for students who did not already attend the course "Mathematical Optimization", which is a more advance lecture covering similar topics. Compared to "Mathematical Optimization", this course has a stronger focus on modeling and applications.
At the end of the course, the students should

- Have acquired object-oriented programming skills with a focus on Java.
- Have an understanding of version control using git
- Have learned to deploy Java applications on servers

This course provides an introduction to object-oriented programming with Java. Four topics are covered:

- Basics of Java (objects, classes, interfaces, abstract classes, static classes, static methods, ...)
- Injection (traditional vs. Guice)
- Code versioning
- Java application deployment on servers

The first part of the lecture introduces the fundamentals of river engineering, such as methods to determine and calculate the river discharge, or sampling methods to characterize the bed material. In addition, the transport processes of sediment (bedload and suspended load) and wood in rivers will be examined, including the principles of incipient motion, and initiation of erosion or deposition processes.

In the second part of the lecture, the methods will be explained to quantify the bed load budget and the morphological changes (erosion, deposition) in river systems. Specifically, natural channel formation processes, different bed forms and plan forms of rivers (straight, meandering, braided) are examined.

The last part of the lecture focuses on the design of river engineering structures, including examples from an ongoing flood and river rehabilitation project at the Alpine Rhine in Austria and Switzerland.

Lecture notes
Lecture slides can be downloaded via Moodle.

Literature
1. Erosion and Sedimentation; Pierre Y. Julien

Prerequisites / notice
Recommended lectures:
- Hydrology (102-0293-AAL), Hydraulics I (101-0203-01L), and Hydraulic Engineering (101-0206-00L).

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: assessed
- Self-direction and Self-management: fostered

101-0469-00L Road Safety W 6 credits 4G M. Deublein, E. Eberling

Abstract
The collection and the methods of statistical and geographical analysis of road accidents are important fundamentals of this course. Safety aspects in design of urban roads are discussed and measures for improving the safety situation are presented. Procedures of infrastructure safety management for administrations and police are another topic.

Objective
- Imparting knowledge base about road safety and the event of accident, presenting possibilities to increase road safety

Content
- Accident origin, collection of road accidents, statistical (descriptive and multivariate, accident prediction models) and geographical analysis of road accidents, risk analysis and rehabilitation measures, road safety instruments for infrastructure with focus on road safety audit, Swiss and international transport policy

Literature

Further literature: will be presented during the course.

101-0492-00L Microscopic Modelling and Simulation of Traffic Operations W 3 credits 2G M. Makridis

Abstract
The course introduces basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies. The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.
Objective
The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a real traffic network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication.

Simulations will be implemented in Aimsun software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario.

Upon completion of the course, the students will:
- Understand the basic models used in microsimulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.).
- Design a road transport network inside the simulation software.
- Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network.
- Understand how to design a complete study, implement and validate it for planning purposes, e.g. creating a new road infrastructure.
- Make valid and concrete engineering proposals based on the simulation model and alternative scenarios.

Content
In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun. Microscopic modelling and simulation concepts will include:
1) Car following models
2) Lane change models
3) Calibration and validation methodology

Specific tasks for the project will include:
1) Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed.
2) Calibrating and validating the simulation model.
3) Redesigning/extend the model to improve the traffic performance through Aimsun and with/without programming in Python or C++.

The course will be based on a project that each group of students will build (design, calibrate, analyze and presentation) across the semester. A mid-term and final presentation of the work will be asked from each group of students. It consists of weekly 2-hour lectures. The students work in pairs on a group project that completes in the end of the semester. The modelling software used is Aimsun and lectures (theory and hands on experience) are taking place in a computer room.

The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.

Lecture notes
The lecture notes and additional handouts will be provided before the lectures.

Literature
Additional literature recommendations will be provided at the lectures.

Prerequisites / notice
Students need to know some basic road transport concepts. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.

Competencies

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101-0419-02L Railway Infrastructures 2 W 2 credits 2G U. A. Weidmann, M. Kohler, M. J. Manhart

Abstract
Railway technology: interaction between track and vehicles; stress; track construction including features of railway bridges and tunnels; starting up; track diagnostics and forecast; track maintenance and related methods

Objective
The lecture gives a deeper insight into railway technology, the interaction between track and vehicles as well as in construction and dimensioning of the track. Methods for starting up and the diagnosis of the state of the track and its forecast are shown. State-of-the-art maintenance strategies and technologies are presented.

Content
1 - Railway technology
   Track, power supply / catenaries, information technology, safety / interlockings / dispatching

2 - Interaction
   Interaction between track and vehicles, vehicle dynamics

3 - Railway Track
   Stress; track construction including special features of railway bridges and tunnels

4 - Starting up
   Goals, methods, procedures

5 - Diagnostics, maintenance strategies
   Track diagnostics and forecast

6 - Track maintenance
   Maintenance strategies, fundamentals of track maintenance and related methods

Lecture notes
The slides will be made available.


A list with related technical literature will be handed out.

Literature
Prerequisite: 101-0419-01 Railway Infrastructures 1 (FS)
Structural reliability aims at quantifying the probability of failure of systems due to uncertainties in their design, manufacturing and environmental conditions. Risk analysis combines this information with the consequences of failure in view of optimal decision making. The course presents the underlying probabilistic modelling and computational methods for reliability and risk assessment.

The goal of this course is to provide the students with a thorough understanding of the key concepts behind structural reliability and risk analysis. After this course the students will have refreshed their knowledge of probability theory and statistics to model uncertainties in view of engineering applications. They will be able to analyze the reliability of a structure and to use risk assessment methods for decision making under uncertain conditions. They will be aware of the state-of-the-art computational methods and software in this field.

Engineers are confronted every day to decision making under limited amount of information and uncertain conditions. When designing new structures and systems, the design codes such as SIA or Euro-codes usually provide a framework that guarantees safety and reliability. However the level of safety is not quantified explicitly, which does not allow the analyst to properly choose between design variants and evaluate a total cost in case of failure. In contrast, the framework of risk analysis allows one to incorporate the uncertainty in decision making.

The first part of the course is a reminder on probability theory that is used as a main tool for reliability and risk analysis. Classical concepts such as random variables and vectors, dependence and correlation are recalled. Basic statistical inference methods used for building a probabilistic model from the available data, e.g. the maximum likelihood method, are presented.

The second part is related to structural reliability analysis, i.e. methods that allow one to compute probabilities of failure of a given system with respect to prescribed criteria. The framework of reliability analysis is first set up. Reliability indices are introduced together with the first order-second moment method (FOSM) and the first order reliability method (FORM). Methods based on Monte Carlo simulation are then reviewed and illustrated through various examples. By-products of reliability analysis such as sensitivity measures and partial safety coefficients are derived and their links to structural design codes is shown. The reliability of structural systems is also introduced as well as the methods used to reassess existing structures based on new information.

The third part of the course addresses risk assessment methods. Techniques for the identification of hazard scenarios and their representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. Elements of Bayesian decision making, i.e. pre-, post and pre-post risk assessment methods are presented.

The course also includes a tutorial using the UQLab software dedicated to real world structural reliability analysis.

Lectures notes

Slides of the lectures are available online every week. A printed version of the full set of slides is proposed to the students at the beginning of the semester.

Literature


S. Marelli, R. Schöbi, B. Sudret, UQLab user manual - Structural reliability (rare events estimation), Report UQLab-V0.92-107.

Prerequisites / notice

Basic course on probability theory and statistics
The course covers the most fundamental strategic and tactical concepts in production and operations management (POM).

Content
Introduction (most important sources of construction and real estate law), SIA (Swiss Society of Engineers and Architects) Design Engineering Services Contract, SIA-Norm 118 (SIA General Terms and Conditions for Construction Services), liability of designers/civil engineers, construction insurance, property law for civil engineers, sale of land, contaminated sites, statutory mortgage for contractors, public procurement, litigation in construction and real estate, the civil engineer as expert, What else to know ...

Lecture notes
There are 'Lecture Notes' (in German) for this course.

Introduction to Mathematical Optimization
This course is meant for students who did not already attend the course "Mathematical Optimization", which is a more advance lecture covering similar topics. Compared to "Mathematical Optimization", this course has a stronger focus on modeling and applications.

Content
Topics covered in this course include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.

Production and Operations Management
This core course provides insights into the basic theories, principles, concepts, and techniques used to design, analyze, and improve the operational capabilities of an organization.

Content
The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.

Production and Operations Management (POM) is at the heart of any business. It is concerned with the business processes that transform input into output and deliver products and services to customers. Factory management is an important part of POM, but it is much more than what takes place inside the production facilities of companies like ABB, Boeing, BMW, LEGO, Nestlé, Roche, TESLA, and Toyota. Did you know that the largest portion of assets and employees in most organizations are engaged in the operations function? Although this course focuses on manufacturing, all types of organizations depend on their operational capabilities. With the ongoing globalization and digitization of manufacturing, POM has won a deserved status for providing a competitive advantage.

This course covers the following topics: Introduction to POM, Manufacturing strategy, Forecasting and capacity, Process design, Layout, Production and Operations Management (POM).

Performance management, Performance improvement, Quality management, and Maintenance.

This course is administered via Moodle. The course is designed around five elements:
2. Video lectures. Short video lectures presenting basic POM concepts.
3. Class lectures. Deep-dives with case examples on select topics.
4. FactoryVR group assignment. FactoryVR allows students to visit factories virtually.
5. Quizzes. A few quizzes during the semester help students check their progress and prepare for the written exam.

Suggested literature is provided in the syllabus.
Abstract
This course provides an overview of the main natural hazards and their importance in a national and international context. The probability, risk, and implications of various natural hazards will be discussed, along with potential management options. The course consists of introductory lectures and exercises, seminars with guest lectures by experts and a field trip.

Objective
By the end of the course, students will be able to:

• explain the main natural hazards, their processes and their importance in different contexts.
• describe the likelihood, risk, and consequences of natural hazards and their management options.
• identify and discuss the development of natural hazards in the context of climate change.

Literature
will be distributed and available on Moodle

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Personal Competencies

| Critical Thinking | fostered |

052-0801-00L Global History of Urban Design I

Abstract
This course focuses on the history of the design of cities, as well as on the ideas, processes and actors that engender and lead their development and transformation. The history of urban design will be approached as a cross-cultural field of knowledge that integrates scientific, economic and technical innovation as well as social and cultural advances.

Objective
The lectures deal mainly with the definition of urban design as an independent discipline, which maintains connections with other disciplines (politics, sociology, geography) that are concerned with the transformation of the city. The aim is to make students conversant with the multiple theories, concepts and approaches of urban design as they were articulated throughout time in a variety of cultural contexts, thus offering a theoretical framework for students’ future design work.

Content
In the first semester the genesis of the objects of study, the city, urban culture and urban design, are introduced and situated within their intellectual, cultural and political contexts:

01. The History and Theory of the City as Project
02. Of Rituals, Water and Mud: The Urban Revolution in Mesopotamia and the Indus
03. The Idea of the Polis: Rome, Greece and Beyond
04. The Long Middle Ages and their Counterparts: From the Towns of Tuscany to Delhi
05: Between Ideal and Laboratory: Of Middle Eastern Grids and European Renaissance Principles
06: Of Absolutism and Enlightenment: Baroque, Defense and Colonization
07: The City of Labor: Company Towns as Cross-Cultural Phenomenon
08: Garden Cities of Tomorrow: From the Global North to the Global South and Back Again
09: Civilized Wilderness and City Beautiful: The Park Movement of Olmsted and The Urban Plans of Burnham
10: The Extension of the European City: From the Viennese Ringstrasse to Amsterdam Zuid

Lecture notes
Prior to each lecture a chapter of the reader (Skript) will be made available through the webpage of the Chair. These chapters will provide an introduction to the lecture, the basic visual references of each lecture, key dates and events, as well as references to the compulsory and additional reading.

Literature
There are three books that will function as main reference literature throughout the course:


These books will be reserved for consultation in the ETH Baubibliothek, and will not be available for individual loans.

A list of further recommended literature will be found within each chapter of the reader (Skript).

Prerequisites / notice
Students are required to familiarize themselves with the conventions of architectural drawing (reading and analyzing plans at various scales).

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<td></td>
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<td>Negotiation</td>
<td>fostered</td>
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</table>

0101-0187-00L Structural Reliability and Risk Analysis

Abstract
Structural reliability aims at quantifying the probability of failure of systems due to uncertainties in their design, manufacturing and environmental conditions. Risk analysis combines this information with the consequences of failure in view of optimal decision making. The course presents the underlying probabilistic modelling and computational methods for reliability and risk assessment.

Objective
The goal of this course is to provide the students with a thorough understanding of the key concepts behind structural reliability and risk analysis. After this course the students will have refreshed their knowledge of probability theory and statistics to model uncertainties in view of engineering applications. They will be able to analyze the reliability of a structure and to use risk assessment methods for decision making under uncertain conditions. They will be aware of the state-of-the-art computational methods and software in this field.
Engineers are confronted every day to decision making under limited amount of information and uncertain conditions. When designing new structures and systems, the design codes such as SIA or Euro-codes usually provide a framework that guarantees safety and reliability. However, the level of safety is not quantified explicitly, which does not allow the analyst to properly choose between design variants and evaluate a total cost in case of failure. In contrast, the framework of risk analysis allows one to incorporate the uncertainty in decision making.

The first part of the course is a reminder on probability theory that is used as a main tool for reliability and risk analysis. Classical concepts such as random variables and vectors, independence and correlation are recalled. Basic statistical inference methods used for building a probabilistic model from the available data, e.g. the maximum likelihood method, are presented.

The second part is related to structural reliability analysis, i.e. methods that allow one to compute probabilities of failure of a given system with respect to prescribed criteria. The framework of reliability analysis is first set up. Reliability indices are introduced together with the first order-second moment method (FORM) and the first order reliability method (FOSM). Methods based on Monte Carlo simulation are then reviewed and illustrated through various examples. By-products of reliability analysis such as sensitivity measures and partial safety coefficients are derived and their links to structural design codes is shown. The reliability of structural systems is also introduced as well as the methods used to reassess existing structures based on new information.

The third part of the course addresses risk assessment methods. Techniques for the identification of hazard scenarios and their representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. Elements of Bayesian decision making, i.e. pre-, post and pre-post risk assessment methods are presented.

The course also includes a tutorial using the UQLab software dedicated to real world structural reliability analysis.

Lecture notes
Slides of the lectures are available online every week. A printed version of the full set of slides is proposed to the students at the beginning of the semester.

Literature

S. Marelli, R. Schöbi, B. Sudret, UQLab user manual - Structural reliability (rare events estimation), Report UQLab-v0.92-107.

Prerequisites / notice
Basic course on probability theory and statistics
Content

Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Literature


Prerequisites / notice

Solid background in linear algebra.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Sensitivity to Diversity: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Prerequisites / notice

Recommended lectures:
- Hydrology (102-0293-AAL), Hydraulics I (101-0203-01L), and Hydraulic Engineering (101-0206-00L).
- 2. River Mechanics; Pierre Y. Julien

Short practical exercises (voluntary) will be offered throughout the semester to improve the application of the learned subjects.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed

Social Competencies
- Communication: fostered

Personal Competencies
- Cooperation and Teamwork: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Urban Design III

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed

Social Competencies
- Communication: fostered

Personal Competencies
- Cooperation and Teamwork: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Abstract

Students are introduced to a narrative of ‘Urban Stories’ through a series of three tools driven by social, governance, and environmental transformations in today’s urbanization processes. Each lecture explores one city’s spatial and organizational ingenuity born out of a particular place’s realities, allowing students to transfer these inventions into a catalog of conceptual tools.

Urban Design III

W 2 credits 2V

H. Klumpner
F. T. Salva Rocha Franco

052-0707-00L

River Engineering

W 3 credits 2G

V. Weitbrecht, I. Schalko, K. Sperger

0101-0258-00L
Cadastral Systems

How can students of architecture become active agents of change? What does it take to go beyond a building’s scale, making design-relevant decisions to the city rather than a single client? How can we design in cities with a lack of land, tax base, risk, and resilience, understanding that Zurich is the exception and these other cities are the rule? How can we discover, set rather than follow trends and understand existing urban phenomena activating them in a design process? The lecture series produces a growing catalog of operational urban tools across the globe, considering Governance, Social, and Environmental realities. Instead of limited binary comparing of cities, we are building a catalog of change, analyzing what design solutions cities have been developing informally incrementally over time, why, and how. We look at the people, institutions, culture behind the design and make concepts behind these tools visible. Students get first-hand information from cities where the chair as a Team has researched, worked, or constructed projects over the last year, allowing competent, practical insight about the people and topics that make these places unique. Students will be able to use and expand an alternative repertoire of experiences and evidence-based design tools, go to the conceptual core of them, and understand how and to what extent they can be relevant in other places. Urban Stories is the basic practice of architecture and urban design. It introduces a repertoire of urban design instruments to the students to use, test, and start their designs.

Urban form cannot be reduced to physical space. Cities result from social construction, under the influence of technologies, ecology, culture, the impact of experts, and accidents. Urban un-concluded processes respond to political interests, economic pressure, cultural inclinations, along with the imagination of architects and urbanists and the informal powers at work in complex adaptive systems. Current urban phenomena are the result of urban evolution. The facts stored in urban environments include contributions from its entire lifecycle, visible in the physical environment, and non-physical aspects. This imaginary city exists along with its potentials and problems and with the conflicts that have evolved. Knowledge and understanding, along with a critical observation of the actions and policies, are necessary to understand the diversity and instability present in the contemporary city and understand how urban form evolved to its current state.

How did cities develop into the cities we live in now? Urban plans, instruments, visions, political decisions, economic reasonings, cultural inputs, and social organization have been used to operate in urban settlements in specific moments of change. We have chosen cities that exemplify how these instruments have been implemented and how they have shaped urban environments. We transcribe these instruments into urban operational tools that we have recognized and collected within existing tested cases in contemporary cities across the globe.

This lecture series will introduce urban knowledge and the way it has introduced urban models and operational modes within different concrete realities, therefore shaping cities. The lecture series translates urban knowledge into operational tools, extracted from cities where they have been tested and become exemplary samples, most relevant for understanding how the urban landscape has taken shape. The tools are clustered in twelve thematic clusters and three tool scales for better comparability and cross-reflection.

The Tool case studies are compiled into a global urbanization toolbox, which we use as typological models to read the city and critically reflect upon it. The presented contents are meant to serve as inspiration for positioning in future professional life and provide instruments for future design decisions.

In an interview with a local designer, we measure our insights against the most pressing design topics in cities today, including inclusion, affordable housing, provision of public spaces, and infrastructure for all.

Lecture notes

- The learning material, available via https://moodle-ap2.let.ethz.ch/s comprises of:
  - Toolbox ‘Reader’ with an introduction to the lecture course and tool summaries
  - Weekly exercise tasks
  - Infographics with basic information of each city
  - Quiz question for each tool
  - Additional reading material
  - Interviews with experts
  - Archive of lecture recordings

Literature

- Reading material will be provided throughout the semester.

<table>
<thead>
<tr>
<th>103-0687-00L</th>
<th>Cadastral Systems</th>
<th>W 2 credits</th>
<th>2G</th>
<th>J. Lüthy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Conception, structure and impact of cadastral systems such as property cadastre, PLR-cadastre, digital twin and related spatial data infrastructures (SDI) as well as their importance for civil society.</td>
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<tr>
<td>Content</td>
<td>Students will get an understanding of the conception, structure and impact of cadastral systems and related concepts such as land administration, land registry, PLR-cadastre, spatial data infrastructures and Digital Twins. The link between cadastral systems, gender equality, economic prosperity and the contribution of property cadastre to achieving the United Nation Sustainable Development Goals (UN SDGs) is discussed. The Swiss cadastral system (“Amtliche Vermessung”) as well as a number of international systems in developed as well as in developing countries are discussed. The importance of the data from the property cadastre for the National Spatial Data Infrastructure (NSDI) and digital transformation will be investigated using various examples.</td>
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</table>
Electives ETH Zurich

Science in Perspective

Course Catalogue of ETH Zurich

Recommended Science in Perspective (Type B) for D-BAUG

Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0031-AAL</td>
<td>Systems Engineering Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
<td>E-</td>
<td>3 credits</td>
<td>9R</td>
<td>B. T. Adey</td>
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</tbody>
</table>

Abstract
- Systems Engineering is a way of thinking that helps engineer sustainable systems, i.e. ones that meet the needs of stakeholders in the short, medium and long terms.
- This course provides an overview of the main principles of Systems Engineering, and includes an introduction to the use of operations research methods in the determination of optimal systems.

Objective
The world’s growing population, changing demographics, and changing climate pose formidable challenges to humanity’s ability to live sustainably. Ensuring that humanity can live sustainably requires accommodating Earth’s growing and changing population through the provision and operation of a sustainable and resilient built environment. This requires ensuring excellent decision-making as to how the built environment is constructed and modified.

The objective of this course is to ensure the best possible decision making when engineering sustainable systems, i.e. ones that meet the needs of stakeholders in the short, medium and long term. In this course, you will learn the main principles of Systems Engineering that can help you from the first idea that a system may not meet expectations, to the quantitative and qualitative evaluation of possible system modifications. Additionally, the course includes an introduction to the use of operations research methods in the determination of optimal solutions in complex systems.

More specifically upon completion of the course, you will have gained insight into:
- how to structure the large amount of information that is often associated with attempting to modify complex systems
- how to set goals and define constraints in the engineering of complex systems
- how to generate possible solutions to complex problems in ways that limit exceedingly narrow thinking
- how to compare multiple possible solutions over time with differences in the temporal distribution of costs and benefits and uncertainty as to what might happen in the future
- how to assess values of benefits to stakeholders that are not in monetary units
- how to assess whether it is worth obtaining more information in determining optimal solution
- how to take a step back from the numbers and qualitatively evaluate the possible solutions in light of the bigger picture
- the basics of operations research and how it can be used to determine optimal solutions to complex problems, including linear, integer and network programming, dealing with multiple objectives and conducting sensitivity analyses.

Content
This is a self-study course, there are no lectures or help sessions. A Moodle page with the relevant literature, study materials, and course information is provided. For questions regarding course content or administration, students may approach the lecturers/teaching assistants.

Lecture notes
The script for the original course is in German. The English material that can be used for the self-study course is:

2 Books (provided as PDFs):

2 exams from previous semesters (2017 and 2021) for practice, with solutions provided.
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Project Management

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
General introduction to the development, the life cycle and the characteristics of projects. Introduction to, and experience with, the methods and tools to help with the preparation, evaluation, organisation, planning, controlling and completion of projects.

Objective
To introduce the methods and tools of project management. To impart knowledge in the areas of project organisation and structure, project planning, resource management, project controlling and on team leadership and team work.

Content
- From strategic planning to implementation (Project phases, goals, constraints, and feasibility)
- Project leadership (Leadership, Teams)
- Project organization (Structure)
- Project planning (Schedule, cost and resource planning)
- Project controlling
- Risk and Quality Management
- Project completion

Lecture notes
This is a self-study course, there are no lectures or help sessions. A Moodle page with the relevant literature, study materials, and course information is provided. For questions regarding course content or administration, students may approach the lecturers/teaching assistants.

Literature
Material that can be used for the self-study course is:
- 2 Books:
  - Shub, Bard and Globerson, 2nd ed. Chapters 1, 6-11 (provided as PDFs)
  - Nicholas and Steyn, 4th ed., Chapters 1, 5-15 (Available online)
- 2 exams from previous semesters (2012 fall and spring) for practice, with solutions provided.

Spatial Planning and Landscape Development

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
The lecture introduces into the main-features of spatial planning. Attended will be the subjects of planning as a national responsibility, instruments of spatial planning, techniques for problem solving in spatial planning and the Swiss concept for regional planning.

Objective
- To get to know the interaction between the community and our living space and their resulting conflicts.
- Link theory and practice in spatial planning.
- To get to know instruments and facilities to process problems in spatial planning.

Transport Basics

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
- Introduction to the fundamentals of transportation
- Developing an understanding of the interactions between land use and transportation
- Introduction to the dynamics of transport systems: daily patterns and historical developments

Objective
Introduction to the fundamentals of transportation.
### Content
- Accessibility
- Equilibrium in transport networks
- Fundamental transport models
- Traffic flow and control
- Vehicle dynamics on rail and road
- Transport modes and supply patterns
- Time tables

### Competencies
#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: fostered

#### Personal Competencies
- Critical Thinking: fostered

### Spatial Development and Infrastructure Systems Master - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Type Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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### Key for Hours

<table>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

### ECTS
- European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tr>
<td>401-0151-00L</td>
<td>Linear Algebra</td>
<td>O</td>
<td>5 credits</td>
<td>3V+2U</td>
<td>V. C. Gradinaru</td>
</tr>
<tr>
<td>Abstract</td>
<td>Contents: Linear systems - the Gaussian algorithm, matrices - LU decomposition, determinants, vector spaces, least squares - QR decomposition, linear maps, eigenvalue problem, normal forms - singular value decomposition; numerical aspects.</td>
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<tr>
<td>Objective</td>
<td>Einführung in die Lineare Algebra für Ingenieure unter Berücksichtigung numerischer Aspekte</td>
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<tr>
<td>Lecture notes</td>
<td>eigenes Aufschrieb und K. Nipp / D. Stoffer, Lineare Algebra, vdf Hochschulverlag, S. Auflage 2002</td>
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<tr>
<td>Literature</td>
<td>K. Nipp / D. Stoffer, Lineare Algebra, vdf Hochschulverlag, S. Auflage 2002</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<td></td>
<td>Techniques and Technologies</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<td>Decision-making</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
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<td>Personal Competencies</td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<td>Creative Thinking</td>
<td>assessed</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td>異</td>
<td>Discrete Mathematics</td>
<td>O</td>
<td>7 credits</td>
<td>4V+2U</td>
<td>U. Maurer</td>
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<tr>
<td>Abstract</td>
<td>Content: Mathematical reasoning and proofs, abstraction, Sets, relations (e.g. equivalence and order relations), functions, (un-)countability, number theory, algebra (groups, rings, fields, polynomials, subalgebras, morphisms), logic (propositional and predicate logic, proof calculus).</td>
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<tr>
<td>Objective</td>
<td>The primary goals of this course are (1) to introduce the most important concepts of discrete mathematics, (2) to understand and appreciate the role of abstraction and mathematical proofs, and (3) to discuss a number of applications, e.g. in cryptography, coding theory, and algorithm theory.</td>
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<tr>
<td>Content</td>
<td>See course description.</td>
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<tr>
<td>Lecture notes</td>
<td>available (in english)</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<td></td>
<td>Technics and Technologies</td>
<td>assessed</td>
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<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<td></td>
<td>Decision-making</td>
<td>assessed</td>
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<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
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<td></td>
<td>Creative Thinking</td>
<td>fostered</td>
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<td></td>
<td>Critical Thinking</td>
<td>fostered</td>
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<td></td>
<td>Self-awareness and self-reflection</td>
<td>fostered</td>
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<td></td>
<td>Self-direction and self-management</td>
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<tr>
<td>252-0856-00L</td>
<td>Computer Science</td>
<td>O</td>
<td>6 credits</td>
<td>2V+2U+2P</td>
<td>F. Friedrich Wicker, R. Sasse</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.</td>
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<tr>
<td>Objective</td>
<td>Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens &quot;behind the scenes&quot; when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.</td>
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<tr>
<td>Content</td>
<td>The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture slides and all other material will be made available for download on the course web page.</td>
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</tbody>
</table>
| Literature | Bjarne Stroustrup: Einführung in die Programmierung mit C++, Pearson Studium, 2010
Andrew Koenig and Barbara E. Moo: Accelerated C++, Addison-Wesley, 2000 |
| Competencies | Subject-specific Competencies | Concepts and Theories | assessed |
|             | Technics and Technologies | assessed |
| Method-specific Competencies | Analytical Competencies | assessed |
|             | Media and Digital Technologies | assessed |
|             | Problem-solving | assessed |
| Social Competencies | Communication | fostered |
| Personal Competencies | Cooperation and Teamwork | fostered |
|             | Creative Thinking | fostered |
|             | Critical Thinking | fostered |
| 401-0231-10L | Analysis 1                                 | O    | 8 credits | 4V+3U | F. Ziltener                      |
| Abstract   | Reelle und komplexe Zahlen, Grenzwerte, Folgen, Reihen, Potenzreihen, stetige Abbildungen, Differential- und Integrale Echnung einer Variablen, Einführung in gewöhnliche Differentialgleichungen |
| Objective  | Einführung in die Grundlagen der Analysis |
| Lecture notes | Christian Blatter: Ingenieur-Analysis (Kapitel 1-4) |
| Literature | Konrad Koenigberger, Analysis I.
Christian Blatter, Analysis I. |
Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Techniques and Technologies
- fostered

402-0043-00L Physics I O 4 credits 3V+1U R. Grange

Abstract
Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics of point-like and ridged bodies, periodic motion and mechanical waves.

Objective
The concepts and tools in physics, as well as the methods of an experimental science are taught. The student should learn to identify, communicate and solve physical problems in his/her own field of science.

Content
Mechanics (motion, Newton's laws, work and energy, conservation of momentum, rotation, gravitation, fluids)
Periodic Motion and Waves (periodic motion, mechanical waves, acoustics).

Lecture notes
The lecture follows the book “Physics” by Paul A. Tipler.

Literature
Paul A. Tipler and Gene P. Mosca, Physics (for Scientists and Engineers), W. H. Freeman and Company

Basic Courses

Block G1

Number Title Type ECTS Hours Lecturers

401-0353-00L Analysis 3 O 4 credits 2V+2U F. Ziltener

Abstract
In this lecture we treat problems in applied analysis. The focus lies on the solution of quasilinear first order PDEs with the method of characteristics, and on the study of three fundamental types of partial differential equations of second order: the Laplace equation, the heat equation, and the wave equation.

Objective
The aim of this class is to provide students with a general overview of first and second order PDEs, and teach them how to solve some of these equations using characteristics and/or separation of variables.

Content
1.) General introduction to PDEs and their classification (linear, quasilinear, semilinear, nonlinear / elliptic, parabolic, hyperbolic)
2.) Quasilinear first order PDEs
- Solution with the method of characteristics
- Conservation laws
3.) Hyperbolic PDEs
- wave equation
- d'Alembert formula in (1+1)-dimensions
- method of separation of variables
4.) Parabolic PDEs
- heat equation
- maximum principle
- method of separation of variables
5.) Elliptic PDEs
- Laplace equation
- maximum principle
- method of separation of variables
- variational method

Literature

Prerequisites / notice
Prerequisites: Analysis I and II, Fourier series (Complex Analysis)

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

401-0647-00L Introduction to Mathematical Optimization O 5 credits 2V+1U D. Adjiashvili

Abstract
Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering.
Objective

The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.

Content

Topics covered in this course include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.

Literature

Information about relevant literature will be given in the lecture.

Prerequisites / notice

This course is meant for students who did not already attend the course "Mathematical Optimization", which is a more advance lecture covering similar topics. Compared to "Mathematical Optimization", this course has a stronger focus on modeling and applications.

### 401-2673-00L Numerical Methods for CSE

#### Abstract

The course gives an introduction into fundamental techniques and algorithms of numerical mathematics which play a central role in numerical simulations in science and technology. The course focuses on fundamental ideas and algorithmic aspects of numerical methods. The exercises involve actual implementation of numerical methods in C++.

#### Objective

- Knowledge of the fundamental algorithms in numerical mathematics.
- Knowledge of the essential terms in numerical mathematics and the techniques used for the analysis of numerical algorithms.
- Ability to choose the appropriate numerical method for concrete problems.
- Ability to interpret numerical results.
- Ability to implement numerical algorithms efficiently.

#### Content

- Computing with Matrices and Vectors.
- Direct Methods for linear systems of equations.
- Least Squares Techniques.
- Data Interpolation and Fitting.
- Iterative Methods for non-linear systems of equations.
- Filtering Algorithms.
- Approximation of Functions.
- Numerical Quadrature.

#### Lecture notes

Lecture materials (PDF documents and codes) will be made available to the participants through the course web page, whose address will be announced in the beginning of the course.

#### Literature


#### Prerequisites / notice

The course will be accompanied by programming exercises in C++ relying on the template library EIGEN. Knowledge of C++ is taken for granted.

### Block G2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-2813-00L</td>
<td>Programming Techniques for Scientific Simulations I</td>
<td>O</td>
<td>5</td>
<td>4G</td>
<td>R. Käppeli</td>
</tr>
<tr>
<td></td>
<td>Students in the Master's Degree Programme in Computational Science and Engineering must enrol only if this course unit is an additional requirement.</td>
<td></td>
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<tr>
<td></td>
<td>Abstract</td>
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</tr>
<tr>
<td></td>
<td>This lecture provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ programming techniques and scientific software libraries. Based on an overview over the hardware components of PCs and supercomputer, optimization methods for scientific simulation codes are explained.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>The goal of the course is that students learn basic and advanced programming techniques and scientific software libraries as used and applied for scientific simulations.</td>
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</tr>
<tr>
<td>252-0061-00L</td>
<td>Systems Programming and Computer Architecture</td>
<td>O</td>
<td>7</td>
<td>4V+2U</td>
<td>A. Klimovic, T. Roscoe</td>
</tr>
<tr>
<td></td>
<td>Introduction to systems programming. C and assembly language, floating point arithmetic, basic translation of C into assembler, compiler optimizations, manual optimizations. How hardware features like superscalar architecture, exceptions and interrupts, caches, virtual memory, multicore processors, devices, and memory systems function and affect correctness, performance, and optimization.</td>
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</tbody>
</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2168 of 2653
Objective

The course objectives are for students to:

1. Develop a deep understanding of, and intuition about, the execution of all the layers (compiler, runtime, OS, etc.) between programs in high-level languages and the underlying hardware: the impact of compiler decisions, the role of the operating system, the effects of hardware on code performance and scalability, etc.

2. Be able to write correct, efficient programs on modern hardware, not only in C but high-level languages as well.

3. Understand Systems Programming as a complement to other disciplines within Computer Science and other forms of software development.

This course does not cover how to design or build a processor or computer.

Content

This course provides an overview of "computers" as a platform for the execution of (compiled) computer programs. This course provides a programmer's view of how computer systems execute programs, store information, and communicate. The course introduces the major computer architecture structures that have direct influence on the execution of programs (processors with registers, caches, other levels of the memory hierarchy, supervisor/kernel mode, and I/O structures) and covers implementation and representation issues only to the extend that they are necessary to understand the structure and operation of a computer system.

The course attempts to expose students to the practical issues that affect performance, portability, security, robustness, and extensibility. This course provides a foundation for subsequent courses on operating systems, networks, compilers and many other courses that require an understanding of the system-level issues. Topics covered include: machine-level code and its generation by optimizing compilers, address translation, input and output, trap/event handlers, performance evaluation and optimization (with a focus on the practical aspects of data collection and analysis).

Lecture notes

- C programming
- Integers
- Pointers and dynamic memory allocation
- Basic computer architecture
- Compiling C control flow and data structures
- Code vulnerabilities
- Implementing memory allocation
- Linking
- Floating point
- Optimizing compilers
- Architecture and optimization
- Caches
- Exceptions
- Virtual memory
- Multicore
- Devices

Literature

The course is based in part on "Computer Systems: A Programmer's Perspective" (3rd Edition) by R. Bryant and D. O'Hallaron, with additional material.

Prerequisites / notice

252-0029-00L Parallel Programming
252-0028-00L Design of Digital Circuits

Block G3

All course units within Block G3 are offered in the spring semester.

Block G4

All course units within Block G4 are offered in the spring semester.

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>252-0232-00L</td>
<td>Software Engineering</td>
<td>W</td>
<td>6 credits</td>
<td>2V+2U</td>
<td>M. Lüthi, M. Schwerhoff, H. Lehner</td>
</tr>
</tbody>
</table>

Abstract

This course introduces both theoretical and applied aspects of software engineering. It covers:

- Software Architecture
- Informal and formal Modeling
- Design Patterns
- Software Engineering Principles
- Code Refactoring
- Program Testing

Objective

The course has two main objectives:

- Obtain an end-to-end (both, theoretical and practical) understanding of the core techniques used for building quality software.
- Be able to apply these techniques in practice.

Content

While the lecture will provide the theoretical foundations for the various aspects of software engineering, the students will apply those techniques in project work that will span over the whole semester - involving all aspects of software engineering, from understanding requirements over design and implementation to deployment and change requests.

Lecture notes

- no lecture notes

Literature

Will be announced in the lecture
# Design of Parallel and High-Performance Computing

**W 9 credits 2V+2U+4A**  
T. Hoefler

**Abstract**  
Advanced topics in parallel and high-performance computing.

**Objective**  
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

**Content**  
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

**Prerequisites / notice**  
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

## Fields of Specialization

### Astrophysics

#### Theoretical Astrophysics (University of Zurich)

**Number** 401-7851-00L  
**Title** Theoretical Astrophysics (University of Zurich)  
**Type** W  
**ECTS** 10 credits  
**Hours** 4V+2U  
**Lecturers** University lecturers

**Abstract**  
This course covers the foundations of astrophysical fluid dynamics, the Boltzmann equation, equilibrium systems and their stability, the structure of stars, astrophysical turbulence, accretion disks and their stability, the foundations of radiative transfer, collisionless systems, the structure and stability of dark matter halos and stellar galactic disks.

**Content**  
This course covers the foundations of astrophysical fluid dynamics, the theory of collisions and the Boltzmann equation, the notion of equilibrium systems and their stability, the structure of stars, the theory of astrophysical turbulence, the theory of accretion disks and their stability, the foundations of astrophysical radiative transfer, the theory of collisionless system, the structure and stability of dark matter halos and stellar galactic disks.

**Literature**  
Course Materials:  
1- The Physics of Astrophysics, Volume 1: Radiation by Frank H. Shu  
2- The Physics of Astrophysics, Volume 2: Gas Dynamics by Frank H. Shu  
3- Foundations of radiation hydrodynamics, Dimitri Mihalas and Barbara WeibeMihalas  
4- Radiative Processes in Astrophysics, George B. Rybicki and Alan P. Lightman  
5- Galactic Dynamics, James Binney and Scott Tremaine

**Prerequisites / notice**  
This is a full black board ad chalk experience for students with a strong background in mathematics and physics.

- Prerequisites:  
  - Introduction to Astrophysics  
  - Mathematical Methods for the Physicist  
  - Quantum Mechanics  
- Prior Knowledge:  
  - Mechanics  
  - Quantum Mechanics and atomic physics  
  - Thermodynamics  
  - Fluid Dynamics  
  - Electrodynamics

#### Computational Astrophysics (University of Zurich)

**Number** 401-7855-00L  
**Title** Computational Astrophysics (University of Zurich)  
**Type** W  
**ECTS** 6 credits  
**Hours** 2V  
**Lecturers** L. M. Mayer

**Abstract**  
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.  
UZH Module Code: AST245

**Objective**  
Acquire knowledge of main methodologies for computer-based models of astrophysical systems, the physical equations behind them, and train such knowledge with simple examples of computer programmes.

Mind the enrolment deadlines at UZH:  
Physics of the Atmosphere

Objective

Students are able
- to explain the physical structure and chemical composition of the atmosphere
- to quantitatively describe and understand the fundamental physical and chemical processes in the atmosphere
- to explain the interactions and feedbacks between atmosphere - ocean - land surface, troposphere - stratosphere and weather - climate.

Content

Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

Literature


Competencies

Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies

Method-specific Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity

Personal Competencies
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection

Chemistry

Objectives

Introduction to classical (atomic) computer simulation of (bio) molecular systems, development of skills to carry out and interpret these simulations.

Content

Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Lecture notes

The powerpoint slides of the lectures will be made available weekly on the website in pdf format (on the day preceding each lecture).

Literature

See: www.csms.ethz.ch/education/CSBMS

Prerequisites / notice

Since the exercises on the computer do convey and test essentially different skills than those being conveyed during the lectures and tested at the oral exam, the results of the exercises are taken into account when evaluating the results of the exam (learning component, possible bonus of up to 0.25 points on the exam mark).

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Media and Digital Technologies
- Problem-solving

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking

Quantum Mechanics I

Objective

Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems.
The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradoxon and Bell's inequality); Perturbation theory.

Lecture notes
Auf Moodle

Literature
G. Baym, Lectures on Quantum Mechanics
E. Merzbacher, Quantum Mechanics
L.I. Schiff, Quantum Mechanics
R. Feynman and A.R. Hibbs, Quantum Mechanics and Path Integrals
J.J. Sakurai: Modern Quantum Mechanics
A. Messiah: Quantum Mechanics I
S. Weinberg: Lectures on Quantum Mechanics

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Critical Thinking assessed
Creative Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Fluid Dynamics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0709-00L</td>
<td>Stochastic Methods for Engineers and Natural Scientists</td>
<td>W</td>
<td>4</td>
<td>4G</td>
<td>D. W. Meyer-Massetti</td>
</tr>
</tbody>
</table>

Abstract
The course provides an introduction into stochastic methods that are applicable for the description, treatment, and modeling of systems that are subject to uncertainties or that respond to parameter changes in a chaotic manner. Corresponding systems may arise in fluid dynamics, structural mechanics, biology, electrical engineering as well as other areas.

Objective
By the end of the course you will be familiar with a range of mathematical/statistical tools that enable a quantitative treatment of problems that involve uncertainties.

Content
- Probability theory, single and multiple random variables, mappings of random variables
- Estimation of statistical moments and probability densities based on data
- Stochastic differential equations, Itô calculus, PDF evolution equations
- Monte Carlo integration with importance and stratified sampling
- Markov-chain Monte Carlo sampling
- Control-variate and multi-level Monte Carlo estimation
- Kalman filters (classical and ensemble-based)
- Statistical tests for means and goodness-of-fit

Lecture notes
Detailed lecture notes will be provided.

Literature
Some textbooks related to the material covered in the course:

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-direction and Self-management assessed

Hydrodynamics and Cavitation

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0125-00L</td>
<td>Hydrodynamics and Cavitation</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>O. Supponen</td>
</tr>
</tbody>
</table>

Abstract
This course builds on the foundations of fluid dynamics to describe hydrodynamic flows and provides an introduction to cavitation.

Objective
The main learning objectives of this course are:
1. Identify and describe dominant effects in liquid fluid flows through physical modelling.
2. Identify and predict the onset of hydrodynamic instabilities.
3. Describe acoustic wave behaviour in liquids.
4. Explain tension, nucleation and phase-change in liquids.
5. Predict the behaviour of a gas bubble subject to changes in surrounding liquid pressure.
6. Describe hydrodynamic cavitation and its consequences in physical terms.
7. Recognise experimental techniques and industrial and medical applications for cavitation.
8. Read and evaluate research papers on recent research on cavitation and bubble dynamics and communicate the content orally to a multidisciplinary audience.
Content
The course gives an overview on the following topics: basics of hydrodynamics, capillarity, hydrodynamic instabilities, liquid fragmentation. Acoustics in liquids, tension in liquids, phase change. Cavitation and bubble dynamics: single bubbles (nucleation, dynamics, collapse), bubble clouds and cavitating flows. Industrial applications and measurement techniques.

Lecture notes
Class notes and handouts

Literature
Literature will be provided in the course material.

Prerequisites /notice
Fluid dynamics I & II or equivalent

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Problem-solving
- Communication
- Cooperation and Teamwork

Personal Competencies
- Creative Thinking
- Critical Thinking

- fostered

ECTS
6
4
3

Table: Systems and Control

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0103-00L</td>
<td>Control Systems</td>
<td>W</td>
<td>6</td>
<td>2+2U</td>
<td>F. Dörfler</td>
</tr>
</tbody>
</table>

Abstract
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Objective
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Content

Literature

Prerequisites /notice
Prerequisites: Signal and Systems Theory II.

MATLAB is used for system analysis and simulation.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0045-00L</td>
<td>Signals and Systems I</td>
<td>W</td>
<td>4</td>
<td>2+2U</td>
<td>H. Bölcskei</td>
</tr>
</tbody>
</table>

Abstract

Objective
Introduction to mathematical signal processing and system theory.

Content

Lecture notes
Lecture notes, problem set with solutions.

Table: Robotics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0447-00L</td>
<td>Image Analysis and Computer Vision</td>
<td>W</td>
<td>6</td>
<td>3+1U</td>
<td>E. Konukoglu, E. Erdil, F. Yu</td>
</tr>
</tbody>
</table>

Abstract

Objective
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes
Course material Script, computer demonstrations, exercises and problem solutions

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### Prerequisites / notice

**Prerequisites:**

Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

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<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<th>Instructor</th>
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<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>10</td>
<td>3V+2U+4A</td>
<td>C. Cotrini Jimenez</td>
</tr>
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</table>

**Abstract**

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

**Content**

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

**Topics covered in the lecture include:**

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

**Lecture notes**

No lecture notes, but slides will be made available on the course webpage.

**Literature**


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<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Hours</th>
<th>Instructor</th>
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<tbody>
<tr>
<td>263-3210-00L</td>
<td>Deep Learning</td>
<td>8</td>
<td>3V+2U+2A</td>
<td>T. Hofmann</td>
</tr>
</tbody>
</table>

**Abstract**

Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

**Objective**

In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

**Prerequisites / notice**

This is an advanced level course that requires some basic background in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

**Lecture notes**

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

**Prerequisites / notice**

The course is subject to the following condition:

- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:
  - Advanced Machine Learning
    https://ml2.inf.ethz.ch/courses/aml/
  - Computational Intelligence Lab
    http://da.inf.ethz.ch/teaching/2019/CIL/
  - Introduction to Machine Learning
    https://las.inf.ethz.ch/teaching/introml-S19
  - Statistical Learning Theory
    http://ml2.inf.ethz.ch/courses/slt/
  - Computational Statistics
    https://stat.ethz.ch/lectures/ss19/comp-stats.php
  - Probabilistic Artificial Intelligence
    https://ias.inf.ethz.ch/teaching/pai-f18

**Literature**


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<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Hours</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0563-01L</td>
<td>Dynamic Programming and Optimal Control</td>
<td>4</td>
<td>2V+1U</td>
<td>R. D'Andrea</td>
</tr>
</tbody>
</table>

**Abstract**

Introduction to Dynamic Programming and Optimal Control.
Objective
Covers the fundamental concepts of Dynamic Programming & Optimal Control.

Content
Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

Literature

Prerequisites / notice
Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

---

151-0851-00L  Robot Dynamics ● W 4 credits 2V+2U  M. Hutter, R. Siegwart, J. Tordesillas Torres

Abstract
We will provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing.

Objective
The primary objective of this course is that the student deepens an understanding of how to model the most common robotic systems. The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

Content
The course consists of three parts: First, we will refresh and deepen the student’s knowledge in kinematics, dynamics, and rotations of multi-body systems. In this context, the learning material will build upon the courses for mechanics and dynamics available at ETH, with the particular focus on their application to robotic systems. The goal is to foster the conceptual understanding of similarities and differences among the various types of robots. In the second part, we will apply the learned material to classical robotic arms as well as legged systems and discuss kinematic constraints and interaction forces. In the third part, focus is put on modeling fixed wing aircraft, along with related design and control concepts. In this context, we also touch aerodynamics and flight mechanics to an extent typically required in robotics. The last part finally covers different helicopter types, with a focus on quadrrotors and the coaxial configuration which we see today in many UAV applications. Case studies on all main topics provide the link to real applications and to the state of the art in robotics.

Prerequisites / notice
The contents of the following ETH Bachelor lectures or equivalent are assumed to be known: Mechanics and Dynamics, Control, Basics in Fluid Dynamics.

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Robotics (continued)

Only one of the two course units
263-5902-00L Computer Vision resp.
227-0447-00L Image Analysis and Computer Vision
may be recognised for credits for the overall (CSE Bachelor and Master) study programmes.

Only one of the two course units
263-5210-00L Probabilistic Artificial Intelligence resp.
252-0535-00L Advanced Machine Learning
may be recognised for credits for the field of specialisation 'Robotics' for the overall (CSE Bachelor and Master) study programmes. However, the other course unit may be recognised for a different category.

For the category assignment take contact with the Study Administration (www.math.ethz.ch/studiensekretariat).

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Number  Title  Type  ECTS  Hours  Lecturers
263-5902-00L  Computer Vision  W 8 credits 3V+1U+3A  M. Pollefeys, S. Tang, F. Yu

Abstract
The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective
The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content
Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

Prerequisites / notice
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

---

263-5210-00L  Probabilistic Artificial Intelligence  W 8 credits 3V+2U+2A  A. Krause

Abstract
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice
Solid basic knowledge in statistics, algorithms and programming.
The material covered in the course “Introduction to Machine Learning” is considered as a prerequisite.

Competencies
- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management
- Social Competencies
  - Communication
- Personal Competencies
  - Cooperation and Teamwork
  - Critical Thinking
  - Integrity and Work Ethics

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### Physics

<table>
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<tr>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0809-00L</td>
<td>Introduction to Computational Physics</td>
<td>W</td>
<td>8 credits</td>
<td>2V+2U</td>
<td>M. Adelmann</td>
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<tr>
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<td>This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.</td>
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<td>Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.</td>
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<td></td>
<td>Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.</td>
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<td>Lecture notes and slides are available online and will be distributed if desired.</td>
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<td>Literature recommendations and references are included in the lecture notes.</td>
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<td>Lecture and exercise lessons in english, exams in German or in English</td>
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<tr>
<td>402-0205-00L</td>
<td>Quantum Mechanics I</td>
<td>W</td>
<td>8 credits</td>
<td>3V+2U</td>
<td>M. Krisic Marinkovic</td>
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<td><em>Physics BSc students with programme regulations 2016 need to register for &quot;402-0205-10L Quantenmechanik I&quot;</em></td>
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<tr>
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<td>Objective</td>
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<td></td>
<td>Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems.</td>
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<tr>
<td></td>
<td>Content</td>
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<td>The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradox and Bell’s inequality); Perturbation theory.</td>
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<td>Lecture notes</td>
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<tr>
<td></td>
<td>G. Baym, Lectures on Quantum Mechanics</td>
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<td>E. Merzbacher, Quantum Mechanics</td>
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<td>L.I. Schiff, Quantum Mechanics</td>
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<td>R. Feynman and A.R. Hibbs, Quantum Mechanics and Path Integrals</td>
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<td></td>
<td>J.J. Sakurai: Modern Quantum Mechanics</td>
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<td>A. Messiah: Quantum Mechanics I</td>
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<td>S. Weinberg: Lectures on Quantum Mechanics</td>
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<td>Competencies</td>
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<td>Subject-specific Competencies</td>
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<td>Method-specific Competencies</td>
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<tr>
<td>401-3913-01L</td>
<td>Mathematical Foundations for Finance</td>
<td>W</td>
<td>4 credits</td>
<td>3V+2U</td>
<td>D. Possamai</td>
</tr>
<tr>
<td></td>
<td>This course gives a first introduction to the main modelling ideas and mathematical tools from mathematical finance. It mainly aims at non-mathematicians who need an introduction to the main tools from stochastics used in mathematical finance. However, mathematicians who want to learn some basic modelling ideas and concepts for quantitative finance (before continuing with a more advanced course) may also find this of interest. The main emphasis will be on ideas, but important results will be given with (sometimes partial) proofs.</td>
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### Computational Finance

<table>
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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>401-3913-01L</td>
<td>Mathematical Foundations for Finance</td>
<td>W</td>
<td>4 credits</td>
<td>3V+2U</td>
<td>D. Possamai</td>
</tr>
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</table>

Data: 15.06.2024 12:39
Autumn Semester 2024
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Topics to be covered include:
- financial market models in finite discrete time
- absence of arbitrage and martingale measures
- valuation and hedging in complete markets
- basics about Brownian motion
- stochastic integration
- stochastic calculus: Itô's formula, Girsanov transformation, Itô's representation theorem
- Black-Scholes formula

Lecture notes
See information on course homepage

Prerequisites / notice
Prerequisites: Results and facts from probability theory as in the book "Probability Essentials" by J. Jacod and P. Protter will be used freely. Especially participants without a direct mathematics background are strongly advised to familiarise themselves with those tools before (or very quickly during) the course. (A possible alternative to the above English textbook are the (German) lecture notes for the standard course "Wahrscheinlichkeitstheorie").

For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.

Competencies

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<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<tr>
<td>Decision-making</td>
<td>fostered</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<td>Personal Competencies</td>
<td>Adaptable and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
<td>fostered</td>
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<tr>
<td>Integrity and Work Ethics</td>
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</tbody>
</table>

401-4657-00L  Numerical Solution of Stochastic Ordinary Differential Equations

Alternative course titles: "Numerical Analysis of Stochastic Ordinary Differential Equations" / "Computational Methods for Quantitative Finance: Monte Carlo and Sampling Methods"

Abstract
This course is on the numerical approximations of stochastic ordinary differential equations (SDEs) driven by Brownian motions and Lévy processes. SDEs have several applications, for example in financial engineering. The contents cover stochastic processes, stochastic calculus, well-posedness results for SDEs, strong and weak approximations of SDEs, and simulation via Monte Carlo methods.

Objective
The aim of this course is to enable the students to carry out simulations and their mathematical convergence analysis for stochastic models originating from applications such as mathematical finance. For this the course teaches a decent knowledge of the different numerical methods, their underlying ideas, convergence properties and implementation issues.

Content
Brownian motion and Lévy processes
Stochastic integration and stochastic calculus
Stochastic ordinary differential equations (SDEs)
Numerical approximations of SDEs
Stochastic simulation and Monte Carlo methods
Applications to computational finance: Option valuation

Lecture notes
There will be English, typed lecture notes for registered participants in the course.

Literature
P. E. Kloeden and E. Platen:
Numerical Solution of Stochastic Differential Equations.

Bertoin, Jean:
Lévy processes.
Cambridge Tracts in Mathematics, 121.
Cambridge University Press,

Cont, Rama; Tankov, Peter:
Financial modelling with jump processes.
Chapman & Hall/CRC Financial Mathematics Series,

Prerequisites / notice
Mandatory:
Probability and measure theory,
basic numerical analysis and
basics of MATLAB/Python programming.

a) mandatory courses:
Measure - and Probability Theory I
as covered in courses:
ETH 401-2283-00L Analysis III (Measure Theory)
UZH Kursmodul 10498 Hauptvorlesung: Mass- und Integrationstheorie

b) recommended courses:
Stochastic Processes I
Competencies          Subject-specific Competencies          Concepts and Theories          assessed
                      Techniques and Technologies          assessed
Method-specific Competencies          Analytical Competencies          assessed
                      Decision-making          fostered
                      Media and Digital Technologies          fostered
                      Problem-solving          assessed
Social Competencies          Project Management          fostered
                      Communication          fostered
                      Cooperation and Teamwork          fostered
                      Customer Orientation          fostered
                      Leadership and Responsibility          fostered
                      Self-presentation and Social Influence          fostered
                      Sensitivity to Diversity          fostered
                      Negotiation          fostered
Personal Competencies          Adaptability and Flexibility          fostered
                      Creative Thinking          assessed
                      Critical Thinking          assessed
                      Integrity and Work Ethics          fostered
                      Self-awareness and Self-reflection          fostered
                      Self-direction and Self-management          fostered

Electromagnetics

<table>
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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>227-2037-00L</td>
<td>Physical Modelling and Simulation</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>J. Smajic</td>
</tr>
</tbody>
</table>

Abstract
This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.

Objective
Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

Content
The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or chose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

Geophysics

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>651-4007-00L</td>
<td>Continuum Mechanics</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>T. Gerya</td>
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</tbody>
</table>

Abstract
In this course, students learn crucial partial differential equations (conservation laws) that are applicable to any continuum including the Earth's mantle, core, atmosphere and ocean. The course will provide step-by-step introduction into the mathematical structure, physical meaning and analytical solutions of the equations. The course has a particular focus on solid Earth applications.

Objective
The goal of this course is to learn and understand few principal partial differential equations (conservation laws) that are applicable for analysing and modelling of any continuum including the Earth's mantle, core, atmosphere and ocean. By the end of the course, students should be able to write, explain and analyse the equations and apply them for simple analytical cases. Numerical solving of these equations will be discussed in the Numerical Modelling I and II course running in parallel.
A provisional week-by-week schedule (subject to change) is as follows:

Weeks 1, 2: The continuity equation

Weeks 3, 4: Density and gravity

Weeks 5, 6: Stress and strain

Weeks 7, 8: The momentum equation

Week 9: Viscous rheology of rocks
Theory: Solid-state creep of minerals and rocks as the major mechanism of deformation of the Earth`s interior. Dislocation and diffusion creep mechanisms. Rheological equations for minerals and rocks. Effective viscosity and its dependence on temperature, pressure and strain rate. Formulation of the effective viscosity from empirical flow laws. Exercise: Deriving viscous rheological equations for computing effective viscosities from empirical flow laws.

Weeks 10: The heat conservation equation

Week 11, 12: Elasticity and plasticity


GRADING will be based on homeworks (1/3) and oral exam (2/3).

Lecture notes
Script and Exam questions are available by request tgerya@ethz.ch

Literature

Competencies
Subject-specific Competencies: Concepts and Theories assessed
Method-specific Competencies: Analytical Competencies assessed

Geophysics: Subject 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>651-4241-00L</td>
<td>Numerical Modelling I and II: Theory and Applications</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>T. Gerya</td>
</tr>
</tbody>
</table>

Abstract
In this 13-week sequence, students learn how to write programs from scratch to solve partial differential equations that are useful for Earth science applications. Programming will be done in MATLAB and will use the finite-difference method and marker-in-cell technique. The course will emphasise a hands-on learning approach rather than extensive theory.

Objective
The goal of this course is for students to learn how to program numerical applications from scratch. By the end of the course, students should be able to write state-of-the-art MATLAB codes that solve systems of partial-differential equations relevant to Earth and Planetary Science applications using finite-difference method and marker-in-cell technique. Applications include Poisson equation, buoyancy driven variable viscosity flow, heat diffusion and advection, and state-of-the-art thermomechanical code programming. The emphasis will be on commonality, i.e., using a similar approach to solve different applications, and modularity, i.e., re-use of code in different programs. The course will emphasise a hands-on learning approach rather than extensive theory, and will begin with an introduction to programming in MATLAB.
A provisional week-by-week schedule (subject to change) is as follows:

Week 1: Introduction to the finite difference approximation to differential equations. Introduction to programming in Matlab. Solving of 1D Poisson equation.


Week 3: Solving momentum and continuity equations in case of constant viscosity with stream function/vorticity formulation.


Weeks 5: Conservative finite differences for the momentum equation. "Free slip" and "no slip" boundary conditions. Solving momentum and continuity equations in case of variable viscosity using pressure-velocity formulation with staggered grid.


Week 7: Advection in 2-D with Marker-in-cell method. Combining flow calculation and advection for buoyancy driven flow.


Week 9: Solving 2D heat conservation equation in case of constant thermal conductivity with explicit and implicit approaches.

Week 10: Solving 2D heat conservation equation in case of variable thermal conductivity with implicit approach. Temperature advection with markers. Creating thermomechanical code by combining mechanical solution for 2D buoyancy driven flow with heat diffusion and advection based on marker-in-cell approach.

Week 11: Implementation of radioactive, adiabatic and shear heating to the thermomechanical code.

Week 12: Programming of solution of coupled solid-fluid momentum and continuity equations for the case of melt percolation in a rising mantle plume.


Week 14: Final project description for slab breakoff modeling.

GRADING will be based on weekly programming homeworks (50%) and a term project (50%) to develop an application of their choice to a more advanced level.

### Literature

<table>
<thead>
<tr>
<th>Competencies</th>
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<th>Hours</th>
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<td>Creative Thinking</td>
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### Geophysics: Subject 3

Offered in the spring semester

### Geophysics: Subject 4

Offered in the spring semester

### Geophysics: Subject 5

This course provides an overview on the most widely used seismological methods to image the Earth's interior with a focus on crustal and upper-mantle structures. Topics include controlled source methods such as refraction and wide-angle reflection, as well as passive body-wave and surface-wave based methods. The course will discuss the strengths and weaknesses of each method.

Hours

Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides an

fostered

This course focuses on modeling spatio-temporal problems in biology, in particular on the cell and tissue level. The main focus is on

W

Spatio-Temporal Modelling in Biology

1. Introduction to Modelling in Biology
2. Bioimage Analysis
3. Morphogen Gradients
4. Precision & Robustness of Patterning
5. Mathematical Description of Growing Biological Systems
6. Travelling Waves & Wave Pinning
7. Turing Patterns
8. Chemotaxis
9. Epithelial Organisation
10. Tissue Simulation Frameworks
11. Tissue Mechanics & Fluid Dynamics
12. Growth Control
13. Image-Based Modelling
14. Summary

ECTS

6 credits

51-4273-00L

Numerical Modelling in Fortran

W

3 credits

2V

P. Tackley

Abstract

This course gives an introduction to programming in Fortran, and is suitable for students who have only minimal programming experience. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts.

Objective

Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in this language, and is suitable for students who have only minimal programming experience, for example with MATLAB scripts. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts, using example scientific problems relevant to Earth science.

Lecture notes

See http://jupiter.ethz.ch/~pjt/FORTRAN/FortranClass.html.

Competencies

Subject-specific Competencies
Techniques and Technologies

assessed

Method-specific Competencies
Media and Digital Technologies

assessed

Problem-solving

assessed

Geophysics: Subject 6

Offered in the spring semester

Geophysics: Subject 7

Offered in the spring semester

Geophysics: Subject 8

Number

Title

Type

ECTS

Hours

Lecturers

651-4273-00L

Numerical Modelling in Fortran

W

3 credits

2V

P. Tackley

Abstract

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Objective

Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in this language, and is suitable for students who have only minimal programming experience, for example with MATLAB scripts. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts, using example scientific problems relevant to Earth science.

Lecture notes

See http://jupiter.ethz.ch/~pjt/FORTRAN/FortranClass.html.

Competencies

Subject-specific Competencies
Techniques and Technologies

assessed

Method-specific Competencies
Media and Digital Technologies

assessed

Problem-solving

assessed

Biology

Number

Title

Type

ECTS

Hours

Lecturers

636-0007-00L

Computational Systems Biology

W

6 credits

3V+2U

J. Stelling

Abstract

Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modelling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

Objective

The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

Content

Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

Lecture notes

http://www.csb.ethz.ch/education/lectures.html

Literature


636-0706-00L

Spatio-Temporal Modelling in Biology

W

4 credits

3G

D. Iber

Abstract

This course focuses on modeling spatio-temporal problems in biology, in particular on the cell and tissue level. The main focus is on mechanisms and concepts, but mathematical and numerical techniques are introduced as required. Biological examples discussed in the course provide an introduction to key concepts in developmental biology.

Objective

Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides an introduction to dynamical system, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

Content

1. Introduction to Modelling in Biology
2. Bioimage Analysis
3. Morphogen Gradients
4. Precision & Robustness of Patterning
5. Mathematical Description of Growing Biological Systems
6. Travelling Waves & Wave Pinning
7. Turing Patterns
8. Chemotaxis
9. Epithelial Organisation
10. Tissue Simulation Frameworks
11. Tissue Mechanics & Fluid Dynamics
12. Growth Control
13. Image-Based Modelling
14. Summary
This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood to develop biologically-realistic models. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neural architectures of feedforward and recurrent networks are discussed in the context of coordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.

### Electives

In the 'electives' subcategory, at least two course units must be successfully completed.

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<td>Visualization, Simulation and Interaction - Virtual Reality II</td>
<td>W</td>
<td>4</td>
<td>3G</td>
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**Abstract:**
This lecture provides deeper knowledge on the possible applications of virtual reality, its basic technology, and future research fields. The goal is to provide a strong knowledge on Virtual Reality for a possible future use in business processes.

**Objective:**
Virtual Reality can not only be used for the visualization of 3D objects, but also offers a wide application field for small and medium enterprises (SME). This could be for instance an enabling technology for net-based collaboration, the transmission of images and other data, the interaction of the human user with the digital environment, or the use of augmented reality systems. The goal of the lecture is to provide a deeper knowledge of today's VR environments that are used in business processes. The technical background, the algorithms, and the applied methods are explained more in detail. Finally, future tasks of VR will be discussed and an outlook on ongoing international research is given.

**Content:**
“Visualization, Simulation and Interaction - Virtual Reality I” is recommended, but not mandatory.

**Didactical concept:**
The course consists of lectures and exercises.

**Competencies:**
- **Subject-specific Competencies:** Concepts and Theories (assessed)
- **Method-specific Competencies:** Analytical Competencies (assessed)
- **Social Competencies:** Communication (assessed)
- **Personal Competencies:** Creative Thinking (assessed)

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<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>B. Berisha, D. Mohr</td>
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**Abstract:**
Most problems in engineering are of nonlinear nature. The nonlinearities are caused basically due to the nonlinear material behavior, contact conditions and instability of structures. The principles of the nonlinear Finite-Element-Method (FEM) will be introduced for treating such problems. The finite element program ABAQUS is introduced to investigate real engineering problems.
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start

Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing

Nonlinear FEA

Lecture notes will be provided. However, students are encouraged to take their own notes.

Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the

Discrete Event Systems

2V+2U+4A

L. Josipovic

The course provides an introduction to non-linear finite element analysis. The treated sources of non-linearity are related to material

Introduction to discrete event systems. We start out by studying popular models of discrete event systems. Then we analyze discrete event

1. Regular Languages
2. Non-Regular Languages
3. Markov Chains
4. Stochastic Discrete Event Systems
5. Worst-Case Event Systems
6. Verification of Finite Automata
7. Petri Nets

The mathematics arsenal centered around differential equations that has been employed in systems engineering to model and study

- Instability problems
- Material behavior (metals and rubber)
- General forming processes

Special attention will be paid to the modeling of the nonlinear material behavior, thermo-mechanical processes and processes with large

- Crash
- Collapse of structures
- Material behavior (metals and rubber)
- General forming processes

Typical applications of the nonlinear Finite-Element-Methods are simulations of:

- Instability problems
- Solvers and convergence
- Modeling of tool contact and the influence of friction
- Element formulations
- Implicit and explicit FEM methods
- FEM formulations of coupled thermo-mechanical problems
- Lagrange and Euler approaches
- FEM implementation of constitutive equations
- Elasto-plastic material models
- Fundamentals of continuum mechanics to characterize large plastic deformations
- introduction into FEM

The ability to independently create a virtual model which describes the complex non linear systems will be acquired through accompanying exercises. These will include the Matlab programming of important model components such as constitutive equations. The FEM Program ABAQUS will be introduced to investigate real engineering problems

Mechanics 1, 2, Dynamics, Continuum Mechanics I and Introduction to FEA. Ideally also Continuum Mechanics II.

Autumn Semester 2024

Lecture slides

Lecture notes will be provided. However, students are encouraged to take their own notes.

This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as

memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel

Optimization processes for this new generation of systems.

with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as

automatic parallelism in practical high-performance computing. The FEM Program ABAQUS will be introduced to investigate real engineering

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2183 of 2653

151-0529-00L Nonlinear FEA W 4 credits 2V+2U L. De Lorenzis

Does not take place this semester.

Mechanics II: Nonlinear FEA”

The previous course title until HS23 “Computational

154-3500-00L Discrete Event Systems W 6 credits 4G L. Josipovic, L. Vanbever, R. Wattenhofer

Introduction to discrete event systems. We start out by studying popular models of discrete event systems. Then we analyze discrete event

systems from an average-case and from a worst-case perspective, and study verification. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Petri Nets.

Objective

Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the

proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans.

The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a

keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

In this lecture we give an introduction to discrete event systems. We start out the course by exploring the limits of what is computable and

what is not. In doing so, we will consider three distinct models of computation which are often used to model discrete event systems: finite

automata, push-down automata and Turing machines (ranked in terms of expressiveness power). In the second part of the course we

analyze discrete event systems. We first examine discrete event systems from an average-case perspective: we model discrete events as

stochastic processes, and then apply continuous time markov chains and queueing theory for an understanding of the typical behavior of a

system. Then we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial

queueing. In the last part of the course we introduce methods that allow to formally verify certain properties of Finite Automata and Petri

Nets. These are some typical analysis questions we will look at: Do two given systems behave the same? Does a given system behave as

intended? Does the system eventually enter a dangerous state?

Content

1. Regular Languages
2. Non-Regular Languages
3. Markov Chains
4. Stochastic Discrete Event Systems
5. Worst-Case Event Systems
6. Verification of Finite Automata
7. Petri Nets
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

**Objective**
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

**Content**
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog.
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

**Lecture notes**
Textbook and all further documents in English.

**Literature**
This third course in our VLSI series is concerned with full-custom digital integrated circuits. The goals include learning the design of digital circuits on the schematic, layout, gate, and register-transfer levels. The use of state-of-the-art CAD software (Cadence Virtuoso) in order to simulate, optimize, and characterize digital circuits is another important topic of this course.

At the end of this course, you will
- understand the design of the main building blocks of state-of-the-art digital integrated circuits
- be able to design and optimize digital integrated circuits on the schematic, layout, and gate levels
- be able to use standard industry software (Cadence Virtuoso) for drawing, simulating, and characterizing digital circuits
- understand the performance trade-offs between delay, area, and power consumption

The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack towards logic gates and increasingly complex digital circuit structures. The topics of this course include:
- Nanometer MOSFETs
- Static and dynamic behavior of complementary MOS (CMOS) inverters
- CMOS gate design, sizing, and timing
- Full-custom standard-cell design
- Wire models and parasitics
- Latch and flip-flop circuits
- Gate-level timing analysis and optimization
- Static and dynamic power consumption; low-power techniques
- Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
- Arithmetic and logic circuits
- Fixed-point and floating-point arithmetic
- Synchronous and asynchronous design principles
- Memory circuits (ROM, SRAM, and DRAM)
- In- and near-memory processing architectures
- Full-custom accelerator circuits for machine learning

The exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

### Prerequisites / notice

This course can be taken in parallel with "VLSI 1: HDL-based design for FPGAs" and is designed to complement the topics of this course. Basic analog circuit knowledge is required.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Method-specific Competencies
- Analytical Competencies: assessed
- Problem-solving: assessed

### Literature

- N. H. E. Weste and D. M Harris, CMOS VLSI Design: A Circuits and Systems Perspective (4th Ed.), Addison-Wesley

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### 227-0417-00L Information Theory I

This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

### Literature

- T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

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### 227-0971-00L Computational Psychiatry

Please note that participation in this course and the practical sessions requires additional registration at: http://www.translationalneuromodeling.org/cpcourse/

This six-day course teaches state-of-the-art methods in computational psychiatry. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples. The hope is that the acquisition of a joint language and tool-kit will enable more effective communication and joint translational research between fields that are usually worlds apart.

This course aims at bridging the gap between mathematical modelers and clinical neuroscientists by teaching computational techniques in the context of clinical applications. The hope is that the acquisition of a joint language and tool-kit will enable more effective communication and joint translational research between fields that are usually worlds apart.

This six-day course teaches state-of-the-art methods in computational psychiatry. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples. Furthermore, practical exercises provide in-depth exposure to different software packages. Please see http://www.translationalneuromodeling.org/cpcourse/ for details.

### Literature

- http://www.translationalneuromodeling.org/cpcourse/
This course acquaints students with core knowledge in computer graphics, image processing, multimedia and computer vision. Topics include: Graphics pipeline, perception and camera models, transformation, shading, global illumination, texturing, sampling, filtering, image representations, image and video compression, edge detection and optical flow.

### Objective
This course provides an in-depth introduction to the core concepts of computer graphics, image processing, multimedia and computer vision. The course forms a basis for the specialization track Visual Computing of the MSc master program at ETH.

### Content
Course topics will include: Graphics pipeline, perception and color models, camera models, transformations and projection, projections, lighting, shading, global illumination, texturing, sampling theorem, Fourier transforms, image representations, convolution, linear filtering, diffusion, nonlinear filtering, edge detection, optical flow, image and video compression.

In theoretical and practical homework assignments students will learn to apply and implement the presented concepts and algorithms.

#### Lecture notes
A scriptum will be handed out for a part of the course. Copies of the slides will be available for download. We will also provide a detailed list of references and textbooks.

#### Literature

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### 252-0543-01L Computer Graphics

#### Abstract
This course covers fundamental and advanced concepts of modern computer graphics. Students will learn the fundamentals of digital scene representations, advanced physically-based light transport algorithms for generating photorealistic images from these scene representations, and inverse rendering methods for recovering digital scene representations from captured images.

#### Objective
At the end of the course, the students will be able to build a rendering system based on path-tracing algorithms. The students will learn the principles of physically-based rendering and computer graphics. In addition, the course is intended to stimulate the student’s curiosity to explore the field of computer graphics in subsequent classes or on their own.

#### Content
We will begin with an introduction to light emission and radiometric quantities, followed by an exploration of geometry representations and texture mapping.

Next, we will mathematically formulate the physics of light transport and appearance modeling. Subsequently, we will introduce relevant concepts from Monte Carlo integration and develop path-tracing algorithms to solve these equations by simulating light transport for direct and global illumination due to hard surfaces and participating media, such as fog, smoke, and translucent objects.

Moreover, we will present techniques for significantly improving path-tracing efficiency, including importance sampling, multiple importance sampling, stratified sampling, denoising, and acceleration data structures.

The course lectures will conclude with an overview of image-based capture and rendering methods. Topics covered will include geometry reconstruction, material acquisition, differentiable rendering, and image-based rendering.

#### Lecture notes
no

#### Literature
Books:
- Physically Based Rendering: From Theory to Implementation
- High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting
- Multiple view geometry in Computer Vision

#### Prerequisites
Prerequisites:
- Fundamentals of calculus and linear algebra, basic concepts of algorithms and data structures, programming skills in C++, and the Visual Computing course are recommended.

The programming assignments will be in C++. This will not be taught in the class.

#### Competencies

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<th>Method-specific Competencies</th>
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<td>Critical Thinking</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>Leadership and Responsibility</td>
<td>Integrity and Work Ethics</td>
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<td>Problem-solving</td>
<td>Project Management</td>
<td>Self-direction and Self-management</td>
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#### Assessed
- assessed
- fostered

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### 252-0546-00L Physically-Based Simulation in Computer Graphics

#### Abstract
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

#### Objective
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

#### Content
The lecture covers topics in physically-based modeling, such as particle systems, mass-spring models, finite difference and finite element methods. These approaches are used to represent and simulate deformable objects or fluids with applications in animated movies, 3D games and medical systems. Furthermore, the lecture covers topics such as rigid body dynamics, collision detection, and character animation.

#### Prerequisites
- Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++, and the Visual Computing course are recommended.

#### Notice
- Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

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### 252-0834-00L Information Systems for Engineers

#### Abstract
This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).
Objective

Do you want to be able to query your own data productively and efficiently in your future semester projects, bachelor's thesis, master thesis, or PhD thesis? Are you looking for something beyond the Python+Pandas hype? This course teaches you how to do so as well as the dos and don'ts.

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Map cube queries to SQL.
14. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook

Literature

- Lecture material (slides).
- Book: "Database Systems: The Complete Book", H. Garcia-Molina, J.D. Ullman, J. Widom (it is not required to buy the book, as the library has it)

Prerequisites / notice

For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logic
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python
401-3627-00L  High-Dimensional Statistics  W  4 credits  2V  not available

Abstract
"High-Dimensional Statistics" deals with modern methods and theory for statistical inference when the number of unknown parameters is much larger order than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed.

Objective
Knowledge of methods and basic theory for high-dimensional statistical inference

Content
Lasso and Group Lasso for high-dimensional linear and generalized linear models; Additive models and many smooth univariate functions; Non-convex loss functions and 1-regularization; Stability selection, multiple testing and construction of p-values; Undirected graphical modeling

Literature

Prerequisites / notice
Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).

401-4623-00L  Time Series Analysis  W  4 credits  2G  F. Balabdaoui

Abstract
The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

Objective
The goal of the course is to have a good overview of the different types of time series and the approaches used in their statistical analysis.

Content
This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exhibited by time series is the dependence between successive observations. The key topics which will be covered as:
- Stationarity
- Autocorrelation
- Trend estimation
- Elimination of seasonality
- Spectral analysis, spectral densities
- Forecasting
- ARMA, ARIMA, Introduction into GARCH models

Literature
The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis

Prerequisites / notice
Basic knowledge in probability and statistics

401-3901-00L  Linear & Combinatorial Optimization  W  10 credits  4V+2U  R. Zenklusen

Abstract
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

Objective
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Content
Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Literature

Prerequisites / notice
Solid background in linear algebra.

Competencies
Subject-specific Competencies
Concepts and Theories  assessed
Techniques and Technologies  assessed

Method-specific Competencies
Analytical Competencies  assessed
Decision-making  assessed
Media and Digital Technologies  fostered
Problem-solving  fostered

Social Competencies
Communication  fostered
Sensitivity to Diversity  fostered
Negotiation  fostered

Personal Competencies
Creative Thinking  assessed
Critical Thinking  assessed
Integrity and Work Ethics  fostered
Self-awareness and Self-reflection  fostered
Self-direction and Self-management  fostered
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on the physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of operating neuromorphic circuits at much lower power and higher densities than digital electronics. Low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions.

Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module IN404 at UZH. Please mind the ETH enrolment deadlines for UZH students: https://ethz.ch/en/studies/non-degree-courses/special-students/university-of-zurich.html

Abstract
This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Objective
Understanding the characteristics of neuromorphic circuit elements.

Content
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on the physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of operating neuromorphic circuits at much lower power and higher densities than digital electronics. Low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.}

Literature
S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

Prerequisites / notice
Particular: The course is highly recommended for those who intend to take the spring semester course 'Neuromorphic Engineering II', that teaches the conception, simulation, and physical layout of such circuits with chip design tools.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.
Boundary Layer Meteorology

Objective
Students are able to:
- Name the basic approaches needed to describe planetary boundary layer flows and associated turbulent exchange processes.
- Apply these concepts to answer comprehension questions and solve simple problems related to the structure and dynamics of the PBL.
- Independently judge the applicability of learned concepts and tools to real-world situations.

Content
- Introduction
- PBL structure and stability
- Turbulence and turbulent transport
- Scaling and similarity theory
- Spectral characteristics
- Conservation equations in a turbulent flow
- Closure problem and closure assumptions
- Rough surfaces and the roughness sublayer
- Complex terrain

Lecture notes
available (i.e. in English)

Literature

Prerequisites
Umwelt-Fluiddynamik (701-0479-00L) (environment fluid dynamics) or equivalent and basic knowledge in atmospheric science

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Problem-solving fostered

Personal Competencies
Creative Thinking fostered

Dynamics of Large-Scale Atmospheric Flow

Objective
Understanding of dynamic processes of large-scale atmospheric flow and their mathematical-physical formulation.

Content
Dynamical Meteorology is concerned with the dynamical processes of the earth’s atmosphere. The fundamental equations of motion in the atmosphere will be discussed along with the dynamics and interactions of synoptic system - i.e. the low and high pressure systems that determine our weather. The motion of such systems can be understood in terms of quasi-geostrophic theory. The lecture course provides a derivation of the mathematical basis along with some interpretations and applications of the concept.

Lecture notes
Dynamics of large-scale atmospheric flow

Literature
- Pichler H., Dynamik der Atmosphäre, Bibliographisches Institut, 456 pp. 1997

Prerequisites
Physics I, II, Environmental Fluid Dynamics

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Social Competencies
Cooperation and Teamwork fostered

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

Advanced Quantum Chemistry

Objective
The aim of the course is to provide an in-depth knowledge of theory and method development in theoretical chemistry. It will be shown that this is necessary in order to be able to solve actual chemical problems on a computer with quantum chemical methods.

Abstract
Advanced, but fundamental topics central to the understanding of theory in chemistry and for solving actual chemical problems with a computer.

Examples are:
- Operators derived from principles of relativistic quantum mechanics
- Relativistic effects + methods of relativistic quantum chemistry
- Open-shell molecules + spin-density functional theory
- New electron-correlation theories

The relativistic re-derivation of all concepts known from (nonrelativistic) quantum mechanics and quantum-chemistry lectures will finally explain the form of all operators in the molecular Hamiltonian - usually postulated rather than deduced. From this, we derive operators needed for molecular spectroscopy (like those required by magnetic resonance spectroscopy). Implications of other assumptions in standard non-relativistic quantum chemistry shall be analyzed and understood, too. Examples are the Born-Oppenheimer approximation and the expansion of the electronic wave function in a set of pre-defined many-electron basis functions (Slater determinants). Overcoming these concepts, which are so natural to the theory of chemistry, will provide deeper insights into many-particle quantum mechanics. Also revisiting the workhorse of quantum chemistry, namely density functional theory, with an emphasis on open-shell electronic structures (radicals, transition-metal complexes) will contribute to this endeavor. It will be shown how these insights allow us to make more accurate predictions in chemistry in practice - at the frontier of research in theoretical chemistry.
Content
1) Introductory lecture: basics of quantum mechanics and quantum chemistry
2) Einstein's special theory of relativity and the (classical) electromagnetic interaction of two charged particles
3) Klein-Gordon and Dirac equation; the Dirac hydrogen atom
4) Numerical methods based on the Dirac-Fock-Coulomb Hamiltonian, two-component and scalar relativistic Hamiltonians
5) Response theory and molecular properties, derivation of property operators, Breit-Pauli-Hamiltonian
6) Relativistic effects in chemistry and the emergence of spin
7) Spin in density functional theory
8) New electron-correlation theories: Tensor network and matrix product states, the density matrix renormalization group

Lecture notes
A set of detailed lecture notes will be provided, which will cover the whole course.

Literature
2) F. Schwabl: Quantenmechanik für Fortgeschrittene (QM II), Springer-Verlag, 1997
3) R. McWeeny: Methods of Molecular Quantum Mechanics, Academic Press, 1992
https://doi.org/10.1063/1.5129672

Note also the standard textbooks:
A) A. Szabo, N.S. Ostlund. Verlag, Dover Publications
B) I. N. Levine, Quantum Chemistry, Pearson

Prerequisites / notice
Strongly recommended (preparatory) courses are: quantum mechanics and quantum chemistry

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered

Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: assessed
- Self-awareness and Self-reflection: fostered

Abstract
Laminar and turbulent flows, instability and origin of turbulence - Statistical description: averaging, turbulent energy, dissipation, closure problem - Scalings. Homogeneous isotropic turbulence, correlations, Fourier representation, energy spectrum - Free turbulence: wake, jet, mixing layer - Wall turbulence: Channel and boundary layer - Computation and modelling of turbulent flows

Objective
Basic physical phenomena of turbulent flows, quantitative and statistical description, basic and averaged equations, principles of turbulent flow computation and elements of turbulence modelling

Content
- Properties of laminar, transitional and turbulent flows.
- Origin and control of turbulence. Instability and transition.
- Statistical description, averaging, equations for mean and fluctuating quantities, closure problem.
- Scalings, homogeneous isotropic turbulence, energy spectrum.
- Turbulent free shear flows. Jet, wake, mixing layer.
- Wall-bounded turbulent flows.
- Turbulent flow computation and modeling.

Literature
Lecture notes are available

Abstract
The course provides an introduction to theoretical foundations and practical usage of the Lattice Boltzmann Method for fluid dynamics simulations.

Objective
Methods like molecular dynamics, DSMC, lattice Boltzmann etc are being increasingly used by engineers all over and these methods require knowledge of kinetic theory and statistical mechanics which are traditionally not taught at engineering departments. The goal of this course is to give an introduction to ideas of kinetic theory and non-equilibrium thermodynamics with a focus on developing simulation algorithms and their realizations.

During the course, students will be able to develop a lattice Boltzmann code on their own. Practical issues about implementation and performance on parallel machines will be demonstrated hands on.

Central element of the course is the completion of a lattice Boltzmann code (using the framework specifically designed for this course).

The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.

Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.
The course builds upon three parts:
I Elementary kinetic theory and lattice Boltzmann simulations introduced on simple examples.
II Theoretical basis of statistical mechanics and kinetic equations.
III Lattice Boltzmann method for real-world applications.

The content of the course includes:

1. Background: Elements of statistical mechanics and kinetic theory;
   Particle’s distribution function, Liouville equation, entropy, ensembles; Kinetic theory; Boltzmann equation for rarefied gas, H-theorem, hydrodynamic limit and derivation of Navier-Stokes equations, Chapman-Enskog method, Grad method, boundary conditions; mean-field interactions, Vlasov equation;
   Kinetic models: BGK model, generalized BGK model for mixtures, chemical reactions and other fluids.

2. Basics of the Lattice Boltzmann Method and Simulations:
   Minimal kinetic models: lattice Boltzmann method for single-component fluid, discretization of velocity space, time-space discretization, boundary conditions, forcing, thermal models, mixtures.

3. Hands on:
   Development of the basic lattice Boltzmann code and its validation on standard benchmarks (Taylor-Green vortex, lid-driven cavity flow etc).

4. Practical issues of LBM for fluid dynamics simulations:
   Lattice Boltzmann simulations of turbulent flows; numerical stability and accuracy.

5. Microflow:
   Rarefraction effects in moderately dilute gases; Boundary conditions, exact solutions to Couette and Poiseuille flows; micro-channel simulations.

6. Advanced lattice Boltzmann methods:
   Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

7. Introduction to LB models beyond hydrodynamics:
   Relativistic fluid dynamics; flows with phase transitions.

Lecture notes:
Lecture notes on the theoretical parts of the course will be made available.

Prerequisites / notice:
The course addresses mainly graduate students (MSc/Ph D) but BSc students can also attend.

636-0017-00L Computational Biology W 3 credits 3G+2A T. Vaughan, C. Magnus, T. Stadler

Abstract
The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Objective
Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:
- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:
- epidemiology
- pathogen evolution
- macroevolution of species

Content
The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS.

Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes:
Lecture slides will be available on moodle.

Literature
The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:
- Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.

Prerequisites / notice:
Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course "Introduction to Programming", which takes place in Basel before the start of the semester.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

Case Studies

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<td>401-3667-74L</td>
<td>Case Studies Seminar (Autumn Semester 2024)</td>
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</table>
Invited speakers from ETH, from other universities as well as from industry give a talk on an applied topic. Beside of attending the scientific talks students are asked to give short presentations (10 minutes) on a published paper out of a list.

Objective

+ actual techniques for the presentation of scientific results in a scientific talk
+ awareness of actual questions in research and development in CSE related areas

Content

In the CSE Case Studies Seminar invited speakers from ETH, from other universities as well as from industry give a talk on an applied topic. Beside of attending the scientific talks students are asked to give short presentations (10 minutes) on a published paper out of a list (containing articles from, e.g., Nature, Science, Scientific American, etc.). If the underlying paper comprises more than 15 pages, two or three consecutive case studies presentations delivered by different students can be based on it. Consistency in layout, style, and contents of those presentations is expected.

Students have to register their presentations online on https://rw.ethz.ch/the-programme/case-studies.html by the first week of the teaching period.

Prerequisites / notice

75% attendance and a short presentation on a published paper out of a list or on some own project are mandatory.

The student talks will be grouped by subject, so we'll decide the actual dates of the individual talks.

Students that realize that they will not fulfill this criteria have to contact the teaching staff or de-register before the end of semester from the Seminar if they want to avoid a "Fail" in their documents. Later de-registrations will not be considered.

Competencies

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Science in Perspective

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-MATH

Bachelor’s Thesis

If you wish to have recognised 402-2000-00L Scientific Works in Physics instead of 401-2000-00L Scientific Works in Mathematics (as allowed for the CSE programme), take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having passed the performance assessment.

Number | Title | Type | ECTS | Hours | Lecturers |
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<td>Scientific Works in Mathematics</td>
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Abstract

Introduction to scientific writing for students with focus on publication standards and ethical issues, especially in the case of citations (references to works of others.)

Objective

Learn the basic standards of scientific works in mathematics.

Content

- Types of mathematical works
- Publication standards in pure and applied mathematics
- Data handling
- Ethical issues
- Citation guidelines

Prerequisites / notice


401-2000-01L | Lunch Sessions – Thesis Basics for Mathematics Students | Z | 0 credits | Speakers |

Abstract

Details and registration for the optional MathBib training course: https://www.math.ethz.ch/mathbib-schulungen

Optional MathBib training course

402-2000-00L | Scientific Works in Physics | W | 0 credits | D. Kienzler |

Abstract

Master students who cannot document to have received an adequate training in working scientifically.

Directive https://www.ethz.ch/content/dam/ethz/common/docs/weis
Abstract

Literature Review: ETH-Library, Journals in Physics, Google Scholar; Thesis Structure: The IMRAD Model; Document Processing: LaTeX and BibTeX, Mathematical Writing, AVETH Survival Guide; ETH Guidelines for Integrity; Authorship Guidelines; ETH Citation Etiquettes; Declaration of Originality.

Objective

Basic standards for scientific works in physics: How to write a Master Thesis. What to know about research integrity.

401-3990-1BL Bachelor’s Thesis

Successful participation in the course unit 401-2000-00L Scientific Works in Mathematics or 402-2000-00L Scientific Works in Physics is required.

Abstract

Approval via the form https://my.cse.ethz.ch/ is MANDATORY (caution: in myStudies all lecturers can be selected despite the fact that some of them are actually not authorised as supervisors).

Objective

The BSc thesis concludes the curriculum. In their BSc thesis, students should demonstrate their ability to carry out independent, structured scientific work. The purpose of the BSc thesis is to deepen knowledge in a certain subject and to bring students into closer contact with applications in an existing computational group. The BSc thesis requires approximately 420 hours of work.

Prerequisite / notice

Approval via the form https://my.cse.ethz.ch/ is MANDATORY (caution: in myStudies all lecturers can be selected despite the fact that some of them are actually not authorised as supervisors).

Colloquia

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<td>R. Alaifari, H. Ammari, R. Hiptmair, S. Mishra, C. Schwab</td>
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<td></td>
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<td></td>
<td>Research colloquium</td>
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Computational Science and Engineering Bachelor - Key for Type

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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<td>Z</td>
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Key for Hours

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<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Core Courses

In the ‘core courses’ subcategory, at least two course units must be successfully completed.

Only one of the two course units
263-5210-00L Probabilistic Artificial Intelligence resp.
252-0535-00L Advanced Machine Learning
may be recognised for credits as a core course. However, the other course unit may be recognised for a different category.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-4656-21L</td>
<td>AI in the Sciences and Engineering</td>
<td>W</td>
<td>6 credits</td>
<td>2V+2U</td>
<td>S. Mishra</td>
</tr>
<tr>
<td></td>
<td><em>Aimed at students in a Master's Programme in Mathematics, Engineering and Physics.</em></td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>AI is having a profound impact on science by accelerating discoveries across physics, chemistry, biology, and engineering. This course aims to present a highly topical selection of AI applications across these fields. Emphasis will be placed on using AI, particularly deep learning, to understand systems modelled by PDEs, and key scientific machine learning concepts and themes will be discussed.</td>
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<tr>
<td></td>
<td><strong>Objective</strong></td>
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<td></td>
<td></td>
<td>Learning objectives:</td>
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<tr>
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<td>- Aware of advanced applications of AI in the sciences and engineering</td>
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<td></td>
<td>- Familiar with the design, implementation, and theory of these algorithms</td>
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<td>- Understand the pros/cons of using AI and deep learning for science</td>
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<td></td>
<td>- Understand key scientific machine learning concepts and themes</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
<td></td>
<td></td>
<td></td>
<td>A selection of the following topics will be presented in the lectures:</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>1. Key scientific tasks common to many scientific domains, such as simulation, inverse problems, equation discovery, design, and control problems, and issues with traditional methods for solving them</td>
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<tr>
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<td></td>
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<td></td>
<td>2. Physics-informed neural networks for solving forward, inverse and equation discovery problems related to PDEs</td>
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<td>3. Neural operators, including Fourier neural operators and DeepONets, for learning efficient surrogate models, and their theoretical foundations</td>
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<td>4. Differentiable scientific algorithms, neural differential equations, and the benefits of hybrid workflows</td>
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<td>5. AI for symbolic regression and equation discovery</td>
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<td>6. Applications of graph neural networks in science</td>
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<td>7. Guest lectures on AI for chemistry and biology</td>
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<td>8. Large language models and other Foundation models for scientific discovery</td>
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<tr>
<td></td>
<td><strong>Lecture notes</strong></td>
<td></td>
<td></td>
<td></td>
<td>Lecture slides, recordings, and tutorials will be available on Moodle.</td>
</tr>
<tr>
<td></td>
<td><strong>Literature</strong></td>
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<td></td>
<td>All the material in the course is based on research articles written in last 1-3 years. The relevant references will be provided.</td>
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<tr>
<td></td>
<td><strong>Prerequisites / notice</strong></td>
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<td>- An understanding of basic ML concepts including supervised learning, overfitting/underfitting, optimisation, and neural networks is required; you should understand the main concepts in the ETH 252-0220-00L Introduction to Machine Learning course (but note, completing this course is not a formal requirement)</td>
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<td>- Familiar with PDEs and numerical methods for solving them</td>
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<td>- Basic competence in Python and some practical familiarity with deep learning frameworks (e.g. PyTorch, TensorFlow, or Keras)</td>
</tr>
<tr>
<td></td>
<td><strong>Competencies</strong></td>
<td></td>
<td></td>
<td></td>
<td>Subject-specific Competencies - Concepts and Theories assessed</td>
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<tr>
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<td></td>
<td>Techniques and Technologies assessed</td>
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<td>Method-specific Competencies - Analytical Competencies assessed</td>
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<td>Problem-solving assessed</td>
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<td>Project Management fostered</td>
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<td></td>
<td>Social Competencies - Communication fostered</td>
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<td>Cooperation and Teamwork fostered</td>
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<td>Personal Competencies - Adaptability and Flexibility fostered</td>
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<td>Creative Thinking assessed</td>
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<td>Critical Thinking assessed</td>
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<td>Integrity and Work Ethics fostered</td>
</tr>
<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10 credits</td>
<td>3V+2U+4A</td>
<td>C. Cotrini Jimenez</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
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<td>Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.</td>
</tr>
<tr>
<td></td>
<td><strong>Objective</strong></td>
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<td></td>
<td>Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.</td>
</tr>
</tbody>
</table>
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

**Fundamentals:**
- What is data?
- Bayesian Learning
- Computational learning theory

**Supervised learning:**
- Ensembles: Bagging and Boosting
- Max Margin methods
- Neural networks

**Unsupervised learning:**
- Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

**Lecture notes**
No lecture notes, but slides will be made available on the course webpage.

**Literature**

**Prerequisites / notice**
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

**401-4671-00L Advanced Numerical Methods for CSE**

- **Abstract**
  This course will focus on teaching different advanced topics in numerical methods for science and engineering. The main aim would be introduce novel algorithms and discuss their implementation.

- **Objective**
  - Ability to adapt the presented paradigms and algorithms to modified or new problems arising from applications in computational science and engineering.
  - Ability to judge the scope, strengths and weaknesses of the numerical methods covered in this course and of methods derived from them.
  - Skills in translating a high-level description of an algorithm into efficient code.

- **Content**
  The course will comprise three main chapters:
  1. **The Boundary Element Method (BEM):**
     It is a numerical method used to solve boundary value problems for linear PDEs. It focuses only on the boundary, rather than the entire volume of the domain to be modeled. [50%]
  2. **Hierarchical Matrices (H-matrices):**
     They are an efficient data structure used to approximate dense matrices with a hierarchical block structure, significantly reducing the computational and memory costs for operations like matrix multiplication and inversion. [25%]
  3. **Hybrid Modeling:**
     The technique combines multiple modeling techniques, such as physics-based models and data-driven approaches, to capitalize on the strengths of each method and improve the accuracy and efficiency of simulations or predictions in complex systems. [25%]

- **Lecture notes**
  Lecture material will be created during the course and will be made available.

- **Prerequisites / notice**
  - Familiarity with basic numerical methods (as taught in the course "Numerical Methods for CSE").
  - Knowledge of numerical methods for differential equations (as covered in the course "Numerical Methods for Partial Differential Equations").

- **Competencies**
  - Subject-specific Competencies
    - Concepts and Theories: assessed
  - Method-specific Competencies
    - Analytical Competencies: assessed
    - Problem-solving: assessed
    - Project Management: fostered
  - Personal Competencies
    - Critical Thinking: fostered

---

**Core Courses (continued)**

Only one of the two course units
263-5210-00L Probabilistic Artificial Intelligence resp.
252-0535-00L Advanced Machine Learning
may be recognised for credits as a core course. However, the other course unit may be recognised for a different category.

For the category assignment take contact with the Study Administration (www.math.ethz.ch/studiensekretariat).
Abstract
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice
The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

Competencies
Subject-specific Competencies
Concepts and Theories
Assessed
Techniques and Technologies
Assessed

Method-specific Competencies
Analytical Competencies
Assessed
Decision-making
Assessed
Media and Digital Technologies
Assessed
Problem-solving
Assessed
Project Management
Assessed

Social Competencies
Communication
Fostered
Cooperation and Teamwork
Fostered

Personal Competencies
Creative Thinking
Assessed
Critical Thinking
Assessed
Integrity and Work Ethics
Fostered

Fields of Specialization

Astrophysics

Objective
Acquire knowledge of main methodologies for computer-based models of astrophysical systems, the physical equations behind them, and train such knowledge with simple examples of computer programmes.

Abstract
This course covers the foundations of astrophysical fluid dynamics, the Boltzmann equation, equilibrium systems and their stability, the structure of stars, astrophysical turbulence, accretion disks and their stability, the foundations of radiative transfer, collisionless systems, the structure and stability of dark matter halos and stellar galactic disks.

Content
This course covers the foundations of astrophysical fluid dynamics, the theory of collisions and the Boltzmann equation, the notion of equilibrium systems and their stability, the structure of stars, the theory of astrophysical turbulence, the theory of accretion disks and their stability, the foundations of astrophysical radiative transfer, the theory of collisionless system, the structure and stability of dark matter halos and stellar galactic disks.

Literature
Course Materials:
1- The Physics of Astrophysics, Volume 1: Radiation by Frank H. Shu
2- The Physics of Astrophysics, Volume 2: Gas Dynamics by Frank H. Shu
3- Foundations of radiation hydrodynamics, Dimitri Mihalas and Barbara Weibel-Mihalas
4- Radiative Processes in Astrophysics, George B. Rybicki and Alan P. Lightman
5- Galactic Dynamics, James Binney and Scott Tremaine

Prerequisites / notice
This is a full black board ad chalk experience for students with a strong background in mathematics and physics.

Prerequisites:
Introduction to Astrophysics
Mathematical Methods for the Physicist
Quantum Mechanics
(All preferred but not obligatory)

Prior Knowledge:
Mechanics
Quantum Mechanics and atomic physics
Thermodynamics
Fluid Dynamics
Electrodynamics

Objective
Acquire knowledge of main methodologies for computer-based models of astrophysical systems, the physical equations behind them, and train such knowledge with simple examples of computer programmes.

Abstract
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

Mind the enrolment deadlines at UZH:
### Physics of the Atmosphere

#### 701-0023-00L Atmosphere

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0023-00L</td>
<td>Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>E. Fischer, U. Lohmann</td>
</tr>
</tbody>
</table>

**Objective**

- Students are able to:
  - to explain the physical structure and chemical composition of the atmosphere
  - to quantitatively describe and understand the fundamental physical and chemical processes in the atmosphere
  - to explain the interactions and feedbacks between atmosphere - ocean - land surface, troposphere - stratosphere and weather - climate.

In the course "Atmosphere", the competencies of process understanding, system understanding and data analysis & interpretation are taught, applied and examined.

**Content**

Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds.

**Lecture notes**

Written information will be supplied.

**Literature**


**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Problem-solving

- **Method-specific Competencies**
  - Communication
  - Cooperation and Teamwork
  - Sensitivity to Diversity

- **Social Competencies**
  - Creativity
  - Critical Thinking
  - Self-awareness and Self-reflection

- **Personal Competencies**
  - Independently judge the applicability of learned concepts and tools to real-world situations.
  - Apply these concepts to answer comprehension questions and solve simple problems related to the structure and dynamics of the PBL.
  - Name the basic approaches needed to describe planetary boundary layer flows and associated turbulent exchange processes.
  - Apply these concepts to answer comprehension questions and solve simple problems related to the structure and dynamics of the PBL.
  - Independently judge the applicability of learned concepts and tools to real-world situations.

**Prerequisites / notice**

Some knowledge of UNIX, scripting languages (see www.physik.uzh.ch/lectures/informatik/python/ as an example), some prior experience programming, knowledge of C, C++ beneficial.

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**651-4053-05L Boundary Layer Meteorology**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4053-05L</td>
<td>The Planetary Boundary Layer (PBL) constitutes the lower part of the atmosphere, is characterized by turbulent mixing and ensures the exchange of energy, mass and momentum between the Earth’s surface and the atmosphere. The course provides the theoretical background for understanding the structure and dynamics of the PBL. Idealized concepts are reviewed and contrasted to real world applications.</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>M. Rotach, P. Calanca</td>
</tr>
</tbody>
</table>

**Objective**

- Students are able to:
  - Name the basic approaches needed to describe planetary boundary layer flows and associated turbulent exchange processes.
  - Apply these concepts to answer comprehension questions and solve simple problems related to the structure and dynamics of the PBL.
  - Independently judge the applicability of learned concepts and tools to real-world situations.

**Content**

- Introduction
- PBL structure and stability
- Turbulence and turbulent transport
- Scaling and similarity theory
- Spectral characteristics
- Conservation equations in a turbulent flow
- Closure problem and closure assumptions
- Rough surfaces and the roughness sublayer
- Complex terrain

**Lecture notes**

Available (i.e. in English)

**Literature**


**Prerequisites / notice**

Umwelt-Fluiddynamik (701-0479-00L) (environment fluid dynamics) or equivalent and basic knowledge in atmospheric science

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies
  - Analytical Competencies
  - Decision-making
  - Problem-solving

- **Method-specific Competencies**
  - Communication
  - Cooperation and Teamwork
  - Sensitivity to Diversity

- **Social Competencies**
  - Creativity
  - Critical Thinking
  - Self-awareness and Self-reflection

**701-1221-00L Dynamics of Large-Scale Atmospheric Flow**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1221-00L</td>
<td>This lecture course is about the fundamental aspects of the dynamics of extratropical weather systems (quasi-geostrophic dynamics, potential vorticity, Rossby waves, baroclinic instability). The fundamental concepts are formally introduced, quantitatively applied and illustrated with examples from the real atmosphere. Exercises (quantitative and qualitative) form an essential part of the course.</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>H. Wernli, J. Riboldi</td>
</tr>
</tbody>
</table>

**Objective**

Understanding of dynamic processes of large-scale atmospheric flow and their mathematical-physical formulation.

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Dynamical Meteorology is concerned with the dynamical processes of the earth's atmosphere. The fundamental equations of motion in the atmosphere will be discussed along with the dynamics and interactions of synoptic system - i.e. the low and high pressure systems that determine our weather. The motion of such systems can be understood in terms of quasi-geostrophic theory. The lecture course provides a derivation of the mathematical basis along with some interpretations and applications of the concept.

Abstract
The process of writing a scientific proposal is introduced and the essential elements, including the peer review process, are outlined and class exercises train scientific writing skills. Knowledge exchange between class participants is promoted through the preparation of a master thesis proposal and evaluation of each other's work. An introduction to presentation skills is provided.

Objectives
- scientific writing
- introduction to peer review process
- correction / feedback to the proposals of other participants
- presentation skills

Content
In this seminar, the process of writing a scientific proposal is introduced. The essential elements of a proposal, including the peer review process, are outlined and class exercises train scientific writing skills. Knowledge exchange between class participants is promoted through the preparation of a master thesis proposal and evaluation of each other's work. Furthermore, an introduction to presentation skills is provided.

Prerequisites / notice
In this seminar it is mandatory to write a proposal about an upcoming MSc thesis or semester project. If no such project is planned, this seminar cannot be taken. Please contact the lecturers (hanna.joos@env.ethz.ch) on time if you plan to take this seminar.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Social Competencies</td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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</table>

**Seminar in Physics of the Atmosphere for CSE**

W 4 credits 2S  H. Joos, A. Merrifield Körnz

**Abstract**
The seminar in Physics of the Atmosphere for CSE introduces the fundamental concepts and theories of atmospheric dynamics. The course covers the dynamics of large-scale atmospheric flow and provides an introduction to dynamical meteorology. The seminar includes lectures, exercises, and a project component to enhance understanding and application of the concepts.

**Objective**
- Understanding the fundamental concepts and theories of atmospheric dynamics
- Applying dynamical meteorological principles to real-world problems
- Developing skills in scientific writing and presentation

**Content**
- Dynamics of large-scale atmospheric flow
- Dynamical meteorology
- Synoptic systems and their interactions
- Case studies of atmospheric events
- Project work with application of dynamical meteorology

**Prerequisites / notice**
- Strong background in physics and mathematics
- Participation in introductory courses in atmospheric science
- Commitment to collaborative learning and project work

**Competencies**

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<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Method-specific Competencies</td>
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<td>assessed</td>
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<tr>
<td>Social Competencies</td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
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</tbody>
</table>

**Chemistry**

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0004-01L</td>
<td>Classical Simulation of (Bio)Molecular Systems</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>P. H. Hünenberger, J. Dolenc, S. Riniker</td>
</tr>
<tr>
<td>529-0003-01L</td>
<td>Advanced Quantum Chemistry</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>M. Reiher, T. Weymouth</td>
</tr>
</tbody>
</table>

**Abstract**

- Classical Simulation of (Bio)Molecular Systems:
  - Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology.
  - Exercises: hands-on computer exercises for learning progressively how to perform a molecular dynamics simulation using the package GROMOS.

- Advanced Quantum Chemistry:
  - Advanced, but fundamental topics central to the understanding of theory in chemistry and for solving actual chemical problems with a computer.
  - Examples are: Operators derived from principles of relativistic quantum mechanics
  - Relativistic effects + methods of relativistic quantum chemistry
  - Open-shell molecules + spin-density functional theory
  - New electron-correlation theories

**Prerequisites / notice**
- Basic knowledge of quantum mechanics
- Familiarity with computational methods in chemistry
- Commitment to rigorous problem-solving and analysis

**Competencies**

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<th>Subject-specific Competencies</th>
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<tr>
<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
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</table>
Objective

The aim of the course is to provide an in-depth knowledge of theory and method development in theoretical chemistry. It will be shown that this is necessary in order to be able to solve actual chemical problems on a computer with quantum chemical methods.

The relativistic re-derivation of all concepts known from (nonrelativistic) quantum mechanics and quantum-chemistry lectures will finally explain the form of all operators in the molecular Hamiltonian - usually postulated rather than deduced. From this, we derive operators needed for molecular spectroscopy (like those required by magnetic resonance spectroscopy). Implications of other assumptions in standard non-relativistic quantum chemistry shall be analyzed and understood, too. Examples are the Born-Oppenheimer approximation and the expansion of the electronic wave function in a set of pre-defined many-electron basis functions (Slater determinants). Overcoming these concepts, which are so natural to the theory of chemistry, will provide deeper insights into many-particle quantum mechanics. Also revisiting the workhorse of quantum chemistry, namely density functional theory, with an emphasis on open-shell electronic structures (radicals, transition-metal complexes) will contribute to this endeavor. It will be shown how these insights allow us to make more accurate predictions in chemistry in practice - at the frontier of research in theoretical chemistry.

Content

1) Introductory lecture: basics of quantum mechanics and quantum chemistry
2) Einstein's special theory of relativity and the (classical) electromagnetic interaction of two charged particles
3) Klein-Gordon and Dirac equation; the Dirac hydrogen atom
4) Numerical methods based on the Dirac-Fock-Coulomb Hamiltonian, two-component and scalar relativistic Hamiltonians
5) Response theory and molecular properties, derivation of property operators, Breit-Pauli-Hamiltonian
6) Relativistic effects in chemistry and the emergence of spin
7) Spin in density functional theory
8) New electron-correlation theories: Tensor network and matrix product states, the density matrix renormalization group

Lecture notes

A set of detailed lecture notes will be provided, which will cover the whole course.

Literature

2) F. Schwabl: Quantenmechanik für Fortgeschrittene (QM II), Springer-Verlag, 1997 [english version available: F. Schwabl, Advanced Quantum Mechanics]
3) R. McWeeny: Methods of Molecular Quantum Mechanics, Academic Press, 1992
   https://doi.org/10.1063/1.5129672

Note also the standard textbooks:
A) A. Szabo, N.S. Ostlund. Verlag, Dover Publications
B) I. N. Levine, Quantum Chemistry, Pearson

Prerequisites

Strongly recommended (preparatory) courses are: quantum mechanics and quantum chemistry

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>fostered</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
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<td>Problem-solving</td>
<td>fostered</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
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<td></td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
</tr>
</tbody>
</table>

402-0205-00L Quantum Mechanics I

8 credits

W Autumn Semester 2024

Physics BSc students with programme regulations 2016 need to register for 402-0205-10L Quantenmechanik I

Abstract

Applications: simple potentials in wave mechanics, scattering and resonance, harmonic oscillator, hydrogen atom, and perturbation theory.

Objective

Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems.

Content

The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradoxon and Bell's inequality); Perturbation theory.

Lecture notes

Auf Moodle

G. Baym, Lectures on Quantum Mechanics
E. Merzbacher, Quantum Mechanics
L.I. Schiff, Quantum Mechanics
R. Feynman and A.R. Hibbs, Quantum Mechanics and Path Integrals
J.J. Sakurai: Modern Quantum Mechanics
A. Messiah; Quantum Mechanics I
S. Weinberg: Lectures on Quantum Mechanics

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2200 of 2653
### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td><strong>Concepts and Theories</strong></td>
<td><strong>Analytical Competencies</strong></td>
<td><strong>Communication</strong></td>
<td><strong>Adaptability and Flexibility</strong></td>
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<tr>
<td><strong>Techniques and Technologies</strong></td>
<td><strong>Decision-making</strong></td>
<td><strong>Leadership and Responsibility</strong></td>
<td><strong>Creative Thinking</strong></td>
</tr>
<tr>
<td><strong>Media and Digital Technologies</strong></td>
<td><strong>Problem-solving</strong></td>
<td><strong>Self-presentation and Social Influence</strong></td>
<td><strong>Critical Thinking</strong></td>
</tr>
<tr>
<td><strong>Assessed</strong></td>
<td><strong>Media and Digital Technologies</strong></td>
<td><strong>Sensitivity to Diversity</strong></td>
<td><strong>Integrity and Work Ethics</strong></td>
</tr>
<tr>
<td><strong>Fostered</strong></td>
<td><strong>Techniques and Technologies</strong></td>
<td><strong>Negotiation</strong></td>
<td><strong>Self-awareness and Self-reflection</strong></td>
</tr>
<tr>
<td><strong>Fostered</strong></td>
<td><strong>Techniques and Technologies</strong></td>
<td><strong>Cooperation and Teamwork</strong></td>
<td><strong>Self-direction and Self-management</strong></td>
</tr>
</tbody>
</table>

### Abstract

The student will carry out a literature study on a topic of his or her liking (suggested by or in agreement with the supervisor) in the area of computer simulation in chemistry (Prof. Hünenberger) or of quantum chemistry (Prof. Reiher), the results of which are to be presented both orally and in written form.

For more information: [http://www.csms.ethz.ch/education/CSE_seminar.html](http://www.csms.ethz.ch/education/CSE_seminar.html)

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### Method-specific Competencies

- **Analytical Competencies**
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving

- **Techniques and Technologies**
  - Media and Digital Technologies
  - Problem-solving

### Social Competencies

- **Communication**
- **Leadership and Responsibility**
- **Self-presentation and Social Influence**
- **Sensitivity to Diversity**
- **Negotiation**

### Personal Competencies

- **Adaptability and Flexibility**
- **Creative Thinking**
- **Critical Thinking**
- **Integrity and Work Ethics**
- **Self-awareness and Self-reflection**
- **Self-direction and Self-management**

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### 401-5940-00L Seminar in Chemistry for CSE

**W** 4 credits 2S

**Abstract**

The student will carry out a literature study on a topic of his or her liking (suggested by or in agreement with the supervisor) in the area of computer simulation in chemistry (Prof. Hünenberger) or of quantum chemistry (Prof. Reiher), the results of which are to be presented both orally and in written form.

For more information: [http://www.csms.ethz.ch/education/CSE_seminar.html](http://www.csms.ethz.ch/education/CSE_seminar.html)

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### Fluid Dynamics

#### One of the course units

- **151-0103-00L Fluid Dynamics II**
- **151-0109-00L Turbulent Flows**

**Objective**

This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.

**Content**

- (1) Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
- (2) Properties of laminar, transitional and turbulent flows.
- (3) Near equilibrium dynamics: Linear and Lyapunov stability.
- (4) Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
- (5) Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance.

**Lecture notes**

Lecture notes are available

**Literature**


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### 151-0213-00L Fluid Dynamics with the Lattice Boltzmann Method

**W** 4 credits 3G

**Abstract**

The course provides an introduction to theoretical foundations and practical usage of the Lattice Boltzmann Method for fluid dynamics simulations.
Objective
Methods like molecular dynamics, DSMC, lattice Boltzmann etc are being increasingly used by engineers all over and these methods require knowledge of kinetic theory and statistical mechanics which are traditionally not taught at engineering departments. The goal of this course is to give an introduction to ideas of kinetic theory and non-equilibrium thermodynamics with a focus on developing simulation algorithms and their realizations.

During the course, students will be able to develop a lattice Boltzmann code on their own. Practical issues about implementation and performance on parallel machines will be demonstrated hands on.

Central element of the course is the completion of a lattice Boltzmann code (using the framework specifically designed for this course).

The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.

Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.

Content
The course builds upon three parts:
I Elementary kinetic theory and lattice Boltzmann simulations introduced on simple examples.
II Theoretical basis of statistical mechanics and kinetic equations.
III Lattice Boltzmann method for real-world applications.

The content of the course includes:

1. Background: Elements of statistical mechanics and kinetic theory:
   Particle's distribution function, Liouville equation, entropy, ensembles; Kinetic theory: Boltzmann equation for rarefied gas, H-theorem, hydrodynamic limit and derivation of Navier-Stokes equations, Chapman-Enskog method, Grad method, boundary conditions; mean-field interactions, Vasov equation; Kinetic models: BGK model, generalized BGK model for mixtures, chemical reactions and other fluids.

2. Basics of the Lattice Boltzmann Method and Simulations:
   Minimal kinetic models: lattice Boltzmann method for single-component fluid, discretization of velocity space, time-space discretization, boundary conditions, forcing, thermal models, mixtures.

3. Hands on:
   Development of the basic lattice Boltzmann code and its validation on standard benchmarks (Taylor-Green vortex, lid-driven cavity flow etc).

4. Practical issues of LBM for fluid dynamics simulations:
   Lattice Boltzmann simulations of turbulent flows; numerical stability and accuracy.

5. Microflow:
   Rarefaction effects in moderately dilute gases; Boundary conditions, exact solutions to Couette and Poiseuille flows; micro-channel simulations.

6. Advanced lattice Boltzmann methods:
   Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

7. Introduction to LB models beyond hydrodynamics:
   Relativistic fluid dynamics; flows with phase transitions.

Lecture notes
Lecture notes on the theoretical parts of the course will be made available.
Selected original and review papers are provided for some of the lectures on advanced topics.
Handouts and basic code framework for implementation of the lattice Boltzmann models will be provided.

Prerequisites / notice
The course addresses mainly graduate students (MSc/Ph D) but BSc students can also attend.

151-0709-00L Stochastic Methods for Engineers and Natural Scientists
W 4 credits 4G D. W. Meyer-Massetti

Abstract
The course provides an introduction into stochastic methods that are applicable for the description, treatment, and modeling of systems that are subject to uncertainties or that respond to parameter changes in a chaotic manner. Corresponding systems may arise in fluid dynamics, structural mechanics, biology, electrical engineering as well as other areas.

Objective
By the end of the course you will be familiar with a range of mathematical/statistical tools that enable a quantitative treatment of problems that involve uncertainties.

Content
- Probability theory, single and multiple random variables, mappings of random variables
- Estimation of statistical moments and probability densities based on data
- Stochastic differential equations, Ito calculus, PDF evolution equations
- Monte Carlo integration with importance and stratified sampling
- Markov-chain Monte Carlo sampling
- Control-variate and multi-level Monte Carlo estimation
- Kalman filters (classical and ensemble-based)
- Statistical tests for means and goodness-of-fit

Lecture notes
Detailed lecture notes will be provided.

Literature
Some textbooks related to the material covered in the course:
Hydrodynamics and Cavitation

**Abstract**
This course builds on the foundations of fluid dynamics to describe hydrodynamic flows and provides an introduction to cavitation.

**Objective**
The main learning objectives of this course are:
1. Identify and describe dominant effects in liquid fluid flows through physical modelling.
2. Identify and predict the onset of hydrodynamic instabilities.
3. Describe acoustic wave behaviour in liquids.
4. Explain tension, nucleation and phase-change in liquids.
5. Predict the behaviour of a gas bubble subject to changes in surrounding liquid pressure.
6. Describe hydrodynamic cavitation and its consequences in physical terms.
7. Recognise experimental techniques and industrial and medical applications for cavitation.
8. Read and evaluate research papers on recent research on cavitation and bubble dynamics and communicate the content orally to a multidisciplinary audience.

**Content**
The course gives an overview on the following topics: basics of hydrodynamics, capillarity, hydrodynamic instabilities, liquid fragmentation, Acoustics in liquids, tension in liquids, phase change. Cavitation and bubble dynamics: single bubbles (nucleation, dynamics, collapse), bubble clouds and cavitating flows. Industrial applications and measurement techniques.

**Literature**
Literature will be provided in the course material.

**Prerequisites / notice**
Fluid dynamics I & II or equivalent

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Seminar in Fluid Dynamics for CSE

**Abstract**
Enlarged knowledge and practical abilities in fundamentals and applications of Computational Fluid Dynamics

**Objective**
Enlarged knowledge and practical abilities in fundamentals and applications of Computational Fluid Dynamics

**Prerequisites / notice**
Contact Prof. P. Jenny before the beginning of the semester

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**Systems and Control**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0103-00L</td>
<td>Control Systems</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>F. Dörfler</td>
</tr>
</tbody>
</table>

**Abstract**
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

**Objective**
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

**Content**

**Literature**

**Prerequisites / notice**
Prerequisites: Signal and Systems Theory II.

MATLAB is used for system analysis and simulation.
Nonlinear Dynamics and Chaos I

**Prerequisites / notice**
Sufficient mathematical maturity, in particular in linear algebra, analysis.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

- **Method-specific Competencies**
  - Analytical Competencies
  - Problem-solving

- **Personal Competencies**
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics

**Content**

1. Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
2. Near equilibrium dynamics: Linear and Lyapunov stability
3. Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations
4. Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
5. Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

**Abstract**
Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

**Objective**
This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.

**Content**

1. Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
2. Near equilibrium dynamics: Linear and Lyapunov stability
3. Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations
4. Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
5. Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

**Lecture notes**
The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

**Prerequisites / notice**
- Prerequisites: Analysis, linear algebra and a basic course in differential equations.

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**151-0532-00L Nonlinear Dynamics and Chaos I**

**W 4 credits 4G**

**G. Haller**

**Abstract**
Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

**Objective**
This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.

**Content**

1. Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
2. Near equilibrium dynamics: Linear and Lyapunov stability
3. Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations
4. Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
5. Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

**Lecture notes**
The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

**Prerequisites / notice**
- Prerequisites: Analysis, linear algebra and a basic course in differential equations.

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**151-0575-01L Signals and Systems**

**W 4 credits 2V+2U**

**A. Carron**

**Abstract**
Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to signals and produce other signals. In this course, we explore how signals can be represented and manipulated, and their effects on systems. We further explore how we can discover basic system properties by exciting a system with various types of signals.

**Objective**
Master the basics of signals and systems. Apply this knowledge to problems in the homework assignments and programming exercise.

**Content**

**Lecture notes**
Lecture notes available on course website.

**Prerequisites / notice**
Control Systems I is helpful but not required.

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**151-0563-01L Dynamic Programming and Optimal Control**

**W 4 credits 2V+1U**

**R. D’Andrea**

**Abstract**
Introduction to Dynamic Programming and Optimal Control.

**Objective**
Covers the fundamental concepts of Dynamic Programming & Optimal Control.

**Content**
Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

**Literature**

**Prerequisites / notice**
Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

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**252-0535-00L Advanced Machine Learning**

**W 10 credits 3V+2U+4A**

**C. Cotrini Jimenez**

**Abstract**
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

**Content**
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory
- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

**Lecture notes**
No lecture notes, but slides will be made available on the course webpage.
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Prerequisites / notice**
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

### 151-0371-00L Advanced Model Predictive Control

**Number of participants limited to 60.**

**Objective**
Design, implement and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.

**Content**
Topics include - Nominal MPC for uncertain systems (nominal robustness) - Robust MPC - Stochastic MPC - Review of regression methods - Set-membership Identification and robust data-driven MPC - Bayesian regression and stochastic data-driven MPC - MPC as safety filter for reinforcement learning

**Lecture notes**
Lecture notes will be provided.

**Prerequisites / notice**
Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control in Spring Semester) strongly recommended.

Background in linear algebra and stochastic systems recommended.

### 401-5850-00L Seminar in Systems and Control for CSE

**Abstract**
Guided self study on a topic related to systems and control

**Competencies**
Subject-specific Competencies Concepts and Theories Techniques and Technologies fostered fostered

### Robotics

Only one of the two course units 263-5902-00L Computer Vision resp. 227-0447-00L Image Analysis and Computer Vision may be recognised for credits for the overall (CSE Bachelor and Master) study programmes.

Only one of the two course units 263-5210-00L Probabilistic Artificial Intelligence resp. 252-0535-00L Advanced Machine Learning may be recognised for credits in the field of specialisation 'Robotics' for the overall (CSE Bachelor and Master) study programmes. However, the other course unit may be recognised for a different category.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>227-0447-00L</td>
<td>Image Analysis and Computer Vision</td>
<td>W</td>
<td>6</td>
<td>3V+1U</td>
<td>E. Konukoglu, E. Erdil, F. Yu</td>
</tr>
</tbody>
</table>

**Abstract**
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

**Objective**
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

**Lecture notes**
Course material Script, computer demonstrations, exercises and problem solutions

**Prerequisites / notice**
Prerequisites: Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

### 252-0535-00L Advanced Machine Learning

**Abstract**
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.
Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
What is data?
Bayesian Learning
Computational learning theory

Supervised learning:
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks

Unsupervised learning:
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation
Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature

Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

252-3005-00L Natural Language Processing W 7 credits 3V+3U+1A R. Cotterell
Abstract
This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Objective
The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

Content
This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Literature
Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

263-3210-00L Deep Learning W 8 credits 3V+2U+2A T. Hofmann
Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://ml2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/ss19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18
The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems. Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

The students are familiar with the challenges of the fascinating and interdisciplinary field of Robotics and Mechatronics. They are aware of how can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Prerequisites / notice
The contents of the following ETH Bachelor lectures or equivalent are assumed to be known: Mechanics and Dynamics, Control, Basics in Fluid Dynamics.

401-5860-00L  Seminar in Robotics for CSE
Abstract
This course provides an opportunity to familiarize yourself with the advanced topics of robotics and mechatronics research. The study plan has to be discussed with the lecturer based on your specific interests and/or the relevant seminar series such as the IRIS's Robotics Seminars and BiRONZ lectures, for example.

Objective
The students are familiar with the challenges of the fascinating and interdisciplinary field of Robotics and Mechatronics. They are introduced in the basics of independent non-experimental scientific research and are able to summarize and to present the results efficiently.

Content
This 4 ECTS course requires each student to discuss a study plan with the lecturer and select minimum 10 relevant scientific publications to read through, or attend 5-10 lectures of the public robotics oriented seminars (e.g. Public robotics seminars such as the IRIS's Robotics Seminars http://www.iris.ethz.ch/iris/series/, and BiRONZ lectures http://www.birl.ethz.ch/bironz/index are good examples). At the end of semester, the results should be presented in an oral presentation and summarized in a report, which takes the discussion of the presentation into account.

Robotic systems (continued)

Only one of the two course units
263-5902-00L Computer Vision resp. 227-0447-00L Image Analysis and Computer Vision may be recognised for credits for the overall (CSE Bachelor and Master) study programmes.

Only one of the two course units
263-5210-00L Probabilistic Artificial Intelligence resp. 252-0535-00L Advanced Machine Learning may be recognised for credits in the field of specialisation 'Robots' for the overall (CSE Bachelor and Master) study programmes. However, the other course unit may be recognised for a different category.

For the category assignment take contact with the Study Administration (www.math.ethz.ch/studiensekretariat).

Number Title Type ECTS Hours Lecturers
263-5902-00L Computer Vision W 8 credits 3V+1U+3A M. Pollefeys, S. Tang, F. Yu
263-5210-00L Probabilistic Artificial Intelligence W 8 credits 3V+2U+2A A. Krause

Prerequisites / notice
Solid basic knowledge in statistics, algorithms and programming. The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.
**Quantum Mechanics I**


**Objective**

Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems.

**Content**

Applications: simple potentials in wave mechanics, scattering and resonance, harmonic oscillator, hydrogen atom, and perturbation theory.

**Lecture notes**

Lecture notes and slides are available online and will be distributed if desired.

**Literature**

Lecture notes and slides are available online and will be distributed if desired.

**Prerequisites / notice**

Lecture notes and slides are available online and will be distributed if desired.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed
  - Project Management: assessed
- Social Competencies
  - Communication: fostered
  - Cooperation and Teamwork: fostered
- Personal Competencies
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered

**Number** 402-0205-00L

**Title** Quantum Mechanics I

**Type** W

**ECTS** 8 credits

**Hours** 3V+2U

**Lecturers** M. Krstic Marinkovic

**Description**

Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

**Abstract**

This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

**Objective**

Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

**Content**

This theory part QIP I together with the experimental part QIP II are an introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

**Lecture notes**

Lecture notes and slides are available online and will be distributed if desired.

**Literature**

Lecture notes and slides are available online and will be distributed if desired.

**Prerequisites / notice**

Lecture notes and slides are available online and will be distributed if desired.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed
  - Project Management: assessed
- Social Competencies
  - Communication: fostered
  - Cooperation and Teamwork: fostered
- Personal Competencies
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered

**Number** 402-0448-01L

**Title** Quantum Information Processing I: Concepts

**Type** W

**ECTS** 5 credits

**Hours** 2V+1U

**Lecturers** J. Renes

**Description**

For the field of specialization 'Physics' basic knowledge in quantum mechanics is required.

**Abstract**

This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

**Objective**

Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

**Content**

This theory part QIP I together with the experimental part QIP II are an introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

**Lecture notes**

Lecture notes and slides are available online and will be distributed if desired.

**Literature**

Lecture notes and slides are available online and will be distributed if desired.

**Prerequisites / notice**

Lecture notes and slides are available online and will be distributed if desired.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories: assessed
- Method-specific Competencies
  - Analytical Competencies: assessed
- Social Competencies
  - Communication: fostered
  - Cooperation and Teamwork: fostered
- Personal Competencies
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered
402-0448-02L QIP II (both offered in the autumn semester) combine to the core course in experimental physics “Quantum Information Processing” (totally 10 ECTS credits). This applies to the Master’s degree programme in Physics.

Abstract
The course covers the key concepts and formalism of quantum information processing. Topics include quantum algorithms, quantum error correction, quantum cryptography, and quantum metrology, with an emphasis on the power of quantum information processing beyond that of classical information processing. The formalism of quantum states, measurements, and channels is developed in detail.

Objective
By the end of the course students are able to explain the basic mathematical formalism of quantum mechanics and apply it to quantum information processing problems. They are able to adapt and apply these concepts and methods to analyze and discuss quantum algorithms and other quantum information-processing protocols.

Content
The topics covered in the course will include quantum circuits, gate decomposition and universal sets of gates, efficiency of quantum circuits, quantum algorithms (Shor, Grover, Deutsch-Josza,...), stabilizer-based quantum error correction, fault-tolerant designs, the BB84 quantum key distribution protocol, and simple methods of quantum metrology.

Lecture notes
Will be provided.

Literature
Quantum Computation and Quantum Information
Michael Nielsen and Isaac Chuang
Cambridge University Press

Prerequisites / notice
A good understanding of finite dimensional linear algebra is recommended.

Competencies
Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed

Method-specific Competencies
Analytical Competencies
Decision-making
assessed

Problem-solving
assessed

Personal Competencies
Adaptability and Flexibility
Creative Thinking
assessed

Critical Thinking
assessed

402-0777-00L Particle Accelerator Physics and Modeling I
W 6 credits 2V+1U A. Adelmann

Abstract
This is the first of two courses, introducing particle accelerators from a theoretical point of view and covers state-of-the-art modelling techniques.

Objective
You obtain a theoretical understanding of the building blocks of particle accelerators. Modern numerical analysis tools allows you to model state-of-the-art particle accelerators. We will develop a Julia simulation tool (JuliAccel.jl) that reflects the theory from the lecture.

Content
Here is the rough plan of the topics, however the actual pace may vary relative to this plan.

- Recap of Relativistic Classical Mechanics and Electrodynamics
- Building Blocks of Particle Accelerators
- Lie Algebraic Structure of Classical Mechanics and Application to Particle Accelerators
- Symplectic Maps & Analysis of Maps
- Symplectic Particle Tracking
- Collective Effects
- Linear & Circular Accelerators

Lecture notes
Lecture notes

Prerequisites / notice
Physics, Computational Science (RW) at MSc. Level
In exceptional cases students at BSc level can attend.
This lecture is also suited for PhD. students

Competencies
Subject-specific Competencies
Concepts and Theories
assessed

Method-specific Competencies
Media and Digital Technologies
assessed

Social Competencies
Communication
assessed

Personal Competencies
Critical Thinking
assessed

401-5810-00L Seminar in Physics for CSE
W 4 credits 2S A. Adelmann

Abstract
During this seminar, students will prepare and deliver a presentations on subjects in contemporary theoretical or computational physics. Additionally, they may implement a complex algorithm.

Objective
You obtain a theoretical understanding of the building blocks of particle accelerators. Modern numerical analysis tools allows you to model state-of-the-art particle accelerators. We will develop a Julia simulation tool (JuliAccel.jl) that reflects the theory from the lecture.

Content
Here is the rough plan of the topics, however the actual pace may vary relative to this plan.

- Recap of Relativistic Classical Mechanics and Electrodynamics
- Building Blocks of Particle Accelerators
- Lie Algebraic Structure of Classical Mechanics and Application to Particle Accelerators
- Symplectic Maps & Analysis of Maps
- Symplectic Particle Tracking
- Collective Effects
- Linear & Circular Accelerators

Lecture notes
Lecture notes

Prerequisites / notice
Physics, Computational Science (RW) at MSc. Level
In exceptional cases students at BSc level can attend.
This lecture is also suited for PhD. students

Competencies
Subject-specific Competencies
Concepts and Theories
assessed

Method-specific Competencies
Media and Digital Technologies
assessed

Social Competencies
Communication
assessed

Personal Competencies
Critical Thinking
assessed

Computational Finance

Number Title Type ECTS Hours Lecturers
401-3913-01L Mathematical Foundations for Finance W 4 credits 3V+2U D. Possamaï

Abstract
First introduction to main modelling ideas and mathematical tools from mathematical finance

Objective
This course gives a first introduction to the main modelling ideas and mathematical tools from mathematical finance. It mainly aims at non-mathematicians who need an introduction to the main tools from stochastics used in mathematical finance. However, mathematicians who want to learn some basic modelling ideas and concepts for quantitative finance (before continuing with a more advanced course) may also find this of interest. The main emphasis will be on ideas, but important results will be given with (sometimes partial) proofs.

Content
Topics to be covered include

- financial market models in finite discrete time
- absence of arbitrage and martingale measures
- valuation and hedging in complete markets
- basics about Brownian motion
- stochastic integration
- stochastic calculus: Itô's formula, Girsanov transformation, Itô's representation theorem
- Black-Scholes formula

Lecture notes
See information on course homepage
Prerequisites: Results and facts from probability theory as in the book "Probability Essentials" by J. Jacod and P. Protter will be used freely. Especially participants without a direct mathematics background are strongly advised to familiarise themselves with those tools before (or very quickly during) the course. (A possible alternative to the above English textbook are the (German) lecture notes for the standard course "Wahrscheinlichkeitstheorie".)

For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories assessed</th>
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<td>Techniques and Technologies fostered</td>
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<tr>
<td>Method-specific Competencies Analytical Competencies assessed</td>
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<tr>
<td>Decision-making fostered</td>
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<tr>
<td>Problem-solving assessed</td>
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<tr>
<td>Personal Competencies Adaptability and Flexibility fostered</td>
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<tr>
<td>Creative Thinking fostered</td>
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<td>Critical Thinking fostered</td>
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<tr>
<td>Integrity and Work Ethics fostered</td>
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401-4657-00L Numerical Solution of Stochastic Ordinary Differential Equations

W 6 credits 3V+1U C. Schwab

Abstract

This course is on the numerical approximations of stochastic ordinary differential equations (SDEs) driven by Brownian motions and Lévy processes. SDEs have several applications, for example in financial engineering.

The contents cover stochastic processes, stochastic calculus, well-posedness results for SDEs, strong and weak approximations of SDEs, and simulation via Monte Carlo methods.

Objective

The aim of this course is to enable the students to carry out simulations and their mathematical convergence analysis for stochastic models originating from applications such as mathematical finance. For this the course teaches a decent knowledge of the different numerical methods, their underlying ideas, convergence properties and implementation issues.

Content

Brownian motion and Lévy processes
Stochastic integration and stochastic calculus
Stochastic ordinary differential equations (SDEs)
Numerical approximations of SDEs
Stochastic simulation and Monte Carlo methods
Applications to computational finance: Option valuation

Lecture notes

There will be English, typed lecture notes for registered participants in the course.

Literature

P. E. Kloeden and E. Platen:
Numerical Solution of Stochastic Differential Equations.

Bertoin, Jean:
Lévy processes.
Cambridge Tracts in Mathematics, 121.
Cambridge University Press.

Cont, Rama; Tankov, Peter:
Financial modelling with jump processes.

Prerequisites / notice

Mandatory:
Probability and measure theory,
basic numerical analysis and
basics of MATLAB/Python programming.

a) mandatory courses:
Measure - and Probability Theory I
as covered in courses:
ETH 401-2283-00L Analysis III (Measure Theory)
UZH Kursmodul 10498 Hauptvorlesung: Mass- und Integrationsstheorie

b) recommended courses:
Stochastic Processes I
Seminar in Computational Finance for CSE

W 4 credits 2S  J. Teichmann

Prerequisites / notice
Requirements: sound understanding of stochastic concepts and of concepts of mathematical Finance, ability to implement econometric or simulation routines in Python.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving fostered
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Electromagnetic Waves: Materials, Effects, and Antennas

Does not take place this semester.

Abstract
This course provides profound knowledge about electromagnetic waves. Various types of materials, nonlinear and resonant effects, and antenna applications are discussed.

Objective
You can describe wave propagation in classical and nonclassical materials and know the fundamental solutions.
You know how waves interact with matter and about nonlinear, scattering and resonant effects.
You can apply the acquired knowledge in scattering, waveguiding, radiation, and antenna problems.

Content
The lecture covers the following topics:
• Generic time-harmonic electromagnetic fields
• Fundamental solutions of the wave equation
• Wave propagation in various types of materials
• Interaction of waves with matter
• Nonlinear effects
• Resonant effects
• Applications like scattering, waveguiding, radiation

Lecture notes
Lecture notes and slides will be handed out during the lectures.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies fostered
Media and Digital Technologies fostered
Problem-solving fostered

Social Competencies
Communication fostered

Personal Competencies
Critical Thinking fostered

Physical Modelling and Simulation

W 6 credits 4G  J. Smajic
The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or chose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

### 227-0301-00L Optical Communication Fundamentals

**Objective**

Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to iteratively improve the models till sufficient accurate results are obtained.

**Content**

The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or chose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

### 401-4785-00L Mathematical and Computational Methods in Photonics

**Objective**

The aim of this course is to review new and fundamental mathematical tools, computational approaches, and inversion and optimal design methods used to address challenging problems in nanophotonics. The emphasis will be on analyzing plasmon resonant nanoparticles, super-focusing & super-resolution of electromagnetic waves, photonic crystals, electromagnetic cloaking, metamaterials, and metasurfaces methods used to address challenging problems in nanophotonics. The emphasis will be on analyzing plasmon resonant nanoparticles, super-focusing & super-resolution of electromagnetic waves, photonic crystals, electromagnetic cloaking, metamaterials, and metasurfaces

**Abstract**

The field of photonics encompasses the fundamental science of light propagation and interactions in complex structures, and its technological applications.

The recent advances in nanoscience present great challenges for the applied and computational mathematics community. In nanophotonics, the aim is to control, manipulate, reshape, guide, and focus electromagnetic waves at nanometer length scales, beyond the resolution limit. In particular, one wants to break the resolution limit by reducing the focal spot and confine light to length scales that are significantly smaller than half the wavelength.

Interactions between the field of photonics and mathematics has led to the emergence of a multitude of new and unique solutions in which today's conventional technologies are approaching their limits in terms of speed, capacity and accuracy. Light can be used for detection and measurement in a fast, sensitive and accurate manner, and thus photonics possesses a unique potential to revolutionize healthcare. Light-based technologies can be used effectively for the very early detection of diseases, with non-invasive imaging techniques or point-of-care applications. They are also instrumental in the analysis of processes at the molecular level, giving a greater understanding of the origin of diseases, and hence allowing prevention along with new treatments. Photonic technologies also play a major role in addressing the needs of our ageing society; from pace-makers to synthetic bones, and from endoscopes to the micro-cameras used in in-vivo processes. Furthermore, photonics are also used in advanced lighting technology, and in improving energy efficiency and quality. By using photonics to control waves across a wide band of wavelengths, we have an unprecedented ability to fabricate new materials with specific microstructures.

The main objective in this course is to report on the use of sophisticated mathematics in diffractive optics, plasmonics, super-resolution, photonic crystals, and metamaterials for electromagnetic invisibility and cloaking. The book merges highly nontrivial multi-mathematics in order to make a breakthrough in the field of mathematical modelling, imaging, and optimal design of optical nanodevices and nanomaterials capable of light enhancement, and of the focusing and guiding of light at a subwavelength scale. We demonstrate the power of layer potential techniques in solving challenging problems in photonics, when they are combined with asymptotic analysis and the elegant theory of Gohberg and Sigal on meromorphic operator-valued functions.

In this course we shall consider both analytical and computational matters in photonics. The issues we consider lead to the investigation of fundamental problems in various branches of mathematics. These include asymptotic analysis, spectral analysis, mathematical imaging, optimal design, stochastic modelling, and analysis of wave propagation phenomena. On the other hand, deriving mathematical foundations, and new and efficient computational frameworks and tools in photonics, requires a deep understanding of the different scales in the wave propagation problem, an accurate mathematical modelling of the nanodevices, and fine analysis of complex wave propagation phenomena. An emphasis is put on mathematically analyzing plasmon resonant nanoparticles, diffractive optics, photonic crystals, super-resolution, and metamaterials.
Abstract
Various topics of electromagnetics, including electromagnetic theory, computational electromagnetics, electromagnetic wave propagation, applications from statics to optics. Traditional problems such as antennas, electromagnetic scattering, waveguides, resonators, etc. as well as modern topics such as photonic crystals, metamaterials, plasmonics, etc. are considered.

Objective
Knowledge of the fundamentals of electromagnetic theory, development and application of numerical methods for solving Maxwell equations, analysis and optimal design of electromagnetic structures

Geophysics

Geophysics: Subject 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tr>
<td>651-4007-00L</td>
<td>Continuum Mechanics</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>T. Gerya</td>
</tr>
</tbody>
</table>

Abstract
In this course, students learn crucial partial differential equations (conservation laws) that are applicable to any continuum including the Earth’s mantle, core, atmosphere and ocean. The course will provide step-by-step introduction into the mathematical structure, physical meaning and analytical solutions of the equations. The course has a particular focus on solid Earth applications.

Objective
The goal of this course is to learn and understand few principal partial differential equations (conservation laws) that are applicable for analysing and modelling of any continuum including the Earth’s mantle, core, atmosphere and ocean. By the end of the course, students should be able to write, explain and analyse the equations and apply them for simple analytical cases. Numerical solving of these equations will be discussed in the Numerical Modelling I and II course running in parallel.

Content
A provisional week-by-week schedule (subject to change) is as follows:

Weeks 1,2: The continuity equation
- Exercise: Computing the divergence of velocity field.

Weeks 3,4: Density and gravity
- Exercises: Computing density, thermal expansion and compressibility from an equation of state. Derivation of gravitational acceleration and its divergence from gravitational potential.

Weeks 5,6: Stress and strain
- Exercises: Analysing strain rate tensor for solid body rotation. Computing stress invariants

Weeks 7,8: The momentum equation
- Exercises: Deriving momentum equation. Computing velocity for magma flow in a channel.

Week 9: Viscous rheology of rocks
- Theory: Solid-state creep of minerals and rocks as the major mechanism of deformation of the Earth’s interior. Dislocation and diffusion creep mechanisms. Rheological equations for minerals and rocks. Effective viscosity and its dependence on temperature, pressure and strain rate. Formulation of the effective viscosity from empirical flow laws.
- Exercise: Deriving viscous rheological equations for computing effective viscosities from empirical flow laws.

Weeks 10: The heat conservation equation

Weeks 11,12: Elasticity and plasticity
- Exercise: Computing viscoelastic stress evolution.


Lecture notes
GRADING will be based on homeworks (1/3) and oral exam (2/3).

Literature

Competencies

Geophysics: Subject 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>651-4241-00L</td>
<td>Numerical Modelling I and II: Theory and Applications</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>T. Gerya</td>
</tr>
</tbody>
</table>

Abstract
In this 13-week sequence, students learn how to write programs from scratch to solve partial differential equations that are useful for Earth science applications. Programming will be done in MATLAB and will use the finite-difference method and marker-in-cell technique. The course will emphasise a hands-on learning approach rather than extensive theory.
The goal of this course is for students to learn how to program numerical applications from scratch. By the end of the course, students should be able to write state-of-the-art MATLAB codes that solve systems of partial-differential equations relevant to Earth and Planetary Science applications using finite-difference method and marker-in-cell technique. Applications include Poisson equation, buoyancy driven variable viscosity flow, heat diffusion and advection, and state-of-the-art thermomechanical code programming. The emphasis will be on commonality, i.e., using a similar approach to solve different applications, and modularity, i.e., re-use of code in different programs. The course will emphasise a hands-on learning approach rather than extensive theory, and will begin with an introduction to programming in MATLAB.

A provisional week-by-week schedule (subject to change) is as follows:

Week 1: Introduction to the finite difference approximation to differential equations. Introduction to programming in Matlab. Solving of 1D Poisson equation.


Week 3: Solving momentum and continuity equations in case of constant viscosity with stream function/vorticity formulation.


Weeks 5: Conservative finite differences for the momentum equation. “Free slip” and “no slip” boundary conditions. Solving momentum and continuity equations in case of variable viscosity using pressure-velocity formulation with staggered grid.


Week 7: Advection in 2-D with Marker-in-cell method. Combining flow calculation and advection for buoyancy driven flow.


Week 9: Solving 2D heat conservation equation in case of constant thermal conductivity with explicit and implicit approaches.

Week 10: Solving 2D heat conservation equation in case of variable thermal conductivity with implicit approach. Temperature advection with markers. Creating thermomechanical code by combining mechanical solution for 2D buoyancy driven flow with heat diffusion and advection based on marker-in-cell approach.

Week 11: Implementation of radioactive, adiabatic and shear heating to the thermomechanical code.

Week 12: Programming of solution of coupled solid-fluid momentum and continuity equations for the case of melt percolation in a rising mantle plume.


Week 14: Final project description for slab breakoff modeling.

GRADING will be based on weekly programming homeworks (50%) and a term project (50%) to develop an application of their choice to a more advanced level.

*** Geophysics: Subject 3
Offered in the spring semester

*** Geophysics: Subject 4
Offered in the spring semester

*** Geophysics: Subject 5

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<tr>
<td>651-4014-00L</td>
<td>Seismic Waves II</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>A. Obermann</td>
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Abstract

This course provides an overview of the most widely used seismological methods to image the Earth’s interior with a focus on crustal and upper-mantle structures. Topics include controlled source methods such as refraction and wide-angle reflection, as well as passive body-wave and surface-wave based methods. The course will discuss the strengths and weaknesses of each method.

Objective

Understand the strengths and weaknesses of various active and passive tomographic methods to image the structure of the Earth.

Literature

Geophysics: Subject 6
Offered in the spring semester

Geophysics: Subject 7
Offered in the spring semester

Geophysics: Subject 8

Geophysics: Seminar

Biology

Competencies | Subject-specific Competencies | Concepts and Theories | assessed
Method-specific Competencies | Analytical Competencies | fostered
Decision-making | fostered
Problem-solving | fostered
Social Competencies | Cooperation and Teamwork | fostered
Personal Competencies | Creative Thinking | fostered
Critical Thinking | fostered

Geophysics: Subject 6

Geophysics: Subject 7

Geophysics: Subject 8

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
651-4273-00L | Numerical Modelling in Fortran | W | 3 credits | 2V | P. Tackley

Abstract
This course gives an introduction to programming in Fortran, and is suitable for students who have only minimal programming experience. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts.

Objective
Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in this language, and is suitable for students who have only minimal programming experience, for example with MATLAB scripts. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts, using example scientific problems relevant to Earth science.

Lecture notes
See http://jupiter.ethz.ch/~pjt/FORTRAN/FortranClass.html

Competencies

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
401-5880-00L | Seminar in Geophysics for CSE | W | 4 credits | 2S | T. Gerya, P. Tackley

Abstract
The seminar in geophysics for CSE is a work on a small research project for 4 credit points. The project can be supervised and graded by any member of the Institute of Geophysics with doctoral degree

Objective
Students will learn modern quantitative geophysical research by conducting a small original project on a relevant subject.

Content
Students should find a project of interest by contacting potential supervisors from the Institute of Geophysics and agree on the content and timing of the project. At the end of the project, a written report of free format should be submitted by the student, which is then graded by the supervisor.

Lecture notes
No script

Literature
Relevant literature should be provided by the project supervisor.

Competencies

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
636-0007-00L | Computational Systems Biology | W | 6 credits | 3V+2U | J. Stelling

Abstract
Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

Objective
The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.
Concepts and Theories

Students will learn state-of-the-art approaches to modeling spatial effects in dynamical biological systems. The course provides an introduction to key concepts in developmental biology. Attendees will apply these concepts to a number of applications yielding biological insight into:

- *epidemiology*
- *pathogen evolution*
- *macroevolution of species*

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

- epidemiology
- pathogen evolution
- macroevolution of species

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. Then we present methods for direct alignment analysis using approaches such as BLAST and GWAS.

Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylogeography, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the course, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

- *Yang, Z. 2006. Computational Molecular Evolution.*
- *Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.*

Prerequisites / notice

Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place in Basel before the start of the semester.

636-0017-00L Computational Biology W 6 credits 3G+2A T. Vaughan, C. Magnus, T. Stadler

Abstract

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Objective

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

- epidemiology
- pathogen evolution
- macroevolution of species

Content

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

- *Yang, Z. 2006. Computational Molecular Evolution.*
- *Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.*

636-0706-00L Spatio-Temporal Modelling in Biology W 4 credits 3G D. Iber

Abstract

This course focuses on modeling spatio-temporal problems in biology, in particular on the cell and tissue level. The main focus is on mechanisms and concepts, but mathematical and numerical techniques are introduced as required. Biological examples discussed in the course provide an introduction to key concepts in developmental biology.

Objective

Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides an introduction to dynamical system, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

Content

1. Introduction to Modelling in Biology
2. Bioimage Analysis
3. Morphogen Gradients
4. Precision & Robustness of Patterning
5. Mathematical Description of Growing Biological Systems
6. Travelling Waves & Wave Pinning
7. Turing Patterns
8. Chemotaxis
9. Epithelial Organisation
10. Tissue Simulation Frameworks
11. Tissue Mechanics & Fluid Dynamics
12. Growth Control
13. Image-Based Modelling
14. Summary

Lecture notes

All lecture material will be made available online via Moodle.

Literature

http://www.csb.ethz.ch/education/lectures.html


The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties.

Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enigmas and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

This course considers the structure and function of biological neuronal networks at different levels. The function of neuronal networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, simple neuronal architectures of feedforward and recurrent networks are discussed in the context of co-ordination, control, and integration of sensory and motor information.

Connections to computer science and artificial intelligence are discussed, but the main focus of the course is on establishing the biological basis of computations in neurons.
Students will have an advanced understanding of the underlying concepts behind modern bioinformatic analyses at genome, metagenome and proteome-wide scales. They will be familiar with the most common data types, where to access them, and how to analytically work with them to address contemporary questions in the field of biology.

Course participants have already acquired basic programming skills in UNIX, Python and R.

Students bring their own computer with keyboard, internet access (browser) and software to connect to the ETH network via VPN.

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This course aims to cover state-of-the-art methods in modern parallel computing on Graphics Processing Unit (GPU), supercomputing and code development with applications to natural sciences and engineering.

When quantitative assessment of physical processes governing natural and engineered systems relies on numerically solving differential equations, fast and accurate solutions require performant algorithms leveraging parallel hardware. The goal of this course is to offer a practical approach to solve systems of differential equations in parallel on GPUs using the Julia language. Julia combines high-level language conciseness to low-level language performance which enables efficient code development.

The course will be taught in a hands-on fashion, putting emphasis on you writing code and completing exercises; lecturing will be kept at a minimum. In a final project you will solve a solid mechanics or fluid dynamics problem of your interest, such as the shallow water equation, the shallow ice equation, acoustic wave propagation, nonlinear diffusion, viscous flow, elastic deformation, viscous or elastic poromechanics, frictional heating, and more. Your Julia GPU application will be hosted on a git-platform and implement modern software development practices.

- Part 1 - Discovering a modern parallel computing ecosystem
  - Learn the basics of the Julia language;
  - Learn how to solve diffusion, wave propagation and advection processes;
  - Implement efficient iterative algorithms;
  - Get started with software development tools: git, version control.

- Part 2 - Developing your own parallel algorithms on GPUs
  - Implement wave propagation and porous convection;
  - Apply spatial and temporal discretisation (finite-differences, various time-stepper);
  - Implement software development tooling: unit tests, continuous integration (CI).

- Part 3 - Multi-GPU computing projects
  - Understand the practical challenges of distributed parallel computing on multi-GPUs;
  - Automatise the software tooling using remote runners.

- Final projects
  - Implement advanced physical processes (solid and fluid dynamic - elastic and viscous solutions).

Digital lecture notes, interactive Julia notebooks, online material.

Links to relevant literature will be provided during classes.

Completed BSc studies. Interest in and basic knowledge of numerics, applied mathematics, and physics/engineering sciences. Basic programming skills (in e.g. Matlab, Python, Julia); advanced programming skills are a plus.

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Digital lecture notes, interactive Julia notebooks, online material.

Links to relevant literature will be provided during classes.

Completed BSc studies. Interest in and basic knowledge of numerics, applied mathematics, and physics/engineering sciences. Basic programming skills (in e.g. Matlab, Python, Julia); advanced programming skills are a plus.

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### Lecture: Visualization, Simulation and Interaction - Virtual Reality II

**Lecture Code:** 263-2800-00L

**Credit:** 9 credits

**Objective:**
- Advanced topics in parallel and high-performance computing.
- Understand concurrency paradigms and models from a higher perspective.
- Acquire skills for designing, structuring and developing parallel high-performance software systems.
- Become familiar with important technical concepts and with concurrency folklore.

**Abstract:**
- Does not take place this semester.

**Content:**
- Introduction to parallel and high-performance computing.
- Advanced topics in parallel and high-performance computing.

**Prerequisites / notice:**
- Mechanics 1, 2, Dynamics, Continuum Mechanics I and Introduction to FEA. Ideally also Continuum Mechanics II.

---

### Lecture: Applied Finite Element Analysis

**Lecture Code:** 151-0833-00L

**Objective:**
- The goal of the lecture is to provide the students with the fundamentals of the non linear Finite Element Method (FEM).
- The lecture focuses on the principles of the nonlinear Finite-Element-Method based on explicit and implicit formulations.

**Abstract:**
- Most problems in engineering are of nonlinear nature. The nonlinearities are caused basically due to the nonlinear material behavior, contact conditions and instability of structures. The principles of the nonlinear Finite-Element-Method (FEM) will be introduced for treating such problems. The finite element program ABAQUS is introduced to investigate real engineering problems.

**Content:**
- Crash
- Collapse of structures
- Material behavior (metals and rubber)
- General forming processes
- Introduction into FEM
- Fundamentals of continuum mechanics to characterize large plastic deformations
- Elasto-plastic material models
- Lagrange and Euler approaches
- FEM implementation of constitutive equations
- Element formulations
- Implicit and explicit FEM methods
- FEM formulations of coupled thermo-mechanical problems
- Modeling of tool contact and the influence of friction
- Solvers and convergence
- Instability problems

**Lecture notes:**
- Lecture slides

**Literature:**

---

### Lecture: Nonlinear FEA

**Lecture Code:** 151-0529-00L

**Objective:**
- The course provides an introduction to non-linear finite element analysis. The treated sources of non-linearity are related to material properties (hyperelasticity, plasticity), kinematics (large deformations, instability problems) and boundary conditions (contact).

**Abstract:**
- The course provides an introduction to non-linear finite element analysis. The treated sources of non-linearity are related to material properties (hyperelasticity, plasticity), kinematics (large deformations, instability problems) and boundary conditions (contact).

**Content:**
- Introduction to various sources of nonlinearities and implications for FEA.
- Non-linear kinematics: large deformations, stability problems.
- Non-linear material behavior: hyperelasticity, plasticity.
- Non-linear boundary conditions: contact problems.

**Prerequisites / notice:**
- Mechanics 1, 2, Dynamics, Continuum Mechanics I and Introduction to FEA. Ideally also Continuum Mechanics II.

---

### Lecture: Design of Parallel and High-Performance Computing

**Lecture Code:** 263-2800-00L

**Objective:**
- Provide a deeper knowledge on the possible applications of parallel computing.
- Develop skills for designing, structuring and developing parallel high-performance software systems.
- Become familiar with important technical concepts and with concurrency folklore.

**Abstract:**
- Advanced topics in parallel and high-performance computing.

**Content:**
- Understand concurrency paradigms and models from a higher perspective.
- Acquire skills for designing, structuring and developing parallel high-performance software systems.
- Become familiar with important technical concepts and with concurrency folklore.

**Prerequisites / notice:**
- Mechanics 1, 2, Dynamics, Continuum Mechanics I and Introduction to FEA. Ideally also Continuum Mechanics II.
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human machine interaction, as well as gaming technology.

After attending this course, students will:
1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.

The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including: Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introduction to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course are student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision(graphics/HMI) research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

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Allan Borodin, Ran El-Yaniv.
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Inf. Comput. 98, 2 (June 1992), pp. 142-170

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Christos Cassandras, Stéphane Lafortune.

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A. Fiat and G. Woeginger

D. Hochbaum

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Tadao Murata

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Michael Sipser.

Competencies

<table>
<thead>
<tr>
<th>Competency</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
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<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Analytical Competencies</td>
<td>Decision-making</td>
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227-0116-00L VLSI 1: HDL Based Design for FPGAs W 6 credits 5G F. K. Gürkaynak

Abstract
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Objective
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

Content
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog.
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Lecture notes
Textbook and all further documents in English.

Literature
Prerequisites:
- Basics of digital circuits.

Examination:
- In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English or German.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

**227-0147-10L**
**VLSI 3: Full-Custom Digital Circuit Design**

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### Abstract
This third course in our VLSI series is concerned with full-custom digital integrated circuits. The goals include learning the design of digital circuits on the schematic, layout, gate, and register-transfer levels. The use of state-of-the-art CAD software (Cadence Virtuoso) in order to simulate, optimize, and characterize digital circuits is another important topic of this course.

### Objective
At the end of this course, you will
- understand the design of the main building blocks of state-of-the-art digital integrated circuits
- be able to design and optimize digital integrated circuits on the schematic, layout, and gate levels
- be able to use standard industry software (Cadence Virtuoso) for drawing, simulating, and characterizing digital circuits
- understand the performance trade-offs between delay, area, and power consumption

### Content
The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack towards logic gates and increasingly complex digital circuit structures. The topics of this course include:
- Nanometer MOSFETs
- Static and dynamic behavior of complementary MOS (CMOS) inverters
- CMOS gate design, sizing, and timing
- Full-custom standard-cell design
- Wire models and parasitics
- Latch and flip-flop circuits
- Gate-level timing analysis and optimization
- Static and dynamic power consumption; low-power techniques
- Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
- Arithmetic and logic circuits
- Fixed-point and floating-point arithmetic
- Synchronous and asynchronous design principles
- Memory circuits (ROM, SRAM, and DRAM)
- In- and near-memory processing architectures
- Full-custom accelerator circuits for machine learning

The exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

### Literature
- N. H. E. Weste and D. M. Harris, CMOS VLSI Design: A Circuits and Systems Perspective (4th Ed.), Addison-Wesley

### Prerequisites / notice
VLSI 3 can be taken in parallel with "VLSI 1: HDL-based design for FPGAs" and is designed to complement the topics of this course. Basic analog circuit knowledge is required.

### Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Problem-solving: assessed

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**227-0417-00L**
**Information Theory I**

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### Abstract
This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

### Objective
The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

### Content
- The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the source-channel separation theorem, feedback capacity

### Literature
- T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

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**227-0124-00L**
**Embedded Systems**

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### Abstract
An embedded system is a combination of hardware and software, either fixed in function or programmable, that is designed for a specific application scenario or for a specific task within a larger system. They are part of industrial machines such as agricultural and manufacturing equipment, automotive systems, medical equipment, household appliances, sensor networks, and the Internet of Things.

### Objective
Understanding the specific requirements and problems that arise in embedded system applications.

### Content
- Understanding the hardware structure of a microcontroller and an embedded system; memory architecture and memory map, internal and external peripherals, low-power and low-energy design as well as instruction sets and computational accelerators.
- Understanding the firmware structure of a microcontroller and an embedded system; low-level instruction set, hardware-software interfaces, communication between components, embedded real-time operating systems, real-time scheduling, shared resources, low-power and low-energy programming as well as computational accelerators.
- Using formal models and methods for designing and optimizing embedded systems.
- Gaining experience with practical applications of the C programming language, embedded real-time operating systems, and debug functionalities of the associated design environment to design, implement, and verify embedded firmware.

### Literature
- T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/
Content

This lecture focuses on the design of embedded systems using formal models and methods.

Lecture notes

Besides the theoretical lecture, the course contains laboratory sessions where students transfer the learned theoretical aspects into praxis by programming a microcontroller and interfacing it with sensors and actuators. Students will be exposed to a commercial microcontroller, and the development board extend with a custom-designed embedded systems educational platform.

Specifically, the following topics will be covered in the course: hardware and software structures of embedded systems, low-level instruction set, memory architecture and memory map, peripherals, hardware-software interfaces, communication between components, firmware design methodologies, firmware design using the C programming language, embedded real-time operating systems, real-time scheduling, shared resources, low-power, and low-energy designs as well as computational accelerators.

Prerequisites / notice

Recommended: basic knowledge of assembly programming and computer architecture.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

227-0971-00L

Computational Psychiatry

W 3 credits 4S K. Stephan

Abstract

This six-day course teaches state-of-the-art methods in computational psychiatry. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples.

Objective

This course aims at bridging the gap between mathematical modelers and clinical neuroscientists by teaching computational techniques in the context of clinical applications. The hope is that the acquisition of a joint language and tool-kit will enable more effective communication and joint translational research between fields that are usually worlds apart.

Content

This six-day course teaches state-of-the-art methods in computational psychiatry. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples. Furthermore, practical exercises provide in-depth exposure to different software packages. Please see http://www.translationalneuromodeling.org/cpcourse/ for details.

252-0237-00L

Concepts of Object-Oriented Programming

W 8 credits 3V+2U+2A P. Müller

Abstract

Course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object and class initialization, program correctness, reflection

Objective

After this course, students will:

- Have a deep understanding of advanced concepts of object-oriented programming and their support in different programming languages.
- Be able to understand language concepts on a semantic level and be able to compare and evaluate language designs.
- Be able to learn new languages more rapidly.

Content

The main goal of this course is to convey a deep understanding of the key concepts of sequential object-oriented programming and their support in different programming languages. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.

- The topics discussed in the course include among others:
  - The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing)
  - The key problems of single and multiple inheritance and how different languages address them
  - Generic type systems, in particular, Java generics, C# generics, and C++ templates
  - The situations in which object-oriented programming does not provide encapsulation, and how to avoid them
  - The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing
  - How to maintain the consistency of data structures

Literature

Will be announced in the lecture.

Prerequisites / notice

Mastering at least one object-oriented programming language (this course will NOT provide an introduction to object-oriented programming); programming experience

252-0543-01L

Computer Graphics

W 8 credits 3V+2U+2A M. Gross, M. Papas

Abstract

This course covers fundamental and advanced concepts of modern computer graphics. Students will learn the fundamentals of digital scene representations, advanced physically-based light transport algorithms for generating photorealistic images from these scene representations, and inverse rendering methods for recovering digital scene representations from captured images.

Objective

At the end of the course, the students will be able to build a rendering system based on path-tracing algorithms. The students will learn the principles of physically-based rendering and computer graphics. In addition, the course is intended to stimulate the student's curiosity to explore the field of computer graphics in subsequent classes or on their own.

Content

We will begin with an introduction to light emission and radiometric quantities, followed by an exploration of geometry representations and texture mapping. Next, we will mathematically formulate the physics of light transport and appearance modeling.

Subsequently, we will introduce relevant concepts from Monte Carlo integration and develop path-tracing algorithms to solve these equations by simulating light transport for direct and global illumination due to hard surfaces and participating media, such as fog, smoke, and translucent objects.

Moreover, we will present techniques for significantly improving path-tracing efficiency, including importance sampling, multiple importance sampling, stratified sampling, denoising, and acceleration data structures.

The course lectures will conclude with an overview of image-based capture and rendering methods. Topics covered will include geometry reconstruction, material acquisition, differentiable rendering, and image-based rendering.

Lecture notes

no
The goal of the course is to have a good overview of the different types of time series and the approaches used in their statistical analysis. Concepts and Theories

The aim of this course is to assess and foster competencies in physically-based animation in computer graphics. This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods. The course considers classical low-dimensional models, with pointers towards today's highly complex models.

Abstract

In this course we study the basics of theoretical statistics. The course includes methods for designing estimators, confidence intervals and tests, and various ways to evaluate the accuracy of estimators, confidence intervals and tests. We consider optimality criteria such as admissibility and minimaxity, as well as Bayesian criteria. We will also present the asymptotic point of view.

Objective

The key topics which will be covered are: ARMA, ARIMA, Introduction into GARCH models, Forecasting, Spectral analysis, spectral densities, Elimination of seasonality, Trend estimation, Stationarity, Autocorrelation, Spectral analysis, spectral densities, ARMA, ARIMA, Introduction into GARCH models.

Literature

The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis.
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.


The main mathematical tools used will be Probability, Linear Algebra (and real analysis), and a working knowledge of these subjects is required. In addition to these prerequisites, this class requires a certain degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

We encourage students who are interested in mathematical data science to take both this course and `227-0434-10L Mathematics of Information" taught by Prof. H. Bölcskei. The two courses are designed to be complementary.

A. Bandeira and H. Bölcskei

We consider this work as experimental part QIP II together with the theory part 402-0448-01L QIP I (both offered in the autumn semester) to be the core course in experimental physics "Quantum Information Processing" (totally 10 ECTS credits). This applies to the Master's degree programme in Quantum Information Processing II: Implementations.

This experimental part QIP II together with the theory part 402-0448-01L QIP I (both offered in the autumn semester) combine to the core course in experimental physics "Quantum Information Processing" (totally 10 ECTS credits). This applies to the Master's degree programme in Quantum Information Processing II: Implementations.
Abstract


Objective

Throughout the past 20 years the realm of quantum physics has entered the domain of information technology in more and more prominent ways. Enormous progress in the physical sciences and in engineering and technology has allowed us to build novel types of information processors based on the concepts of quantum physics. In these processors information is stored in the quantum state of physical systems forming quantum bits (qubits). The interaction between qubits is controlled and the resulting states are read out on the level of single quanta in order to process information. Realizing such challenging tasks is believed to allow constructing an information processor much more powerful than a classical computer. This task is taken on by academic labs, startups and major industry. The aim of this class is to give a thorough introduction to physical implementations pursued in current research for realizing quantum information processors. The field of quantum information science is one of the fastest growing and most active domains of research in modern physics.

Content

Introduction to experimental systems for quantum information processing (QIP).
- Quantum bits
- Coherent Control
- Measurement
- Decoherence
- QIP with Ions
- Superconducting Circuits
- Photons
- NMR
- Rydberg atoms
- NV-centers
- Quantum dots

Lecture notes

Course material be made available at www.qudev.ethz.ch and on the Moodle platform for the course. More details to follow.

Literature

Quantum Computation and Quantum Information
Michael Nielsen and Isaac Chuang
Cambridge University Press

Prerequisites / notice

The class will be taught in English language.

Basic knowledge of concepts of quantum physics and quantum systems, e.g from courses such as Physics III, Quantum Mechanics I and II or courses on topics such as atomic physics, solid state physics, quantum electronics are considered helpful.

More information on this class can be found on the web site www.qudev.ethz.ch
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

M. Vechev

The course is split into 4 parts:

- We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).


The coding project will utilize Python and PyTorch. Thus some programming experience in Python is expected. Students without prior knowledge of PyTorch are expected to acquire it early in the course by solving exercise sheets.

- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

Privacy of Machine Learning

- Threat models (e.g., stealing data, poisoning, membership inference, etc.).
- Attacks to the federated machine learning (across vision, natural language and tabular data).
- Differential privacy for defending machine learning.
- AI Regulations and checking model compliance.

Fairness of Machine Learning

- Introduction to fairness (motivation, definitions).
- Enforcing individual fairness (for both vision and tabular data).
- Enforcing group fairness (e.g., demographic parity, equalized odds).

Robustness, Privacy and Fairness of Foundation Models

- We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).

Critical Thinking

Problem-solving

Analytical Competencies

- Critical Thinking

- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

Privacy of Machine Learning

- Threat models (e.g., stealing data, poisoning, membership inference, etc.).
- Attacks to the federated machine learning (across vision, natural language and tabular data).
- Differential privacy for defending machine learning.
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Fairness of Machine Learning

- Introduction to fairness (motivation, definitions).
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Robustness, Privacy and Fairness of Foundation Models

- We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).


The coding project will utilize Python and PyTorch. Thus some programming experience in Python is expected. Students without prior knowledge of PyTorch are expected to acquire it early in the course by solving exercise sheets.
The lecture "Applied Computer Architecture" gives technical and corporate insights in innovative Computer Systems/Architectures (CPU, GPU, FPGA, dedicated processors) and their real implementations and applications. Often the designs have to deal with technical limits.

Which computer architecture allows the control of the over 1000 magnets at the Swiss Light Source (SLS) at the PSI?

Which architecture is behind the alarm center of the Swiss Railway (SBB)?

Which computer architecture is hidden behind a professional digital audio mixing desk?

How can data streams of about 30 TB/s, produced by a proton accelerator, be processed in real time?

Can the weather forecast also be processed with GPUs?

How could a fast trading system be set up for the stock exchange?

How can a good computer architecture be found?

Which are the driving factors in successful computer architecture design?

### Prerequisites
Prerequisites:
Basics of computer architecture.

### Competencies

#### Method-specific Competencies
- Decision-making: fostered
- Problem-solving: fostered
- Project Management: fostered

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

### Case Studies

#### Number: 401-3667-74L

**Title**: Case Studies Seminar (Autumn Semester 2024)

**Type**: W

**ECTS**: 3 credits

**Hours**: 2S

**Lecturers**: V. C. Gradianaru, R. Hiptmaier, R. Käppeli

**Abstract**: Invited speakers from ETH, from other universities as well as from industry give a talk on an applied topic. Beside of attending the scientific talks students are asked to give short presentations (10 minutes) on a published paper out of a list.

**Objective**: + actual techniques for the presentation of scientific results in a scientific talk

**Content**: In the CSE Case Studies Seminar invited speakers from ETH, from other universities as well as from industry give a talk on an applied topic. Beside of attending the scientific talks students are asked to give short presentations (10 minutes) on a published paper out of a list (containing articles from, e.g., Nature, Science, Scientific American, etc.). If the underlying paper comprises more than 15 pages, two or three consecutive case studies presentations delivered by different students can be based on it. Consistency in layout, style, and contents of those presentations is expected.

Students have to register their presentations online on [https://rw.ethz.ch/the-programme/case-studies.html](https://rw.ethz.ch/the-programme/case-studies.html) by the first week of the teaching period.

**Prerequisites / notice**: 75% attendance and a short presentation on a published paper out of a list or on some own project are mandatory.

Students have to register their presentations online until the first Sunday of the semester on [https://rw.ethz.ch/the-programme/case-studies.html](https://rw.ethz.ch/the-programme/case-studies.html)

The student talks will be grouped by subject, so we'll decide the actual dates of the individual talks.

Students that realize that they will not fulfill this criteria have to contact the teaching staff or de-register before the end of semester from the Seminar if they want to avoid a "Fail" in their documents. Later de-registrations will not be considered.

#### Competencies

**Method-specific Competencies**
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: fostered
- Project Management: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered

**Person Specific Competencies**
- Adaptability and Flexibility: fostered
- Critical Thinking: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### Semester Paper

There are several course units "Semester Paper" that are all equivalent. If, during your studies, you write several semester papers, choose among the different numbers in order to be able to obtain credits again.
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<th>Title</th>
<th>Type</th>
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<td>Lecturers</td>
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<td>Successful participation in the course unit 401-2000-00L Scientific Works in Mathematics or 402-2000-00L Scientific Works in Physics is required. Approval via the form <a href="https://my.cse.ethz.ch/is">https://my.cse.ethz.ch/is</a> MANDATORY (caution: in myStudies all lecturers can be selected despite the fact that some of them are actually not authorised as supervisors).</td>
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**Science in Perspective**

Two credits are needed from the "Science in Perspective" programme with language courses excluded if three credits from language courses have already been recognised for the Bachelor's degree. see https://ethz.ch/content/dam/ethz/common/docs/weisungsammlung/files-en/science-in-perspective.pdf (Eight credits must be acquired in this category: normally six during the Bachelor's degree programme, and two during the Master's degree programme. A maximum of three credits from language courses from the range of the Language Center of the University of Zurich and ETH Zurich may be recognised. In addition, only advanced courses (level B2 upwards) in the European languages English, French, Italian and Spanish are recognised. German language courses are recognised from level C2 upwards.)

- see Science in Perspective: Language Courses ETH/UZH
- see Science in Perspective: Type A: Enhancement of Reflection Capability
- Recommended Science in Perspective (Type B) for D-MATH

**Master's Thesis**

If you wish to have recognised 402-2000-00L Scientific Works in Physics instead of 401-2000-00L Scientific Works in Mathematics (as allowed for the CSE programme), take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having passed the performance assessment.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-2000-00L</td>
<td>Scientific Works in Mathematics</td>
<td>O</td>
<td>0 credits</td>
<td></td>
<td>D. Possamai</td>
</tr>
<tr>
<td>Target audience</td>
<td>Third year Bachelor students; Master students who cannot document to have received an adequate training in working scientifically.</td>
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<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Introduction to scientific writing for students with focus on publication standards and ethical issues, especially in the case of citations (references to works of others.)</td>
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<tr>
<td>Objective</td>
<td>Learn the basic standards of scientific works in mathematics.</td>
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</tr>
<tr>
<td>Content</td>
<td>- Types of mathematical works - Publication standards in pure and applied mathematics - Data handling - Ethical issues - Citation guidelines</td>
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</tr>
<tr>
<td>401-2000-01L</td>
<td>Lunch Sessions – Thesis Basics for Mathematics</td>
<td>Z</td>
<td>0 credits</td>
<td></td>
<td>Speakers</td>
</tr>
<tr>
<td>Students</td>
<td>Details and registration for the optional MathBib training course: <a href="https://www.math.ethz.ch/mathbib-schulungen">https://www.math.ethz.ch/mathbib-schulungen</a></td>
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<tr>
<td>Abstract</td>
<td>Optional MathBib training course</td>
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</tr>
<tr>
<td>402-2000-00L</td>
<td>Scientific Works in Physics</td>
<td>W</td>
<td>0 credits</td>
<td></td>
<td>D. Kienzler</td>
</tr>
<tr>
<td>Target audience</td>
<td>Master students who cannot document to have received an adequate training in working scientifically.</td>
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</tbody>
</table>
| Directive | https://www.ethz.ch/content/dam/ethz/common/docs/weis
Objective
Basic standards for scientific works in physics: How to write a Master Thesis. What to know about research integrity.

401-4990-01L Master's Thesis
Only students who fulfill the following criteria are permitted to commence the Master's thesis:

a. successful completion of the Bachelor's programme;

b. fulfilling of any additional requirements necessary to gain admission to the Master's programme;

c. successful completion of
   1) at least two course units in the category 'Core courses';
   2) at least five course units, including a seminar, in the category 'Fields of specialisation'; and
   3) the semester paper.

Successful participation in the course unit 401-2000-00L Scientific Works in Mathematics or 402-2000-00L Scientific Works in Physics is required.

 Approval via the form https://my.cse.ethz.ch/ is MANDATORY (caution: in myStudies all lecturers can be selected despite the fact that some of them are actually not authorised as supervisors).

Objective
The master's thesis concludes the study programme. Thesis work should prove the students' ability to independent, structured and scientific working.

Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>401-5650-00L</td>
<td>Zurich Colloquium in Applied and Computational Mathematics</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>R. Alaifari, H. Ammari, R. Hiptmair, S. Mishra, C. Schwab</td>
</tr>
</tbody>
</table>

Objective
The master's thesis concludes the study programme. Thesis work should prove the students' ability to independent, structured and scientific working.

Course Units for Additional Admission Requirements
The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-0363-AAL</td>
<td>Analysis III</td>
<td>E-</td>
<td>4</td>
<td>9R</td>
<td>A. Iozzi</td>
</tr>
</tbody>
</table>

Abstract
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective
Mathematical treatment of problems in science and engineering. To understand the properties of the different types of partial differential equations.

Content
Laplace Transforms:
- Laplace Transform, Inverse Laplace Transform, Linearity, s-Shifting
- Transforms of Derivatives and Integrals, ODEs
- Unit Step Function, t-Shifting
- Short Impulses, Dirac's Delta Function, Partial Fractions
- Convolution, Integral Equations
- Differentiation and Integration of Transforms

Fourier Series, Integrals and Transforms:
- Fourier Series
- Functions of Any Period p=2L
- Even and Odd Functions, Half-Range Expansions
- Forced Oscillations
- Approximation by Trigonometric Polynomials
- Fourier Integral
- Fourier Cosine and Sine Transform

Partial Differential Equations:
- Basic Concepts
- Modeling: Vibrating String, Wave Equation
- Solution by separation of variables; use of Fourier series
- D'Alembert Solution of Wave Equation, Characteristics
- Heat Equation: Solution by Fourier Series
- Heat Equation: Solutions by Fourier Integrals and Transforms
- Modeling Membrane: Two Dimensional Wave Equation
- Laplacian in Polar Coordinates; Circular Membrane, Fourier-Bessel Series
- Solution of PDEs by Laplace Transform
Literature


For reference/complement of the Analysis I/II courses:

Prerequisites / notice

Up-to-date information about this course can be found at:
http://www.math.ethz.ch/education/bachelor/lectures/hs2013/other/analysis3_itet

Competencies

406-0603-AAL Stochastics (Probability and Statistics) E- 4 credits 9R M. Kalisch
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

Objective

The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

Content

From "Statistics for research" (online)
Ch 1: The Role of Statistics
Ch 2: Populations, Samples, and Probability Distributions
Ch 3: Binomial Distributions
Ch 6: Sampling Distribution of Averages
Ch 7: Normal Distributions
Ch 8: Student’s t Distribution
Ch 9: Distributions of Two Variables

From "Introductory Statistics with R" (online)
Ch 1: Basics
Ch 2: The R Environment
Ch 3: Probability and distributions
Ch 4: Descriptive statistics and tables
Ch 5: One- and two-sample tests
Ch 6: Regression and correlation

Literature

- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
  From within the ETH, this book is freely available online under:

  From within the ETH, this book is freely available online under:
  http://www.springerlink.com/content/m17578/

Competencies

401-2673-AAL Numerical Methods for CSE E- 9 credits 19R not available
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

The course gives an introduction into fundamental techniques and algorithms of numerical mathematics which play a central role in numerical simulations in science and technology. The course focuses on fundamental ideas and algorithmic aspects of numerical methods. The exercises involve actual implementation of numerical methods in C++.

Objective

* Knowledge of the fundamental algorithms in numerical mathematics
* Knowledge of the essential terms in numerical mathematics and the techniques used for the analysis of numerical algorithms
* Ability to choose the appropriate numerical method for concrete problems
* Ability to interpret numerical results
* Ability to implement numerical algorithms efficiently
Content
* Direct Methods for linear systems of equations
* Least Squares Techniques
* Data Interpolation and Fitting
* Filtering Algorithms
* Approximation of Functions
* Numerical Quadrature
* Iterative Methods for non-linear systems of equations

Lecture notes
Lecture materials (PDF documents and codes) will be made available to participants.

Literature


M. Hanke-Bourgeois "Grundlagen der Numerischen Mathematik und des wissenschaftlichen Rechnens", BG Teubner, 2002

P. Deuflhard and A. Hohmann, "Numerische Mathematik I", DeGruyter, 2002

Prerequisites / notice
Solid knowledge about fundamental concepts and techniques from linear algebra & calculus as taught in the first year of science and engineering curricula.

The course will be accompanied by programming exercises in C++ relying on the template library EIGEN. Familiarity with C++, object oriented and generic programming is an advantage. Participants of the course are expected to learn C++ by themselves.

401-0674-AAL
Numerical Methods for Partial Differential Equations
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Derivation, properties, and implementation of fundamental numerical methods for a few key partial differential equations: convection-diffusion, heat equation, wave equation, conservation laws. Implementation in C++ based on a finite element library.

Objective
Main skills to be acquired in this course:
* Ability to implement fundamental numerical methods for the solution of partial differential equations efficiently.
* Ability to modify and adapt numerical algorithms guided by awareness of their mathematical foundations.
* Ability to select and assess numerical methods in light of the predictions of theory
* Ability to identify features of a PDE (= partial differential equation) based model that are relevant for the selection and performance of a numerical algorithm.
* Ability to understand research publications on theoretical and practical aspects of numerical methods for partial differential equations.
* Skills in the efficient implementation of finite element methods on unstructured meshes.

This course is neither a course on the mathematical foundations and numerical analysis of methods nor an course that merely teaches recipes and how to apply software packages.
Content
1 Case Study: A Two-point Boundary Value Problem [optional]
1.1 Introduction
1.2 A model problem
1.3 Variational approach
1.4 Simplified model
1.5 Discretization
1.5.1 Galerkin discretization
1.5.2 Collocation [optional]
1.5.3 Finite differences
1.6 Convergence
2 Second-order Scalar Elliptic Boundary Value Problems
2.1 Equilibrium models
2.1.1 Taut membrane
2.1.2 Electrostatic fields
2.1.3 Quadratic minimization problems
2.2 Sobolev spaces
2.3 Variational formulations
2.4 Equilibrium models: Boundary value problems
3 Finite Element Methods (FEM)
3.1 Galerkin discretization
3.2 Case study: Triangular linear FEM in two dimensions
3.3 Building blocks of general FEM
3.4 Lagrangian FEM
3.4.1 Simplicial Lagrangian FEM
3.4.2 Tensor-product Lagrangian FEM
3.5 Implementation of FEM in C++
3.5.1 Mesh file format (Gmsh)
3.5.2 Mesh data structures (DUNE)
3.5.3 Assembly
3.5.4 Local computations and quadrature
3.5.5 Incorporation of essential boundary conditions
3.6 Parametric finite elements
3.6.1 Affine equivalence
3.6.2 Example: Quadrilateral Lagrangian finite elements
3.6.3 Transformation techniques
3.6.4 Boundary approximation
3.7 Linearization [optional]
4 Finite Differences (FD) and Finite Volume Methods (FV) [optional]
4.1 Finite differences
4.2 Finite volume methods (FVM)
5 Convergence and Accuracy
5.1 Galerkin error estimates
5.2 Empirical Convergence of FEM
5.3 Finite element error estimates
5.4 Elliptic regularity theory
5.5 Variational crimes
5.6 Duality techniques [optional]
5.7 Discrete maximum principle [optional]
6 2nd-Order Linear Evolution Problems
6.1 Parabolic initial-boundary value problems
6.1.1 Heat equation
6.1.2 Spatial variational formulation
6.1.3 Method of lines
6.1.4 Timestepping
6.1.5 Convergence
6.2 Wave equations [optional]
6.2.1 Vibrating membrane
6.2.2 Wave propagation
6.2.3 Method of lines
6.2.4 Timestepping
6.2.5 CFL-condition
6.3 Convection-Diffusion Problems [optional]
6.3.1 Heat conduction in a fluid
6.3.1 Modelling fluid flow
6.3.2 Heat convection and diffusion
6.3.3 Incompressible fluids
6.3.4 Transient heat conduction
6.3.5 Stationary convection-diffusion problems
6.3.6 Singular perturbation
6.3.7 Upwinding
6.3.8 Transient convection-diffusion BVP
6.3.9 Method of lines
6.3.10 Transport equation
6.3.11 Lagrangian split-step method
6.3.12 Semi-Lagrangian method
6.4 Conservation laws: Examples
6.4.1 Conservation laws in 1D
6.4.2 Conservative finite volume discretization
6.4.3 Semi-discrete conservation form
6.5 Higher order conservative schemes [optional]
6.5.1 Slope limiting
8.5.2 MUSCL scheme
8.6. FV-schemes for systems of conservation laws [optional]

"optional" indicates that the corresponding topic might be skipped depending on the progress of the course.

Lecture notes
The lecture will be taught in flipped classroom format:
- Video tutorials for all thematic units will be published online.
- Solution of homework problems will be covered by video tutorials.
- Lecture documents and tablet notes accompanying the videos will be made available to the audience as PDF.

Literature
Chapters of the following books provide supplementary reading
(detailed references in course material):

However, study of supplementary literature is not important for following the course.

Prerequisites / notice
Mastery of basic calculus and linear algebra is taken for granted.
Familiarity with fundamental numerical methods (solution methods for linear systems of equations, interpolation, approximation, numerical quadrature, numerical integration of ODEs) is essential.

Important: Coding skills and experience in C++ are essential.

Homework assignments involve substantial coding, partly based on a C++ finite element library. The written examination will be computer based and will comprise coding tasks.

### Computational Science and Engineering Master - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

### Key for Hours

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

### ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
There is no required textbook, but an excellent reference is Steve Lavalle's book on "Planning Algorithms."

Abstract
This course is a hands-on introduction to self-driving cars using the Duckietown platform.

Objective
This course includes the basics of modeling, perception, planning, control, and learning for self-driving cars. The focus is on the integration and co-design of components and behaviors rather than algorithmic dept.

Content
Perception, planning, modeling, and control, leveraging primarily on vision data.

Literature
Course notes, primarily in the form of slides and tutorials, will be accessible from Moodle. Additional materials can also be accessed from the EdX MOOC called "Self-driving cars with Duckietown".

Prerequisites / notice
Students should have taken a basic course in probability theory, computer vision, and control systems, and should be familiar and comfortable with programming (Python), Linux, and Git utilization.

In introduction to ROS will be given, but it's strongly advised that students have prior exposure to and experience with ROS to effectively navigate through the homework assignments and the final project.

A shared space will be available to work with the robots.

Comprehensibility
It's advised students will have ~5 square meters of free space at their place to work with their assigned robot.

Competencies
Subject-specific Competencies
Concepts and Theories assessed

Method-specific Competencies
Techniques and Technologies assessed

Social Competencies
Communication fostered

Personal Competencies
Adaptability and Flexibility fostered

Student Competencies
Creative Thinking assessed

Method-specific Competencies
Problem-solving assessed

Student Competencies
Critical Thinking assessed

Abstract
Planning safe and efficient motions for robots in complex environments, often shared with humans and other robots, is a difficult problem combining discrete and continuous mathematics, as well as probabilistic, game-theoretic, and ethical/regulatory aspects. This course will cover the algorithmic foundations of motion planning, with an eye to real-world implementation issues.

Objective
The students will learn how to design and implement state-of-the-art algorithms for planning the motion of robots executing challenging tasks in complex environments.

Content

Lecture notes
Course notes and other education material will be provided for free in an electronic form.

Abstract
Model predictive control (MPC) has established itself as a powerful control technique for complex systems under state and input constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

Objective
Design, implement, and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.

Content
Topics include:
- Nominal MPC for uncertain systems (nominal robustness)
- Robust MPC
- Stochastic MPC
- Review of regression methods
- Set-membership Identification and robust data-driven MPC
- Bayesian regression and stochastic data-driven MPC
- MPC as safety filter for reinforcement learning
Lecture notes will be provided.

**Prerequisites / notice**

Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control in Spring Semester) strongly recommended.

Background in linear algebra and stochastic systems recommended.

### 151-0509-00L Acoustics in Fluid Media: From Robotics to Additive Manufacturing

**Credits:** 4

**Type:** W

**Lecturers:** D. Ahmed

**Abstract**
The course will provide you with the fundamentals of the new and exciting field of ultrasound-based microrobots to treat various diseases. Furthermore, we will explore how ultrasound can be used in additive manufacturing for tissue constructs and robotics.

**Objective**
The course is designed to equip students with skills in the design and development of ultrasound-based manipulation devices and microrobots for applications in medicine and additive manufacturing.

**Content**
Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobots to surface acoustic wave devices

**Lecture notes**

**Literature**

---

**Competencies**

- Subject-specific Competencies:
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- Method-specific Competencies:
  - Analytical Competencies: assessed
  - Decision-making: fostered
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: fostered

- Social Competencies:
  - Communication: assessed
  - Cooperation and Teamwork: assessed
  - Customer Orientation: fostered
  - Leadership and Responsibility: fostered
  - Self-presentation and Social Influence: assessed
  - Sensitivity to Diversity: fostered
  - Negotiation: fostered

- Personal Competencies:
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-direction and Self-management: assessed

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### 151-0532-00L Nonlinear Dynamics and Chaos I

**Credits:** 4

**Type:** W

**Lecturers:** G. Haller

**Abstract**
Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

**Objective**
This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.

**Content**
(1) Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.

(2) Near equilibrium dynamics: Linear and Lyapunov stability

(3) Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations

(4) Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.

(5) Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

**Lecture notes**
The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

**Prerequisites / notice**
- Prerequisites: Analysis, linear algebra and a basic course in differential equations.

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### 151-0563-01L Dynamic Programming and Optimal Control

**Credits:** 4

**Type:** W

**Lecturers:** R. D’Andrea

**Abstract**
Introduction to Dynamic Programming and Optimal Control.

**Objective**
Covers the fundamental concepts of Dynamic Programming & Optimal Control.

**Content**
Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

**Literature**

**Prerequisites / notice**
- Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

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### 151-0593-00L Embedded Control Systems

**Credits:** 4

**Type:** W

**Lecturers:** C. Onder, M. Schmid Daners

**Abstract**
This course provides a comprehensive overview of embedded control systems. The concepts introduced are implemented and verified on a microprocessor-controlled haptic device.

**Objective**
Familiarize students with main architectural principles and concepts of embedded control systems.
An embedded system is a microprocessor used as a component in another piece of technology, such as cell phones or automobiles. In this intensive two-week block course the students are presented the principles of embedded digital control systems using a haptic device as an example for a mechatronic system. A haptic interface allows for a human to interact with a computer through the sense of touch.

Subjects covered in lectures and practical lab exercises include:
- The application of C-programming on a microprocessor
- Digital I/O and serial communication
- Quadrature decoding for wheel position sensing
- Queued analog-to-digital conversion to interface with the analog world
- Pulse width modulation
- Timer interrupts to create sampling time intervals
- System dynamics and virtual worlds with haptic feedback
- Introduction to rapid prototyping

Prerequisite courses are Control Systems I and Informatics I.

This course is restricted to 33 students due to limited lab infrastructure. Interested students please contact Marianne Schmid Daners (E-Mail: marischm@ethz.ch)

After your reservation has been confirmed please register online at www.mystudies.ethz.ch.

Detailed information can be found on the course website http://www.idsc.ethz.ch/education/lectures/embedded-control-systems.html

151-0604-00L  Microrobotics  W  4 credits  3G  B. Nelson

Abstract
Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Objective
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

Content
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microrobots

Lecture notes
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

Prerequisites / notice
The lecture will be taught in English.

151-0615-00L  Real-World Robotics - A Hands-On Project Class  W  4 credits  9A  R. Katzschmann

Abstract
During this course, the students will develop an articulated robotic hand to solve a real-world robotic challenge, where the robot has to perform object grasping. The students will learn the key theoretical concepts required to model, manufacture, control and test their robot, alongside developing the programming, hardware and engineering skills through the hands-on project.

Objective
Learning Objective 1: High-Level System Design
System and product design combined with requirement generation and verification are essential for this robotics project. The students will apply previously acquired system design knowledge and methods to a hands-on challenge.

Learning Objective 2: Robot Design and Simulation
Students will gain experience implementing and simulating robotic systems using modern design, modelling, and simulation techniques such as CAD and Isaac Gym. These techniques are essential in any design process to understand the expected system behaviour. This requires a thorough understanding of the system’s kinematics, dynamics, material, actuation principle, and physical limitations. Students will learn the theory and limitations behind modelling and simulation software.

Learning Objective 3: Robot Fabrication
Students will learn to use the previously designed CAD models for successful robot fabrication. Additionally, the iterative nature of the process will allow them to develop their critical thinking skills in assessing the limitations of their design as well as possible sources for improvements. Building the robot will equip students with essential skills for using robots in the real world.

Learning Objective 4: Control, Integration, and Testing
Students can directly apply the knowledge acquired in their baseline control courses. They will gain theoretical knowledge on how to model and develop intelligent control algorithms. Perception methods and alternative machine-learning techniques will be taught. They will gain experience in testing their robots’ performance in both hard- and software to enhance their design and suggest future improvements.

Learning Objective 5: Robot production
Students will learn how to choose between state-of-the-art industrial production processes to manufacture a soft robot, by understanding their limitations and requirements. They will also learn how to optimize the robot design to account for a specific production process.
Content

During this course, the students will be divided into teams and each group will independently develop an articulated robotic arm to solve a real-world robotic challenge, which will take place at the end of the course. The students will learn the key theoretical concepts required to model, manufacture, control, and test a soft robot, along with developing the programming, hardware and engineering skills through hands-on workshops.

This course is composed of tutorials, which will be available on the course website where the lecturer will provide all the necessary theoretical input, focus talks where robotic experts will present a particular aspect of the manipulator in detail, and workshops where the students will have the possibility to hands-on learn how to implement the solutions required to solve their challenge. Finally, there will be time slots to autonomously work on the manufacturing and development of the team's robot and an online forum will be available to help the students throughout the entire course.

This course is divided into 5 parts:

<table>
<thead>
<tr>
<th>Part 1: Challenge introduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Identify the functional requirements necessary for the final challenge</td>
</tr>
<tr>
<td>- Evaluate the existing manipulator designs to optimize them for the specific task</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 2: Robot Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Develop a CAD model based on the high-level system design.</td>
</tr>
<tr>
<td>- Integrate motors, pneumatics components and other required materials in the design</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 3: Robot Fabrication</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Come up with a fabrication method and plan using the presented fabrication skills.</td>
</tr>
<tr>
<td>- Fabricate the robot and its actuators based on the CAD model.</td>
</tr>
<tr>
<td>- Evaluate, modify, and enhance the fabrication approach.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 4: Soft Robot Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Simulate the soft manipulator through a simulation framework</td>
</tr>
<tr>
<td>- Optimize the simulation parameters to reflect the experimental setup</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 5: Control, Integration, and Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Formulate the dynamic skills needed for real-life application.</td>
</tr>
<tr>
<td>- Develop traditional and learning-based control algorithms and test them in simulation.</td>
</tr>
<tr>
<td>- Integrate controller design into the fabricated robot.</td>
</tr>
<tr>
<td>- Build, test, fail, and repeat until the soft robot works as desired in simple tasks.</td>
</tr>
<tr>
<td>- Upgrade and validate the robot for performance in real-world conditions and verify requirements.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 6: Product development</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Propose a manufacturing process to bring the robot from a prototype to the final product</td>
</tr>
<tr>
<td>- Optimize the robot for production</td>
</tr>
</tbody>
</table>

Lecture notes

All class materials, including slides, tutorials, and supporting literature can be found on the class webpage (rwr.ifi.uzh.ch) and on Moodle, supported by discussion and Q&A forums. Focus talks, Q&A sessions, and workshops will happen on Monday between 14:00 and 16:00.

Literature


Prerequisites / notice

Students are expected to have attended introductory courses in dynamics, control systems and robotics.

The registration to this course is limited to 40 students. For this reason, it is required to apply through the following module:

https://forms.gle/1XfKdKrHra7bmAek8

The graded semester performance consists of the final team performance in the class challenge, a final team presentation and report, weekly Moodle quizzes, and attendance at the focus talks and workshops.

Competencies

<table>
<thead>
<tr>
<th>Competency Type</th>
<th>Competency</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Project Management</td>
<td>assessed</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
</tbody>
</table>

15-0632-00L Vision Algorithms for Mobile Robotics (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: DINF2039

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.s.html

Abstract

For a robot to be autonomous, it has to perceive and understand the world around it. This course introduces you to the key computer vision algorithms used in mobile robotics, such as feature extraction, structure from motion, dense reconstruction, tracking, image retrieval, event-based vision, and visual-inertial odometry (the algorithms behind Hololens, Oculus Quest, and the NASA Mars rovers).

Objective

Learn the fundamental computer vision algorithms used in mobile robotics, in particular: filtering, feature extraction, structure from motion, multiple view geometry, dense reconstruction, tracking, image retrieval, event-based vision, and visual-inertial odometry and Simultaneous Localization And Mapping (SLAM) (the algorithms behind Hololens, Facebook-Oculus Quest, and the NASA Mars rovers).

Content

Each lecture will be followed by a lab session where you will learn to implement a building block of a visual odometry algorithm in Matlab.

By the end of the course, you will integrate all these building blocks into a working visual odometry algorithm.

Lecture notes

Lecture slides will be made available on the course official website: http://rpg.ifi.uzh.ch/teaching.html
Applied Category Theory is an exciting multidisciplinary field of research which harnesses the mathematical language of category theory for applications across a broad range of disciplines. This course is a gentle introduction focused on applications in engineering and the “compositional approach” to systems analysis, co-design, and computation.

1. Learn basic concepts from algebra and category theory, together with ways to make use of these concepts for engineering applications.
2. Become familiar with case studies of applied category theory, for instance involving dynamical systems, databases, and complex system co-design (e.g. in the context of autonomous vehicles).
3. Be able to recognize compositional structures in concrete scenarios at different levels of abstraction.
4. Understand the “compositional way of thinking” as an approach to systems analysis, co-design, and computation.

Note: If you are interested in taking UZH courses, you must register as an incoming mobility student at UZH. For details, see as follows:

UZH course enrollment for ETH student at University of Zurich (UZH) > Mobility within Switzerland – Incoming > Module Mobility: The easiest way to take individual modules/courses to supplement your studies at your home university is with module mobility. This option is not available to students who have dropped out of their home university or have been definitely excluded or banned from the relevant program > Application and Deadlines: Applications are submitted via the UZH application portal (https://www.uzh.ch/cmssl/en/studies/application/cohmobility.html)

Step-by-step guidelines on how ETH students can register for this course, are given on the official course website: https://rpg.ifi.uzh.ch/teaching.html

ATTENTION: When you book the course at UZH, you are automatically registered for the exam at UZH and you can unregister until the October deadline. After registering for the course, you as an ETH student need to check out your “UZH email account” to receive the related information from the lecturer.


Fundamentals of algebra, geometry, matrix calculus, and Matlab programming.

151-0851-00L Robot Dynamics 

**Abstract**

We will provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing.

**Objective**

The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems. The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

**Prerequisites / notice**

The contents of the following ETH Bachelor lectures or equivalent are assumed to be known: Mechanics and Dynamics, Control, Basics in Fluid Dynamics.

151-1116-00L Introduction to Aircraft and Car Aerodynamics

**Abstract**


**Objective**

An introduction to the basic principles and interrelationships of aircraft and automotive aerodynamics. To understand the basic relations of the origin of aerodynamic forces (e lift, drag). To quantify the aerodynamic forces for basic configurations of aircraft and car components. Illustration of the intrinsic problems and results using examples. Using experimental and theoretical methods to illustrate possibilities and limits.

**Prerequisites / notice**


**Lecture notes**

Preparation materials & slides are provided prior to each class

**Literature**

- Schlichting, H. und Truckenbrodt, E: Aerodynamik des Flugzeuges (Bd I und II), Springer Verlag, 1960

Vehicle Aerodynamics

151-9905-00L Applied Category Theory for Engineering I

**Abstract**

Applied Category Theory is an exciting multidisciplinary field of research which harnesses the mathematical language of category theory for applications across a broad range of disciplines. This course is a gentle introduction focused on applications in engineering and the “compositional approach” to systems analysis, co-design, and computation.

1. Learn basic concepts from algebra and category theory, together with ways to make use of these concepts for engineering applications.
2. Become familiar with case studies of applied category theory, for instance involving dynamical systems, databases, and complex system co-design (e.g. in the context of autonomous vehicles).
3. Be able to recognize compositional structures in concrete scenarios at different levels of abstraction.
4. Understand the “compositional way of thinking” as an approach to systems analysis, co-design, and computation.
Content

Review of basic algebraic structures [sets, relations, (semi)groups, monoids, actions, order theory]

Gentle introduction to category theory [series and parallel composition, feedback, actions, functors, universal properties]

Many simple applied examples illustrating concepts along the way. Extended examples from dynamical systems, databases, and systems co-design in engineering.

Homework will consist of 1) basic exercises to check one's understanding of core concepts, and 2) a choice between either A) coding exercises (in python) to learn how to implement concepts in software or B) further theory exercises to deepen mathematical understanding.

Homework will be graded on a schedule that allows some flexibility, and it will constitute 100% of the grade (no exam).

Lecture notes

Slides and a (work-in-progress) textbook for the course will be provided (A. Censi, J. Lorand, G. Zardini, "Applied Compositional Thinking for Engineers").

Literature


Supplementary references include the following books:

Fong, Spivak, “An invitation to applied category theory: Seven sketches in compositionality”

Spivak, “Category theory for the sciences”

Prerequisites / notice

A knowledge of algebra at the level of a bachelor's degree in engineering/computer science.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Method-specific Competencies

Analytical Competencies assessed
Problem-solving assessed
Social Competencies

Communication fostered
Personal Competencies

Creative Thinking assessed
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-direction and Self-management fostered

227-0102-00L Discrete Event Systems

W 6 credits 4G

L. Josipovic, L. Vanbever, R. Wattenhofer

Abstract

Introduction to discrete event systems. We start out by studying popular models of discrete event systems. Then we analyze discrete event systems from an average-case and from a worst-case perspective, and study verification. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Petri Nets.

Objective

Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by exploring the limits of what is computable and what is not. In doing so, we will consider three distinct models of computation which are often used to model discrete event systems: finite automata, push-down automata and Turing machines (ranked in terms of expressiveness power). In the second part of the course we analyze discrete event systems. We first examine discrete event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply continuous time markov chains and queueing theory for an understanding of the typical behavior of a system. Then we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queueing. In the last part of the course we introduce methods that allow to formally verify certain properties of Finite Automata and Petri Nets. These are some typical analysis questions we will look at: Do two given systems behave the same? Does a given system behave as intended? Does the system eventually enter a dangerous state?

Content

1. Regular Languages
2. Non-Regular Languages
3. Markov Chains
4. Stochastic Discrete Event Systems
5. Worst-Case Event Systems
6. Verification of Finite Automata
7. Petri Nets

Lecture notes

Available at https://disco.ethz.ch/courses/des/
An embedded system is a combination of hardware and software, either fixed in function or programmable, that is designed for a specific application scenario or for a specific task within a larger system. They are part of industrial machines such as agricultural and manufacturing equipment, automotive systems, medical equipment, household appliances, sensor networks, and the Internet of Things.

Understanding the specific requirements and problems that arise in embedded system applications.

Understanding the hardware structure of a microcontroller and an embedded system; memory architecture and memory map, internal and external peripherals, low-power and low-energy design as well as instruction sets and computational accelerators.

Understanding the firmware structure of a microcontroller and an embedded system; low-level instruction set, hardware-software interfaces, communication between components, embedded real-time operating systems, real-time scheduling, shared resources, low-power and low-energy programming as well as computational accelerators.

Using formal models and methods for designing and optimizing embedded systems.

Gaining experience with practical applications of the C programming language, embedded real-time operating systems, and debug functionalities of the associated design environment to design, implement, and verify embedded firmware.

Through project-based activities, students will gain substantial experience in applying the C programming language in the context of embedded systems. Projects will involve developing and implementing firmware, utilizing embedded real-time operating systems, and exploring the debugging functionalities within design environments. This hands-on approach aims to bridge the gap between theoretical knowledge and practical application, allowing students to experience the full lifecycle of embedded system development from design to implementation and verification.

Content

This lecture focuses on the design of embedded systems using formal models and methods.

Besides the theoretical lecture, the course contains laboratory sessions where students transfer the learned theoretical aspects into praxis by programming a microcontroller and interfacing it with sensors and actuators. Students will be exposed to a commercial microcontroller, and the development board extend with a custom-designed embedded systems educational platform.

Specifically, the following topics will be covered in the course: hardware and software structures of embedded systems, low-level instruction set, memory architecture and memory map, peripherals, hardware-software interfaces, communication between components, firmware design methodologies, firmware design using the C programming language, embedded real-time operating systems, real-time scheduling, shared resources, low-power, and low-energy designs well as computational accelerators.

Lecture notes

Lecture material, publications, exercise sheets, and laboratory documentation will be available on the course's Moodle page.
Prerequisites: Introductory course on power electronics is recommended.

Competencies
- Subject-specific Competencies: Concepts and Theories, assessed
- Method-specific Competencies: Analytical Competencies, assessed
- Personal Competencies: Critical Thinking, assessed

Abstract
Three-phase inverter systems are discussed related to voltage DC link inverter systems and the design of the main power components based on analytical calculations is explained.

Objective
- Stability and stabilization, observers, state and output feedback, separation principle.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Sufficient mathematical maturity, in particular in linear algebra, analysis.

Literature

Prerequisites / notice
- Stability and stabilization, observers, state and output feedback, separation principle.
- Sufficient mathematical maturity, in particular in linear algebra, analysis.

Competencies
- Subject-specific Competencies: Concepts and Theories, assessed
- Method-specific Competencies: Analytical Competencies, assessed
- Personal Competencies: Integrity and Work Ethics, assessed

Abstract
The course language is English.

Objective
- Ordinary differential equations, existence and uniqueness of solutions.
- Controlability and observability, duality. Time invariant systems treated as a special case.
- Controlability and observability, duality. Time invariant systems treated as a special case.

Content
- Linear spaces, normed linear spaces and Hilbert spaces.
- Controlability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

Literature
Sufficient mathematical maturity, in particular in linear algebra, analysis.

Prerequisites / notice
- Stability and stabilization, observers, state and output feedback, separation principle.
- Sufficient mathematical maturity, in particular in linear algebra, analysis.

Competencies
- Subject-specific Competencies: Concepts and Theories, assessed
- Method-specific Competencies: Analytical Competencies, assessed
- Personal Competencies: Creative Thinking, assessed

Abstract
- Linear spaces, normed linear spaces and Hilbert spaces.
- Controlability and observability, duality. Time invariant systems treated as a special case.

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- Stability and stabilization, observers, state and output feedback, separation principle.
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Competencies
- Subject-specific Competencies: Concepts and Theories, assessed
- Method-specific Competencies: Analytical Competencies, assessed
- Personal Competencies: Creative Thinking, assessed

Abstract
Three-phase inverter systems are discussed related to voltage DC link inverter systems and the design of the main power components based on analytical calculations is explained.

Objective
- Stability and stabilization, observers, state and output feedback, separation principle.
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Prerequisites / notice
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Sufficient mathematical maturity, in particular in linear algebra, analysis.

Prerequisites / notice
- Stability and stabilization, observers, state and output feedback, separation principle.
- Sufficient mathematical maturity, in particular in linear algebra, analysis.

Competencies
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- Stability and stabilization, observers, state and output feedback, separation principle.

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Prerequisites / notice
- Stability and stabilization, observers, state and output feedback, separation principle.
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Competencies
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- Method-specific Competencies: Analytical Competencies, assessed
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Prerequisites / notice
- Stability and stabilization, observers, state and output feedback, separation principle.
- Sufficient mathematical maturity, in particular in linear algebra, analysis.

Competencies
- Subject-specific Competencies: Concepts and Theories, assessed
- Method-specific Competencies: Analytical Competencies, assessed
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Three-phase inverter systems are discussed related to voltage DC link inverter systems and the design of the main power components based on analytical calculations is explained.

Objective
- Stability and stabilization, observers, state and output feedback, separation principle.
- Sufficient mathematical maturity, in particular in linear algebra, analysis.

Content
- Ordinary differential equations, existence and uniqueness of solutions.
- Controlability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.
**Abstract**
The goal of this course is understanding the stationary dependencies in electrical power systems. The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power networks.

**Objective**
The goal of this course is understanding the stationary dependencies in electrical power systems and the application of analysis tools in normal but also in faulty state.

**Content**
The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power grids. Approaches such as the Newton-Raphson algorithm applied to power flow equations, superposition technique for short-circuit analysis and symmetrical components are discussed as well as power flow computation techniques for distribution grids and state estimation.

**Lecture notes**
Lecture notes, Lecture slides are provided in PDF format.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concept and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods and Technologies</td>
<td>analyzed</td>
<td></td>
</tr>
<tr>
<td>Analytical Competencies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>fostered</td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>fostered</td>
<td></td>
</tr>
</tbody>
</table>

227-0560-00L **Computer Vision and Artificial Intelligence for Autonomous Cars** W 6 credits 3V+2P C. Sakaridis

Up until FS2022 offered as Deep Learning for Autonomous Driving

**Abstract**
This course introduces the core computer vision techniques and algorithms that autonomous cars use to perceive the semantics and geometry of their driving environment, localize themselves in it, and predict its dynamic evolution. Emphasis is placed on techniques tailored for real-world settings, such as multi-modal fusion, domain-adaptive and outlier-aware architectures, and multi-agent methods.

**Objective**
Students will learn about the fundamentals of autonomous cars and of the computer vision models and methods these cars use to analyze their environment and navigate themselves in it. Students will be presented with state-of-the-art representations and algorithms for semantic, geometric and temporal visual reasoning in automated driving and will gain hands-on experience in developing computer vision algorithms and architectures for solving such tasks.

After completing this course, students will be able to:
1. understand the operating principles of visual sensors in autonomous cars
2. differentiate between the core architectural paradigms and components of modern visual perception models and describe their logic and the role of their parameters
3. systematically categorize the main visual tasks related to automated driving and understand the primary representations and algorithms which are used for solving them
4. critically analyze and evaluate current research in the area of computer vision for autonomous cars
5. practically reproduce state-of-the-art computer vision methods in automated driving
6. independently develop new models for visual perception

**Content**
The content of the lectures consists in the following topics:

1. Fundamentals
   (a) Fundamentals of autonomous cars and their visual sensors
   (b) Fundamental computer vision architectures and algorithms for autonomous cars

2. Semantic perception
   (a) Semantic segmentation
   (b) Object detection
   (c) Instance segmentation and panoptic segmentation

3. Geometric perception and localization
   (a) Depth estimation
   (b) 3D reconstruction
   (c) Visual localization
   (d) Unimodal visual/lidar 3D object detection

4. Robust perception: multi-modal, multi-domain and multi-agent methods
   (a) Multi-modal 2D and 3D object detection
   (b) Visual grounding and verbo-visual fusion
   (c) Domain-adaptive and outlier-aware semantic perception
   (d) Vehicle-to-vehicle communication for perception

5. Temporal perception
   (a) Multiple object tracking
   (b) Motion prediction

The practical projects involve implementing complex computer vision architectures and algorithms and applying them to real-world, multi-modal driving datasets. In particular, students will develop models and algorithms for:
1. Semantic segmentation and depth estimation
2. Sensor calibration for multi-modal 3D driving datasets
3. 3D object detection using lidars
4. Robust perception: multi-modal, multi-domain and multi-agent methods
5. Temporal perception
6. independently develop new models for visual perception

**Lecture notes**
Lecture slides are provided in PDF format.

**Prerequisites / notice**
Students are expected to have a solid basic knowledge of linear algebra, multivariate calculus, and probability theory, and a basic background in computer vision and machine learning. All practical projects will require solid background in programming and will be based on Python and libraries of it such as PyTorch.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concept and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
<td>analyzed</td>
<td></td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>fostered</td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>fostered</td>
<td></td>
</tr>
</tbody>
</table>

| Method-specific Competencies  | Analytical Competencies | assessed |
|-------------------------------| Media and Digital Technologies | fostered |

| Social Competencies           | Communication | fostered |
|-------------------------------| Cooperation and Teamwork | fostered |

| Personal Competencies         | Creative Thinking | assessed |
|-------------------------------| Critical Thinking | assessed |
### System Identification
**Code**: 227-0689-00L  
**Type**: Lecture  
**Credits**: 4  
**Prerequisites**/notice: Control systems (227-0216-00L) or equivalent.

<table>
<thead>
<tr>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.</td>
</tr>
<tr>
<td>To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.</td>
</tr>
<tr>
<td>Literature</td>
</tr>
<tr>
<td>Closed-loop identification strategies. Trade-off between controller performance and information available for identification.</td>
</tr>
</tbody>
</table>

**References** will be given at the end of individual lectures.

"System Identification; Theory for the User"  

### Industrial Process Control
**Code**: 227-0697-00L  
**Type**: Lecture  
**Credits**: 4  
**Prerequisites**/notice: Control systems (227-0216-00L) or equivalent.

<table>
<thead>
<tr>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to industrial automation systems with application to the process industry, power generation as well as discrete manufacturing. General understanding of industrial automation systems in different industries. Purpose, architecture, technologies, application examples, current and future trends.</td>
</tr>
<tr>
<td>Analysis and design of open loop control problems: discrete automata, finite state machines, decision tables, and petri-nets. Practical analysis and design of closed-loop control for the process industry.</td>
</tr>
<tr>
<td>Automation Engineering: Application programming in IEC 61131-3 (ladder diagrams, function blocks, sequence control, structured text); PLC programming and simulation, process visualization and operation; engineering integration from sensors, cabling, topology design, function, visualization, diagnosis, to documentation; Industry standards (e.g. OPC, Profibus); Ergonomic design, safety (IEC61508) and availability, supervision and diagnosis.</td>
</tr>
<tr>
<td>Automation standards: Communication, Architecture, Engineering, dependable systems, functional safety, automation security. Extensive practical examples from different process industries, power generation, gas compressor control, and automotive manufacturing.</td>
</tr>
</tbody>
</table>

**References** will be given at the end of individual lectures.

### Advanced Machine Learning
**Code**: 252-0535-00L  
**Type**: Lecture  
**Credits**: 10  
**Prerequisites**/notice: Control systems (227-0216-00L) or equivalent.

<table>
<thead>
<tr>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.</td>
</tr>
<tr>
<td>Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.</td>
</tr>
<tr>
<td>The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.</td>
</tr>
</tbody>
</table>

**Topics covered in the lecture include:**
- Fundamentals: What is data? Bayesian Learning
- Computational learning theory
- Supervised learning: Ensembles: Bagging and Boosting
- Max Margin methods
- Neural networks
- Unsupervised learning: Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

**References** will be available via the course Moodle.


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In this seminar, recent papers of the pattern recognition and machine learning literature are presented and discussed. Possible topics cover the seminar "Advanced Topics in Machine Learning" familiarizes students with recent developments in pattern recognition and machine learning. Original articles have to be presented and critically reviewed. The students will learn how to structure a scientific presentation in English which covers the key ideas of a scientific paper. An important goal of the seminar presentation is to summarize the essential ideas of the paper in sufficient depth while omitting details which are not essential for the understanding of the work. The presentation style will play an important role and should reach the level of professional scientific presentations.

The seminar will cover a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from computer vision or bioinformatics - two fields, which relies more and more on machine learning methodology and statistical models. The seminar provides an introduction to the field of machine learning, emphasising the central role of the user in system design. Through detailed case studies, students will be introduced to different methods used to analyse the user experience and shown how these can inform the design of new interfaces, systems and technologies.

The goal of the course is that students should understand the principles of user-centred design and be able to apply these in practice. As well as understand the basic notions of Computational Design in a HCI context.

Objective
The seminar will introduce students to several methods of analysing the user experience, showing how these can be used at different stages of system development from requirements analysis through to usability testing.

Students will get experience of designing and carrying out user studies as well as analysing results. The course will also cover the basic principles of interaction design. Practical exercises related to touch and gesture-based interaction will be used to reinforce the concepts introduced in the lecture. To get students to further think beyond traditional system design, we will discuss issues related to ambient information and awareness.

Abstract
The goal is to get an in-depth understanding of actual problems and research topics in the field of computer vision as well as improve presentations and critical analysis skills.

Objective
This seminar covers advanced topics in computer vision, such as 3D reconstruction, image understanding, object detection, people tracking, motion prediction, and other related topics. Each time the course is offered, a collection of research papers is selected and each student presents one paper to the class and leads a discussion about the paper and related topics.

The seminar will cover a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from computer vision or bioinformatics - two fields, which relies more and more on machine learning methodology and statistical models.

Content
The seminar will cover a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from computer vision or bioinformatics - two fields, which relies more and more on machine learning methodology and statistical models.

This seminar covers advanced topics in computer vision, such as 3D reconstruction, image understanding, object detection, people tracking, motion prediction, and other related topics. Each time the course is offered, a collection of research papers is selected and each student presents one paper to the class and leads a discussion about the paper and related topics.

Prerequisites / notice
Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
This course focuses on the emerging, interdisciplinary field of physical human-robot interaction, bringing together themes from robotics, assessed

Physical Human Robot Interaction (pHRI)

The objective of this course is to give an introduction to the fundamentals of physical human-robot interaction, through lectures on the assessed

P. Wolf

Computer Vision

This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual assessed

P. Wolf

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Project Management

Communication

Cooperation and Teamwork

Creative Thinking

Critical Thinking

Integrity and Work Ethics

263-5902-00L

Computer Vision

W

8 credits

3V+1U+3A

M. Pollefeys, S. Tang, F. Yu

Abstract

The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective

The objectives of this course are:

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

Prerequisites /

It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

263-5905-00L

Mixed Reality

W

5 credits

3G+1A

Z. Bauer, C. Holz, M. Pollefeys

Abstract

The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human machine interaction, as well as gaming technology.

Objective

After attending this course, students will:

1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.

Content

The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including: Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introduction to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course will be student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/graphics/HMI research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

Prerequisites /

Prerequisites include:

- Good programming skills (C# / C++ / Java etc.)
- Computer graphics/vision experience: Students should have taken, at a minimum, Visual Computing. Higher level courses are recommended, such as Introduction to Computer Graphics, 3D Vision, Computer Vision.

376-1504-00L

Physical Human Robot Interaction (pHRl)

W

4 credits

2V+2U

O. Lambercy, P. Wolf

Abstract

This course focuses on the emerging, interdisciplinary field of physical human-robot interaction, bringing together themes from robotics, real-time control, human factors, haptics, virtual environments, interaction design and other fields to enable the development of human-oriented robotic systems.

Objective

The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab training. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and de- sign safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1) Identify critical human factors in physical human-robot interaction and use these to derive design requirements;
2) Compare and select mechatronic components that optimally fulfill the defined design requirements;
3) Derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;
4) Design control hardware and software and implement and test human-interactive control strategies on the physical setup;
5) Characterize and optimize such systems using both engineering and psychophysical evaluation metrics;
6) Investigate and optimize one aspect of the physical setup and convey and defend the gained insights in a technical presentation.

Content

This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in device design for humans such as transparency and stability analysis, safety hardware and procedures. The course is organized into lectures that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical human-robot interaction, laboratory sessions and lab visits.

Students will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. The hardware features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic paddle (https://relab.ethz.ch/downloads/open-hardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

Lecture notes

Will be distributed on Moodle before the lectures.
The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks. We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

Prerequisites / notice

Notice:
The registration is limited to 26 students
There are 4 credit points for this lecture.
The lecture will be held in English.
The students are expected to have basic control knowledge from previous courses.
http://www.relab.ethz.ch/education/courses/phri.html

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making fostered
Problem-solving assessed
Project Management assessed

Social Competencies

Communication assessed

Personal Competencies

Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking assessed
Self-direction and Self-management fostered

Literature


For further resources, please visit the websites mentioned in the lecture notes.

636-0007-00L

Computational Systems Biology W 6 credits 3V+2U J. Stelling

Abstract

Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

Objective

The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

Content

Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.
Any courses offered by the Departments of MAVT, ITET or INFK. Your tutor must agree to this choice.

151-0623-00L ETH Zurich Distinguished Seminar in Robotics, Systems and Controls  W  1 credit  1S  B. Nelson, M. Hutter, R. Katzschmann, C. Menon, R. Riener, R. Siegwart

Abstract This course consists of a series of seven lectures given by researchers who have distinguished themselves in the area of Robotics, Systems, and Controls.

Objective Obtain an overview of various topics in Robotics, Systems, and Controls from leaders in the field. Please see http://www.msr.ethz.ch/education/distinguished-seminar-in-robotics--systems--controls--151-0623-0.html for a list of upcoming lectures.

Content This course consists of a series of seven lectures given by researchers who have distinguished themselves in the area of Robotics, Systems, and Controls. MSc students in Robotics, Systems, and Controls are required to attend every lecture. Attendance will be monitored. If for some reason a student cannot attend one of the lectures, the student must select another ETH or University of Zurich seminar related to the field and submit a one page description of the seminar topic. Please see http://www.msr.ethz.ch/education/distinguished-seminar-in-robotics--systems--controls--151-0623-0.html for a suggestion of other lectures.

Prerequisites / notice Students are required to attend all seven lectures to obtain credit. If a student must miss a lecture then attendance at a related special lecture will be accepted that is reported in a one page summary of the attended lecture. No exceptions to this rule are allowed.

▲ Science in Perspective

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-MAVT

▲ Semester Project

Number Title Type ECTS Hours Lecturers
151-1014-00L Semester Project Robotics, Systems and Control O 8 credits 17A Professors

Abstract The subject of the Semester Project and the choice of the supervisor (ETH-professor) are to be approved in advance by the tutor.

Objective The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

▲ Industrial Internship

Number Title Type ECTS Hours Lecturers
151-1090-00L Industrial Internship O 8 credits external organisers

Abstract No registration required via myStudies.

Objective The main objective of the minimum twelve-week internship is to expose Master's students to the industrial work environment. The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

▲ Master's Thesis

Number Title Type ECTS Hours Lecturers
151-1016-00L Master's Thesis Robotics, Systems and Control O 30 credits 64D Professors

Abstract The Master's Thesis must be approved in advance by the tutor and is supervised by a professor of ETH Zurich or an adjunct faculty of RSC.

Objective The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem. The subject of the master's thesis, as well as the project plan and roadmap, are proposed by the tutor and further elaborated with the student.

Robotics, Systems and Control Master - Key for Type

<table>
<thead>
<tr>
<th></th>
<th>O</th>
<th>W+</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory</td>
<td>E-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eligible for credits</td>
<td>Dr</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Courses outside the curriculum

Suitable for doctorate
### Key for Hours

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**
- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
### Science, Technology, and Policy Master

#### Social Sciences

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

**Abstract**

This course teaches the basics of public opinion surveys. We start with the theoretical foundations of the formation of (public) opinion formation and ideology, then turn to the practical lessons of developing and implementing own surveys with a focus on causal inference via survey experiments. Finally, we give practical insights into the analysis of (complex) survey data.

**Objective**

The goals of this class are:
- to understand the basics of public opinion research
- to translate this theoretical knowledge into the practical design and implementation of surveys
- to make use of survey experiments for causal inference

At the end of the course, students should be able to use and evaluate public opinion data and design survey experiments to test policy-relevant questions.

<table>
<thead>
<tr>
<th>Number</th>
<th>Concepts, Theories, and Methods for Public Policy Analysis</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>860-0004-00L</td>
<td>ISTP-PhD students please register via the Study Administration.</td>
<td>O</td>
<td>4 credits</td>
<td>2S</td>
<td>T. Bernauer, S. Bechtold, E. K. Smith, I. Günther, D. Hangartner, V. Koubi, M. Leese, T. Schmidt, B. Steffen, E. Tilley, to be announced</td>
</tr>
</tbody>
</table>

**Abstract**

This course first provides a broad conceptual and historical perspective on technological and scientific innovation, and then focuses on different modes of policy analysis and their application to policy problems in various areas of activity.

**Objective**

This course picks up on the ISTP Cornerstone course in Science, Technology and Policy and goes into greater depth on issues covered in that course, as well as additional issues where science and technology are among the causes of societal challenges but can also help in finding solutions.

<table>
<thead>
<tr>
<th>Number</th>
<th>Colloquium Science, Technology, and Policy (HS)</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>860-0005-00L</td>
<td></td>
<td>O</td>
<td>1 credit</td>
<td>1K</td>
<td>T. Schmidt, T. Bernauer, E. Tilley</td>
</tr>
</tbody>
</table>

**Abstract**

Presentations by guest speakers from academia and practice/policy. Students are assigned to play a leading role in the discussion and write a report on the respective event.

**Objective**

Students obtain insights into different policy-related research fields and participate in scientific discussions.

<table>
<thead>
<tr>
<th>Number</th>
<th>Policy Analysis</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>860-0031-00L</td>
<td>Does not take place this semester.</td>
<td>O</td>
<td>4 credits</td>
<td>2V</td>
<td>B. Steffen, T. Schmidt, to be announced</td>
</tr>
</tbody>
</table>

**Abstract**

The course Policy Analysis 1 will introduce important concepts and methods for ex-ante policy analysis. It will mostly focus on the policy content (vis-à-vis the policy process). We will primarily discuss quantitative methods. The course will contain several practical assignments in which students have to apply the concepts and methods studied.

**Objective**

Students should gain the skill to perform policy analyses independently. To this end, students will be enabled to understand a policy problem and the rationale for policy intervention; to select appropriate impact categories and methods to address a policy problem through policy analysis; to assess policy alternatives, using various ex-ante policy analysis methods; and to communicate the results of the analysis.

<table>
<thead>
<tr>
<th>Number</th>
<th>Principles of Microeconomics</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0503-00L</td>
<td></td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Filippini</td>
</tr>
</tbody>
</table>

**Abstract**

The course introduces basic principles, problems and approaches of microeconomics. This provides the students with reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution.

**Objective**

The learning objectives of the course are:

1. Students must be able to discuss basic principles, problems and approaches in microeconomics.
2. Students can analyse and explain simple economic principles in a market using supply and demand graphs.
3. Students can contrast different market structures and describe firm and consumer behaviour.
4. Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole.
5. Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics.
6. Students can apply simple mathematical concepts on economic problems.
The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture "Principles of Microeconomics" is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.

Topics covered by the course are:
- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade

This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to everyday economic problems.

Prerequisites / notice
GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.

For students taking only the course 'Principles of Microeconomics' there is a shorter version of the same book:

Lecture notes
Lecture notes, exercises and reference material can be downloaded from Moodle.

Complementary:

Prerequisites / notice

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Content</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content</strong></td>
<td>The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture &quot;Principles of Microeconomics&quot; is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.</td>
<td>Gain a familiarity with foundational concepts and techniques in statistics and mathematics. The applied part of the course will focus on implementing these techniques in R, as well as the practical skills required to develop their own data based research projects.</td>
</tr>
</tbody>
</table>
| **Topics covered by the course are:** | - Supply and demand  
- Consumer demand: neoclassical and behavioural perspective  
- Cost of production: neoclassical and behavioural perspective  
- Welfare economics, deadweight losses  
- Governmental policies  
- Market failures, common resources and public goods  
- Public sector, tax system  
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)  
- International trade | Produce summaries of statistical analyses that non-specialists can understand. |

**Lecture notes**
Lecture notes, exercises and reference material can be downloaded from Moodle.

**Literature**

For students taking only the course 'Principles of Microeconomics' there is a shorter version of the same book:

**Prerequisites / notice**
GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.

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**Complementary:**

**Competencies**

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</table>
| **Subject-specific Competencies** | Concepts and Theories  
Techniques and Technologies | Produce summaries of statistical analyses that non-specialists can understand. |
| **Method-specific Competencies** | Analytical Competencies  
Decision-making  
Media and Digital Technologies  
Problem-solving  
Project Management | Produce summaries of statistical analyses that non-specialists can understand. |
| **Social Competencies** | Communication  
Cooperation and Teamwork  
Customer Orientation  
Leadership and Responsibility  
Self-presentation and Social Influence  
Sensitivity to Diversity  
Negotiation | Produce summaries of statistical analyses that non-specialists can understand. |
| **Personal Competencies** | Adaptability and Flexibility  
Creative Thinking  
Critical Thinking  
Integrity and Work Ethics  
Self-awareness and Self-reflection  
Self-direction and Self-management | Produce summaries of statistical analyses that non-specialists can understand. |

**860-0041-00L Data Analysis for Public Policy Research**

<table>
<thead>
<tr>
<th>Data Analysis for Public Policy Research</th>
<th>O 4 credits</th>
<th>ZV</th>
<th>E. K. Smith</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This course covers the necessary fundamentals for the use of statistics to understand policy. Theoretically the course will provide a survey of foundational concepts and techniques statistics and mathematics. The applied part of the course will focus on implementing these techniques in R, as well as the practical skills required to develop their own data based research projects.</td>
<td>Gain a familiarity with foundational concepts and techniques in statistics, and be able to apply these to new problems. Be comfortable independently conducting a variety of tasks in R, such as data cleaning, visualisation and analysis. Produce summaries of statistical analyses that non-specialists can understand.</td>
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<td><strong>Objective</strong></td>
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<tr>
<td><strong>Content</strong></td>
<td>The course introduces students to the necessary fundamentals of statistics, and its application, to understand policy. Theoretically the course will provide a survey of foundational concepts and techniques statistics and mathematics. The applied part of the course will focus on implementing these techniques in R, as well as developing the practical skills in the language required to be able to independently conduct data based research projects.</td>
<td>Produce summaries of statistical analyses that non-specialists can understand.</td>
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**Social Competencies**

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<th>Objective</th>
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</thead>
</table>
| **Communication**           | Cooperation and Teamwork  
Customer Orientation  
Leadership and Responsibility  
Self-presentation and Social Influence  
Sensitivity to Diversity  
Negotiation | Produce summaries of statistical analyses that non-specialists can understand. |

**363-0565-00L Principles of Macroeconomics**

<table>
<thead>
<tr>
<th>Principles of Macroeconomics</th>
<th>O 3 credits</th>
<th>ZV</th>
<th>J.-E. Sturm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?</td>
<td>This course introduces students to the necessary fundamentals of macroeconomics and explains their relevance to everyday economic problems.</td>
<td></td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer. Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>The course Moodle page contains announcements, course information and lecture slides.</td>
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This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filippini).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.

Public policies result from decision-making processes that take place within formal institutions of the state (parliament, government, public administration, courts). That is, policies are shaped by the characteristics of decision-making processes and the characteristics of public institutions and related actors (e.g. interest groups). In this course, students acquire the contextual knowledge for analyzing public policies. They learn why and how public policies and laws are developed, designed, and implemented at national and international levels, and what challenges arise in this regard.

Students learn about the structure of the study programme, the different types of courses and how to select courses within the various course categories.


course: 860-0001-00L

Public Institutions and Policy-Making Processes

Number of participants limited to 35.

Priority for Science, Technology, and Policy Master.

Abstract

Students acquire the contextual knowledge for analyzing public policies. They learn why and how public policies and laws are developed, designed, and implemented at national and international levels, and what challenges arise in this regard.

Objective

Public policies result from decision-making processes that take place within formal institutions of the state (parliament, government, public administration, courts). That is, policies are shaped by the characteristics of decision-making processes and the characteristics of public institutions and related actors (e.g. interest groups). In this course, students acquire the contextual knowledge for analyzing public policies. They learn why and how public policies and laws are developed, designed, and implemented at national and international levels, and what challenges arise in this regard. The course is organized in three modules. The first module (Stefan Bechtold) examines basic concepts and the role of law, law-making, and law enforcement in modern societies. The second module (Thomas Bernauer) deals with the functioning of legislatures, governments, and interest groups. The third module (Frank Schimmelfennig) focuses on the European Union and international organisations.

Content

Public policies result from decision-making processes that take place within formal institutions of the state (parliament, government, public administration, courts). That is, policies are shaped by the characteristics of decision-making processes and the characteristics of public institutions and related actors (e.g. interest groups). In this course, students acquire the contextual knowledge for analyzing public policies. They learn why and how public policies and laws are developed, designed, and implemented at national and international levels, and what challenges arise in this regard. The course is organized in three modules. The first module (Stefan Bechtold) examines basic concepts and the role of law, law-making, and law enforcement in modern societies. The second module (Thomas Bernauer) deals with the functioning of legislatures, governments, and interest groups. The third module (Frank Schimmelfennig) focuses on the European Union and international organisations.

Lecture notes

Course materials can be found on Moodle.

Literature

Readings can be found on Moodle.

Prerequisites / notice

This is a Master level course. The course is capped at 27 students, with ISTP Master students having priority.

MSc STP Introductory Day

The course gives an overview of the structure of the MSc STP programme and the content of the obligatory courses in social sciences.

Students learn about the structure of the study programme, the different types of courses and how to select courses within the various course categories.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Project Management

Communication

Cooperation and Teamwork

Customer Orientation

Leadership and Responsibility

Self-presentation and Social Influence

Sensitivity to Diversity

Negotiation

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

Social Competencies

Practical Competencies

Abstract

The course provides methods and tools for ecological evaluations dealing with nature conservation and landscape planning. It covers census methods, ecological criteria, indicators, indices and critically appraises objectivity and accuracy of the available methods, tools and procedures. Birds and plants are used as main example guiding through different case studies.

Objective

Students will be able to:

1) critically consider biological data books and local, regional, and national inventories;
2) evaluate the validity of ecological criteria used in decision making processes;
3) critically appraise the handling of ecological data and criteria used in the process of evaluation;
4) perform an ecological evaluation project from the field survey up to the decision making and planning.

Lecture notes

Powerpoint slides are available on the moodle page. Additional documents are handed out as copies.

Literature

Basic literature and references are listed on the webpage.

Minor in Natural Sciences and Engineering

Urbanization and Planning

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1453-00L</td>
<td>Ecological Assessment and Evaluation</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td>F. Knaus</td>
</tr>
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</table>
The course is organized in four parts. I start with the key observation that economic activity (both in terms of population density and productivity) is unevenly distributed in space. For instance, the share of the population living in urban centers is increasing globally, from 16% in 1900 and 50% in 2000 to about 68% by the year 2050 (UN, World Economic Prospects, 2014). The goal of the first part is then to understand the economic forces at play behind these trends, looking at the effects within and across urban areas. I will also discuss how natural or man-made geographical characteristics (e.g., rivers, mountains, borders, etc.) affect the development of such urban systems.

In the second part, I discuss the planning and pricing of transport networks, moving from simple local models to more complex transport models at a global scale. The key aspects include: the first and second best road pricing, the public provision of transport networks and the demographic effects of transport networks.

In the third part, I combine the previous two parts and analyze the interaction between urban systems and transport networks. Thereby, the main focus is to understand the economic mechanisms that can lead to a general equilibrium of all actors involved. However, as the study of the historical development of urban systems and transport networks provides interesting insights, I will discuss how their interaction in the past shapes today’s economic geography.

Finally, I broaden the scope of the course and explore related topics. There will be a particular emphasis on the relation between urban systems and fiscal federalism as well as environmental policies. Both aspects are important determinants of the contemporary developments of urban systems, and as such deserve our attention.

In general, this class focuses on the latest research developments in urban and regional economics, though it does not require prior knowledge in this field. It pays particular attention to economic approaches, which are based on theoretical frameworks with strong microfoundations and allow for precise policy recommendations.

More specifically upon completion of the course, students had their first experience with defining the service to be provided by infrastructure, developing and evaluating asset strategies, and converting them into programs / project portfolios. Establishing a monitoring program for an infrastructure system, and establishing basic rules and principles to ensure an infrastructure management organisation is running well.
The weekly lectures are structured as follows:

1. Introduction: An introduction to infrastructure management and the project.
2. Service: Determination of what service you are trying to provide with an infrastructure network is important in justifying the interventions you think are required and ensuring that investment decisions are aligned throughout an infrastructure management organisation. This lecture introduces the concept of service and connects it to measurable indicators.
3. Help session 1: This session provides time for your group to ask questions as you define the service you want your infrastructure network to provide.
4. Presentation 1: 4 groups will present their ideas on how they want their networks to provide service.
5. Interventions: Justifying the interventions you want to execute to ensure you continue to provide the defined service requires you to model deterioration, determining economically justifiable strategies and explain which interventions will be postponed if you can’t do all you would like. This lecture is focused on explaining the main principles behind each of these concepts.
6. Help session 2: This session provides time for your group to ask questions as you justify the interventions you want to execute on your infrastructure network over time and explain what you will postpone if you cannot do all of them.
7. Presentation 2: 4 groups will present how they have justified interventions and how they have selected the ones they would like to postpone if required.
8. Monitoring: To ensure you the infrastructure network is providing what you expect you need to monitor its performance and how projects are being done. This lecture is focused on the principles to ensure a monitoring system is set up that ensure that the infrastructure system is providing the expected service.
9. Help session 3: This session provides time for your group to ask questions on how to establish the monitoring systems for your infrastructure networks.
10. Presentation 3: 4 groups will present how they intended to monitor their systems and projects.
11. Organisation: Managing infrastructure only works well with great teams of people with great processes. This lecture focuses on the principles of ensuring a well function organisation and well-functioning processes.
12. Help session 4: This session provides time for your group to ask questions on how to ensure well-functioning organisations and well-functioning processes.
13. Presentation 4: 4 groups will present how they intended to ensure well-functioning organisations and well-functioning processes.

### Lecture notes
- The lecture materials consist of handouts and the slides.
- The lecture materials will be distributed via Moodle by the beginning of each lecture.
- The questions to be discussed in the discussion session will be distributed by the end of the day on the Monday before the discussion session.

### Literature
- Appropriate literature will be handed out when required via Moodle.

### Prerequisites / notice
- This course has no prerequisites.

### Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Assessed</th>
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<tbody>
<tr>
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</table>

### Abstract
The course content of the lecture Landscape Planning and Environmental Systems (103-0347-00 V) will be illustrated in practical GIS exercises (e.g. habitat modelling, land use change, ecosystem services, connectivity).

### Objective
- Practical application of theory from the lectures
- Quantitative assessment and evaluation of landscape characteristics
- Learning useful applications of GIS for landscape planning
- Developing landscape planning measures for practical case studies

### Content
- Applications of GIS in landscape planning
- Landscape analysis
- Landscape structural metrics
- Modelling habitats and land use change
- Calculating urban ecosystem services
- Ecological connectivity

### Literature
- A script and presentation slides for each exercise will be provided on Moodle.

### Prerequisites
- Basic GIS skills are strongly recommended.
Landscape Planning and Environmental Systems

Abstract
In the course, students learn about methods for the identification and measurement of landscape characteristics, as well as measures and policies for landscape planning. Landscape planning is put into the context of environmental systems (soil, water, air, climate, flora and fauna) and discussed with regard to socio-political questions of the future.

Objective
The aims of this course are:

1) To illustrate the concept of landscape planning, the economic relevance of landscape and nature in the context of the environmental systems (soil, water, air, climate, flora and fauna).
2) To show landscape planning as an integral information system for the coordination of different instruments by illustrating the aims, methods, instruments and their functions in landscape planning.
3) To show the importance of ecosystem services.
4) To learn basics about nature and landscape: Analysis and assessment of the complex interactions between landscape elements, effects of current and future land use (ecosystem goods and services, landscape functions).
5) To identify and measure the characteristics of landscape.
6) Learn how to use spatial data in landscape planning.

Content
In this course, the following topics are discussed:
- Definition of the concept of landscape
- Relevance of landscape planning
- Landscape metrics
- Landscape change
- Methods, instruments and aims of landscape planning (policy)
- Socio-political questions of the future
- Environmental systems, ecological connectivity
- Ecosystem services
- Urban landscape services
- Practice of landscape planning
- Use of GIS in landscape planning

Lecture notes
No script. The documentation, consisting of presentation slides are partly handed out and are provided for download on Moodle.

Prerequisites / notice
The contents of the course will be illustrated in the associated course 103-0347-01 U (Landscape Planning and Environmental Systems (GIS Exercises)) or in Project LAND within the Experimental and Computer Lab (for Environmental Engineers). A combination of courses is recommended.
Objective

Public transport is a key driver for making our cities more livable, clean and accessible, providing safe, and sustainable travel options for millions of people around the globe. Proper planning of public transport system also ensures that the system is competitive in terms of speed and cost. Public transport is a crucial asset, whose social, economic and environmental benefits extend beyond those who use it regularly; it reduces the amount of cars and road infrastructure in cities; reduces injuries and fatalities associated to car accidents, and gives transport accessibility to very large demographic groups.

Goal of the class is to understand the main characteristics and differences of public transport networks. Their various performance criteria based on various perspective and stakeholders. The most relevant decision making problems in a planning tactical and operational point of view

At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate possible improvements to existing networks of public transport and the management of those networks; optimize the use of resources in public transport.

General structure:
general introduction of transport, modes, technologies, system design and line planning for different situations, mathematical models for design and line planning timetabling and tactical planning, and related mathematical approaches operations, and quantitative support to operational problems, evaluation of public transport systems.

Content

Basics for line transport systems and networks
Passenger/Supply requirements for line operations
Objectives of system and network planning, from different perspectives and users, design dilemmas Conceptual concepts for passenger transport: long-distance, urban transport, regional, local transport

Planning process, from demand evaluation to line planning to timetables to operations
Matching demand and modes
Line planning techniques
Timetabling principles
Allocation of resources
Management of operations
Measures of realized operations
Improvements of existing services

Lecture notes

Lecture slides are provided.

Literature

Ceder, Avi: Public Transit Planning and Operation, CRC Press, 2015, ISBN 978-1466563919 (English)

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptable and Flexible
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

103-0317-00L Spatial Planning and Development

W 3 credits 2G D. Kaufmann, A. Kuitenbrouwer

Spatial Planning and Development

Only for master students, otherwise a special permission by the lecturer is required.

Abstract

The course deals with theoretical, methodological and practical foundations around the understanding and production of urban space. It discusses theoretical planning frameworks, and tasks of spatial planning at various scales, addresses current and future challenges of spatial development and reviews approaches for a sustainable development in Switzerland and beyond.
The overall aim of the course is to raise students’ awareness and curiosity about the aspects that guide and shape our environment. Through lectures, readings, discussions, and exercises, the course seeks to achieve this goal by accumulating crucial notions from both theoretical and practice-based examples, and applying such knowledge into tasks of spatial planning.

At the end of this course, students should feel empowered to critically engage with the teaching topic from a variety of approaches. By taking up the lecture, the students should be able to (a) analyse, interpret and reflect complex cross-scale tasks of spatial development and transformation, and to use their theoretical, methodical and professional knowledge to tackle them.

You as students will...

... assess present and future core challenges of spatial planning and development.
... discuss the role of spatial planning and development in shaping our living environment.
... differentiate the levels, scales and tasks of spatial planning instruments and processes.
... reflect on theoretical concepts and practical examples of decision-making of spatial tasks.
... identify and apply spatially relevant principles and systems for action-oriented planning and decision-making.
... acquire theoretical, methodological, practical know-how to examine, clarify, and solve tasks on spatial development

Content

Spatial development as a discipline deals with the development, (trans)formation, and arrangement of our urban environment. We simultaneously perceive and contribute to its transformation, making space the result of manifold intended and unintended changes. To mediate between different demands, interests and interventions of multiple actors, a forward-looking, evidence-based, and action-oriented planning is necessary. As guidance for future action, (spatial) planning has to be committed to the sustainable handling as well as just allocation of resources, in particular of the non-replicable resource land.

The course focuses on both theoretical concepts and practice-oriented approaches to gain knowledge and be equipped to address current issues in spatial planning and development. This is mirrored in the course’s structure made of both of lectures and exercises.

The lecture series introduces necessary key concepts and covers the following main topics:
- Drivers of spatial development, inward development, core tasks and current challenges for (spatial) planners.
- Interplay of formal and informal planning instruments across scales and actors.
- Differentiation urban typologies, their characteristics and challenges
- Types of spatial analysis and key figures
- Planning approaches and the (political) steering of spatial development.
- Types of processes and participation in spatial development.
- Approaches for planning complex urban situations
- Concepts for sustainable development

The exercises provide a framework for practical application of the learned theoretical concepts of spatial planning to real-life situations.

Lecture notes

A course will be set up on Moodle for the provision of lectures and documents, to upload group deliverables and to ask questions in a discussion Forum. All documents provided are exclusively available for use within this course.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Cooperation and Teamwork: fostered

Personal Competencies
- Critical Thinking: assessed
- Self-direction and Self-management: fostered

052-0707-00L Urban Design III

W 2 credits 2V H. Klumpner

F. T. Salva Rocha Franco

Objective

How can students of architecture become active agents of change? What does it take to go beyond a building’s scale, making design-relevant decisions to the city rather than a single client? How can we design in cities with a lack of land, tax base, risk, and resilience, understanding that Zurich is the exception and these other cities are the rule? How can we discover, set rather than follow trends and understand existing urban phenomena activating them in a design process? The lecture series produces a growing catalog of operational urban tools across the globe, considering Governance, Social, and Environmental realities. Instead of limited binary comparing of cities, we are building a catalog of change, analyzing what design solutions cities have been developing informally incrementally over time, why, and how. We look at the people, institutions, culture behind the design and make concepts behind these tools visible. Students get first-hand information from cities where the chair as a Team has researched, worked, or constructed projects over the last year, allowing competent, practical insight about the people and topics that make these places unique. Students will be able to use and expand an alternative repertoire of experiences and evidence-based design tools, go to the conceptual core of them, and understand how and to what extent they can be relevant in other places. Urban Stories is the basic practice of architecture and urban design. It introduces a repertoire of urban design instruments to the students to use, test, and start their designs.
Urban form cannot be reduced to physical space. Cities result from social construction, under the influence of technologies, ecology, culture, the impact of experts, and accidents. Urban un-concluded processes respond to political interests, economic pressure, cultural inclinations, along with the imagination of architects and urbanists and the informal powers at work in complex adaptive systems. Current urban phenomena are the result of urban evolution. The facts stored in urban environments include contributions from its entire lifecycle, visible in the physical environment, and non-physical aspects. This imaginary city exists along with its potentials and problems and with the conflicts that have evolved. Knowledge and understanding, along with a critical observation of the actions and policies, are necessary to understand the diversity and instability present in the contemporary city and understand how urban form evolved to its current state.

How did cities develop into the cities we live in now? Urban plans, instruments, visions, political decisions, economic reasonings, cultural inputs, and social organization have been used to operate in urban settlements in specific moments of change. We have chosen cities that exemplify how these instruments have been implemented and how they have shaped urban environments. We transcribe these instruments into urban operational tools that we have recognized and collected within existing tested cases in contemporary cities across the globe.

This lecture series will introduce urban knowledge and the way it has introduced urban models and operational modes within different concrete realities, therefore shaping cities. The lecture series translates urban knowledge into operational tools, extracted from cities where they have been tested and are most relevant for understanding how the urban landscape has taken shape. The tools are clustered in twelve thematic clusters and three tool scales for better comparability and cross-reflection.

The Tool case studies are compiled into a global urbanization toolbox, which we use as typological models to read the city and critically reflect upon it. The presented contents are meant to serve as inspiration for positioning in future professional life and provide instruments for future design decisions.

In an interview with a local designer, we measure our insights against the most pressing design topics in cities today, including inclusion, affordable housing, provision of public spaces, and infrastructure for all.

### Energy and Mobility

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<tr>
<th>Number</th>
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<tr>
<td>151-0216-00L</td>
<td>Wind Energy</td>
<td>W</td>
<td>4</td>
<td>2+1U</td>
<td>N. Chokani</td>
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<tr>
<td>Abstract</td>
<td>The objective of this course is to introduce the students to the fundamentals, technologies, modern day application, and economics of wind energy. These subjects are introduced through a discussion of the basic principles of wind energy generation and conversion, and a detailed description of the broad range of relevant technical, economic and environmental topics.</td>
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<tr>
<td>Content</td>
<td>This mechanical engineering course focuses on the technical aspects of wind turbines; non-technical issues are not within the scope of this technically oriented course. On completion of this course, the student shall be able to conduct the preliminary aerodynamic and structural design of the wind turbine blades. The student shall also be more aware of the broad context of drivetrains, dynamics and control, electrical systems, and meteorology, relevant to all types of wind turbines.</td>
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| 227-0731-00L | Power Market I - Portfolio and Risk Management | W    | 6    | 4G    | D. Reichelt, G. A. Koeppe |
| Abstract     | Portfolio and risk management in the electrical power business, Pan-European power market and trading, futures and forward contracts, hedging, options and derivatives, performance indicators for the risk management, modelling of physical assets, cross-border trading, ancillary services, balancing power market, Swiss market model. |
| Objective    | Knowledge on the worldwide liberalisation of electricity markets, pan-european power trading and the role of power exchanges. Understand financial products (derivatives) based on power. Management of a portfolio containing physical production, contracts and derivatives. Evaluate trading and hedging strategies. Apply methods and tools of risk management. |
The main objective of this course is to provide students with some basic tools to analyze the fundamental economic forces at play in urban systems and as such deserve our attention. Why do urban areas grow or decline? How do transport networks affect the location of individuals and firms? Does the location of a firm determine its productivity? Can transport infrastructure investments reduce economic disparities? These are some of the questions that students should be able to answer after having completed the course.

In the second part, I discuss the planning and pricing of transport networks, moving from simple local models to more complex transport models at a global scale. The key aspects include: the first and second best road pricing, the public provision of transport networks and the natural or man-made geographical characteristics (e.g., rivers, mountains, borders, etc.) affect the development of such urban systems.

In the third part, I combine the previous two parts and analyze the interaction between urban systems and transport networks. Thereby, the main focus is to understand the economic mechanisms that can lead to a general equilibrium of all actors involved. However, as the study of the historical development of urban systems and transport networks provides interesting insights, I will discuss how their interaction in the past shapes today’s economic geography.

Finally, I broaden the scope of the course and explore related topics. There will be a particular emphasis on the relation between urban systems and fiscal federalism as well as environmental policies. Both aspects are important determinants of the contemporary developments of urban systems, and as such deserve our attention.

In general, this class focuses on the latest research developments in urban and regional economics, though it does not require prior knowledge in this field. It pays particular attention to economic approaches, which are based on theoretical frameworks with strong micro-foundations and allow for precise policy recommendations.
**Abstract**
Physical fundamentals of the fission reaction and the sustainable chain reaction, thermal design, construction, function and operation of nuclear reactors and power plants, light water reactors and other reactor types, conversion and breeding.

**Objective**
Students get an overview on energy conversion in nuclear power plants, on construction and function of the most important types of nuclear reactors with special emphasis to light water reactors. They obtain the mathematical/physical basis for quantitative assessments concerning most relevant aspects of design, dynamic behaviour as well as material and energy flows.

**Content**
Nuclear physics of fission and chain reaction. Thermodynamics of nuclear reactors. Design of the reactor core. Introduction into the dynamic behaviour of nuclear reactors. Overview on types of nuclear reactors, difference between thermal reactors and fast breeders. Construction and operation of nuclear power plants with pressurized and boiling water reactors, role and function of the most important safety systems, special features of the energy conversion. Development tendencies of reactor technology.

**Lecture notes**
Hand-outs will be distributed. Additional literature and information on the website of the lab: https://www.ethz.ch/content/specialinterest/mavt/energy-technology/lab-of-nuclear-energy-systems/en/studium/teaching-materials/151-0163-00l-nuclear-energy-conversion.html

**Literature**

R. L. Murray: Nuclear Energy (Sixth Edition), An Introduction to the Concepts, Systems, and Applications of Nuclear Processes, Elsevier

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**151-1633-00L**
**Energy Conversion**

<table>
<thead>
<tr>
<th>W</th>
<th>4 credits</th>
<th>3G</th>
<th>I. Karlin, G. Sansavini, S. A. Hosseini</th>
</tr>
</thead>
</table>

**Abstract**
This course provides the students with an introduction to thermodynamics and energy conversion. Students shall gain basic understanding of energy and energy interactions as well as their link to energy conversion technologies.

**Objective**
Thermodynamics is key to understanding and use of energy conversion processes in Nature and technology. Main objective of this course is to give a compact introduction into basics of Thermodynamics: Thermodynamic states and thermodynamic processes; Work and Heat; First and Second Laws of Thermodynamics. Students shall learn how to use energy balance equation in the analysis of power cycles and shall be able to evaluate efficiency of internal combustion engines, gas turbines and steam power plants. The course shall extensively use thermodynamic charts to building up students' intuition about opportunities and restrictions to increase useful work output of energy conversion. Thermodynamic functions such as entropy, enthalpy and free enthalpy shall be used to understand chemical and phase equilibrium. The course also gives introduction to refrigeration cycles, combustion and refrigeration. The course compactly covers the standard course of thermodynamics for engineers, with additional topics of a general physics interest (nonideal gas equation of state and Joule-Thomson effect) also included.

In the course "Energy Conversion", the competencies of process understanding and system understanding are applied and examined and the competencies process understanding and modeling are taught.

**Content**
1. Thermodynamic systems, states and state variables
2. Properties of substances: Water, air and ideal gas
3. Energy conservation in closed and open systems: work, internal energy, heat and enthalpy
4. Second law of thermodynamics and entropy
5. Energy analysis of steam power cycles
6. Energy analysis of gas power cycles
7. Refrigeration and heat pump cycles
8. Nonideal gas equation of state and Joule-Thomson effect
9. Maximal work and exergy
10. Mixtures
11. Chemical reactions and combustion systems; chemical and phase equilibrium

**Lecture notes**
Lecture slides and supplementary documentation will be available online.

**Literature**

**Prerequisites / notice**
This course is intended for students outside of D-MAVT.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: fostered
  - Problem-solving: assessed
  - Project Management: fostered

- **Social Competencies**
  - Communication: fostered
  - Cooperation and Teamwork: fostered
  - Customer Orientation: fostered
  - Leadership and Responsibility: assessed
  - Self-presentation and Social Influence: fostered
  - Sensitivity to Diversity: fostered
  - Negotiation: fostered

- **Personal Competencies**
  - Adaptability and Flexibility: fostered
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: assessed

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**151-0567-00L**
**Engine Systems**

<table>
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<th>W</th>
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<th>C. Onder</th>
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**Abstract**
Introduction to current and future engine systems and their control systems

**Objective**
Introduction to methods of control and optimization of dynamic systems. Application to real engines. Understand the structure and behavior of drive train systems and their quantitative descriptions.

**Content**
Physical description and mathematical models of components and subsystems (mixture formation, load control, supercharging, emissions, drive train components, etc.) Case studies of model-based optimal design and control of engine systems with the goal of minimizing fuel consumption and emissions.

**Lecture notes**
Introduction to Modeling and Control of Internal Combustion Engine Systems

Guzzella Lino, Onder Christopher H.
ISBN: 978-3-642-10774-0

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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2260 of 2653
### Data and Computer Science

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<thead>
<tr>
<th>Number</th>
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<tr>
<td>263-3210-00L</td>
<td>Deep Learning</td>
<td>W</td>
<td>8</td>
<td>3V+2U+2A</td>
<td>T. Hofmann</td>
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#### Data and Computer Science

**Deep Learning**
- Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.
- In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.
- This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.
- The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:
- Advanced Machine Learning
  [https://ml2.inf.ethz.ch/courses/aml/](https://ml2.inf.ethz.ch/courses/aml/)
- Computational Intelligence Lab
- Introduction to Machine Learning
  [https://las.inf.ethz.ch/teaching/introml-S19](https://las.inf.ethz.ch/teaching/introml-S19)
- Statistical Learning Theory
  [http://ml2.inf.ethz.ch/courses/slt/](http://ml2.inf.ethz.ch/courses/slt/)
- Computational Statistics
- Probabilistic Artificial Intelligence
  [https://las.inf.ethz.ch/teaching/pai-f18](https://las.inf.ethz.ch/teaching/pai-f18)

**System Security**
- The first part of the course covers general security concepts and hardware-based support for security.
- In the second part, the focus is on system design and methodologies for building secure systems.
- In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.
The first part of the lecture covers hardware-based security concepts. Topics include the concept of physical and software-based side channel attacks on hardware resources, architectural support for security (e.g., memory management and permissions, disk encryption), and trusted execution environments (Intel SGX, ARM TrustZone, AMD SEV, and RISC-V Keystone).

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: common software faults (e.g., buffer overflows, etc.), bug-detection, writing secure software (design, architecture, QA, testing), compiler-supported security (e.g., control-flow integrity), and language-supported security (e.g., memory safety).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

<table>
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<tr>
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<td>Techniques and Technologies</td>
<td>Decision-making</td>
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263-4640-00L  Network Security  W   8 credits  2V+2U+3A  P. De Vaere, S. Frei, K. Paterson, A. Perrig

Abstract
Some of today’s most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems.
This course provides an in-depth study of network attack techniques and methods to defend against them.

Objective
- Students are familiar with fundamental network-security concepts.
- Students can implement network-security protocols based on cryptographic libraries.

Content
The course will cover topics spanning four broad themes with a focus on the first two themes:
1. network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students can implement network-security protocols based on cryptographic libraries.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

Prerequisites / notice
This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L.
Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.
The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

Competencies
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252-0535-00L  Advanced Machine Learning  W   10 credits  3V+2U+4A  C. Cotrini Jimenez

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

**Fundamentals:**
- What is data?
- Bayesian Learning
- Computational learning theory

**Supervised learning:**
- Ensembles: Bagging and Boosting
- Max Margin methods
- Neural networks

**Unsupervised learning:**
- Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution. PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

### 263-2400-00L

**Reliable and Trustworthy Artificial Intelligence**

**W** 6 credits  **2V+2U+1A**  **M. Vechev**

**Abstract**

Creating reliable, secure, robust, and fair machine learning models is a core challenge in artificial intelligence and one of fundamental importance. The goal of the course is to teach both the mathematical foundations of this new and emerging area as well as to introduce students to the latest and most exciting research in the space.

**Objective**

Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of engineering and research problems. To facilitate deeper understanding, the course includes a group coding project where students will build a system based on the learned material.

**Content**

Robustness of Machine Learning

- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

Privacy of Machine Learning

- Threat models (e.g., stealing data, poisoning, membership inference, etc.).
- Attacking federated machine learning (across vision, natural language and tabular data).
- Differential privacy for defending machine learning.
- AI Regulations and checking model compliance.

Fairness of Machine Learning

- Introduction to fairness (motivation, definitions).
- Enforcing individual fairness (for both vision and tabular data).
- Enforcing group fairness (e.g., demographic parity, equalized odds).

Robustness, Privacy and Fairness of Foundation Models

- We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).

**Prerequisites / notice**

While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in "Intro to ML" classes at most institutions (e.g., "Introduction to Machine Learning" at ETH).

The coding project will utilize Python and PyTorch. Thus some programming experience in Python is expected. Students without prior knowledge of PyTorch are expected to acquire it early in the course by solving exercise sheets.

The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.

**Objective**

The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in-depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.

**Content**

The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understanding these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

**Literature**

The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

**Prerequisites / notice**

The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

- **Method-specific Competencies**
  - Analytical Competencies
  - Problem-solving

- **Personal Competencies**
  - Creative Thinking
  - Critical Thinking

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**263-3845-00L Data Management Systems**

**Abstract**

The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.

**Objective**

The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in-depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.

**Content**

The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understanding these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

**Literature**

The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

**Prerequisites / notice**

The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

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**263-5902-00L Computer Vision**

**Abstract**

The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

**Objective**

The objectives of this course are:

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

**Content**

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

**Prerequisites / notice**

It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

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**252-3005-00L Natural Language Processing**

**Abstract**

This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

**Objective**

The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

**Content**

This course presents an introduction to general topics and techniques used to solve those. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

**Literature**

Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.
The course will be structured as half lecture content and half seminar content. Lectures will review state of the medical practice prior to the discovery, obstacles in moving the field forward, and the need for improvement. Lecture will be followed by the seminar part where students will take turns presenting the assigned publications and leading the discussions. Students' presentations will focus on the main findings, and specific steps taken to translate the finding into clinical practice.

Publications will include examples of:
- specific CS/bioinformatics/statistics applications that has been brought to "bedside" – has been approved by European Medicines Agency / Food and Drug Administration (USA) for clinical use or are widely used in medical research;
- examples of failures of how a discovery did not translate into an endproduct and why;
- current active research areas.

Covered topics will include some of the following:
- Drug discovery: Computer-aided drug discovery has become an integral part of the drug development process, enabling researchers to design and screen large libraries of molecules in silico (i.e., using computer simulations) before synthesizing and testing them in the lab. This has led to the discovery of new drug candidates for a wide range of diseases, including cancer, Alzheimer's disease, and HIV/AIDS.
- Genomics: Advances in computational genomics have enabled researchers to analyze and interpret large-scale genomic data, including DNA sequencing data, to identify disease-causing mutations, genetic risk factors, and drug targets. Examples of the development of personalized medicine, where treatments are tailored to an individual's genetic makeup. Examples when drug target identified by genetics has led to approved treatment.
- Imaging: Computer vision and image processing techniques have revolutionized medical imaging, enabling researchers to extract quantitative information from medical images that were previously inaccessible. This has led to the development of new diagnostic and prognostic tools for a wide range of diseases, including cancer, cardiovascular disease, and neurological disorders.
- Real-world data applications: emulation of clinical trials using electronic health records data.
- Large language models: Generating clinical trial protocols using large language models. Natural Language Processing for information extraction and interpretation.
- Learning healthcare systems: Advances in data analytics and information technology have enabled the development of learning healthcare systems, which use real-time data from electronic health records, medical devices, and other sources to improve patient outcomes and reduce healthcare costs. This has the potential to transform the way healthcare is delivered, making it more personalized, efficient, and effective.

In addition to the presentations, students will also be required to write critical reviews of the assigned publications throughout the course. The reviews will be evaluated based on the students' ability to identify the strengths and weaknesses of the publications and to provide insightful and constructive feedback.

Prerequisites / notice
- The course is intended for advanced undergraduate and graduate students with a background in computer science, bioinformatics, or a related field and interest in applying their skills to medical research.
- This course assumes a working knowledge of R/Python and intermediate statistical analysis, including linear, logistic, survival regressions or ability and interest to learn them outside of the class.

Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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Life Science and Health

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<tr>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>376-0021-00L</td>
<td>Materials and Mechanics in Medicine</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>M. Zenobi-Wong, J. G. Snedeker</td>
</tr>
<tr>
<td>Abstract</td>
<td>Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.</td>
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<td>Objective</td>
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<tr>
<td>Content</td>
<td>Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.</td>
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<tr>
<td>Lecture notes</td>
<td>course website on Moodle</td>
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<tr>
<td>376-1103-00L</td>
<td>Frontiers in Nanotechnology</td>
<td>W</td>
<td>4</td>
<td>4V</td>
<td>V. Vogel, further lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers. Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within mammade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.</td>
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<tr>
<td>Objective</td>
<td>The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries. Each lecturer will first give an overview of the state-of-the-art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.</td>
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</table>
Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.

**376-1714-00L**  
**Biocompatible Materials**  
**W 4 credits 3V**  
K. Maniura, M. Rottmar, M. Zenobi-Wong

**Abstract**  
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

**Objective**  
The course covers the following topics:  
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.  
2. The concept of biocompatibility.  
3. Introduction into methodology used in biomaterials research and application.  
4. Introduction to different material classes in use for medical applications.

**Content**  
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Lecture notes**  
Handouts are deposited online (moodle).

**Literature**  

(available online via ETH library)

**376-0300-00L**  
**Essentials in Translational Science**  
**W 3 credits 2G**  
J. Goldhahn

**Abstract**  
Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people (e.g. Medicine). The course should help to clarify basics of translational science, illustrate successful applications and enable students to integrate key features into their future projects.

**Objective**  
After completing this course, students will be able to understand:  
Key steps of drug development and their interdependencies. Project management, communication & funding options. Students should be able to apply this knowledge in drug development programs in Pharma, Biotech or their own spin-off.

**Content**  
This lecture will guide you through drug development from bench to bedside and provide industry perspectives which support you in your first industry role or when building a startup. The course will integrate knowledge across the many disciplines which are required to develop new medicines which are transformational for patients.

Key steps of the Drug development process  
- Disease Biology and mechanism of action  
- Translation of ‘Mechanism of Action’ into patient and payer benefit  
- Drug design  
- Drug formulation  
- Toxicology  
- Pharmacokinetics & pharmacodynamics  
- Translational medicine  
- Clinical trials  
- Regulatory requirements  
- Patenting  
- Market access  

- How are these steps connected and impacting each other?

Positive and negative examples will be illustrated by distinguished guest speakers.

**Competencies**  
- Subject-specific Competencies: Concepts and Theories, assessed  
- Techniques and Technologies, fostered  
- Method-specific Competencies: Analytical Competencies, fostered  
- Decision-making, assessed  
- Problem-solving, assessed  
- Project Management, fostered  
- Social Competencies: Communication, fostered  
- Cooperation and Teamwork, fostered  
- Customer Orientation, fostered  
- Negotiation, fostered  
- Personal Competencies: Adaptability and Flexibility, fostered  
- Creative Thinking, fostered  
- Critical Thinking, fostered

**752-6105-00L**  
**Epidemiology and Prevention**  
**W 3 credits 2V**  
M. Puhan, R. Heusser

**Abstract**  
The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.

**Objective**  
The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.
The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

### 752-6151-00L Public Health Concepts

**Abstract**

The module "public health concepts" offers an introduction to key principles of public health. Students get acquainted with the concepts and methods of epidemiology. Students also learn to use epidemiological data for prevention and health promotion purposes. Public health concepts and intervention strategies are presented, using examples from infectious and chronic diseases.

**Objective**

At the end of this module students are able:
- to interpret the results of epidemiological studies
- to critically assess scientific literature
- to know the definition, dimensions and determinants of health
- to plan public health interventions and health promotion projects
- to draw a bridge from evidence to policies and politics

**Content**

Concepts of descriptive and analytical epidemiology, study designs, measures of effect, confounding and bias, screening, surveillance, definition of health and health promotion, health dimensions and health determinants, prevention strategies, public health interventions, public health action cycle, epidemiology and prevention of infectious and chronic diseases (HIV, COVID-19, Obesity, Iodine/PN nutrition).

**Lecture notes**

Handouts are provided to students in the classroom.

### 636-0109-00L Stem Cells: Biology and Therapeutic Manipulation

**Abstract**

Stem cells are central in tissue regeneration and repair, and hold great potential for therapy. We will discuss the role of stem cells in health and disease, and possibilities to manipulate their behavior for therapeutic application. Basic molecular and cell biology, engineering and novel technologies relevant for stem cell research and therapy will be discussed.

**Objective**

Understanding of current knowledge, and lack thereof, in stem cell biology, regenerative medicine and required technologies. Theoretical preparation for practical laboratory experimentation with stem cells.

**Content**

We will use different diseases to discuss how to potentially model, diagnose or heal them by stem cell based therapies. This will be used as a guiding framework to discuss relevant concepts and technologies in cell and molecular biology, engineering, imaging, bioinformatics, tissue engineering, that are required to manipulate stem cells for therapeutic application.

Topics will include:
- Embryonic and adult stem cells and their niches
- Induced stem cells by directed reprogramming
- Relevant basic cell biology and developmental biology
- Relevant molecular biology
- Cell culture systems
- Cell fates and their molecular control by transcription factors and signalling pathways
- Cell reprogramming
- Disease modelling
- Tissue engineering
- Bioimaging, Bioinformatics
- Single cell technologies

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making

**Social Competencies**

- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence

**Personal Competencies**

- Critical Thinking
- Integrity and Work Ethics

### 376-0225-00L Critical Appraisal of Evidence for Exercise in Health and Disease

**Abstract**

This course will discuss the mechanisms and latest evidence-based recommendations of physical activity and exercise for a series of conditions and populations. In the second part of each lecture session, published randomized controlled trials of the respective lecture’s topic will be discussed and critically appraised based on established tools.

**Objective**

On completion of this course students will be able to:
1. understand the role of physical activity and sedentary behavior in the maintenance of health and the etiology, prevention and treatment of disease
2. synthesize effective physical activity and exercise interventions for the prevention and management of several diseases and populations
3. evaluate recent evidence regarding physical activity and exercise interventions
### Content
- New trends in physical activity for prevention and rehabilitation
- Introduction to critical appraisal tools
- Exercise for Cancer Rehabilitation
- Exercise for Musculoskeletal Rehabilitation (Focus on Osteoarthritis and Low Back Pain)
- Exercise in Parkinson’s disease
- Exercise for Rehabilitation of Metabolic Disorders (Focus on Obesity and Diabetes type 2)
- Exercise for age-related diseases and disorders, Part A (Focus on Frailty and Falls)
- Exercise for Stroke Rehabilitation
- Exercise in Dementia and Mild Cognitive Impairment
- Exercise for Rehabilitation of Metabolic Disorders (Focus on Obesity and Diabetes type 2)
- Exercise for age-related diseases and disorders, Part B (Focus on Sarcopenia and Osteoporosis)
- Exercise for Cardiovascular Rehabilitation (Focus on Heart Failure)

### Literature

### Competencies

#### Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

#### Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

#### Personal Competencies
- Critical Thinking
- Integrity and Work Ethics

### Resources and Environment

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<thead>
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<tr>
<td>103-0347-00L</td>
<td>Landscape Planning and Environmental Systems</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>A. Grét-Regamey</td>
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</table>

**Abstract**
In the course, students learn about methods for the identification and measurement of landscape characteristics, as well as measures and policies for landscape planning. Landscape planning is put into the context of environmental systems (soil, water, air, climate, flora and fauna) and discussed with regard to socio-political questions of the future.

**Objective**
The aims of this course are:
1. To illustrate the concept of landscape planning, the economic relevance of landscape and nature in the context of the environmental systems (soil, water, air, climate, flora and fauna).
2. To show landscape planning as an integral information system for the coordination of different instruments by illustrating the aims, methods, instruments and their functions in landscape planning.
3. To show the importance of ecosystem services.
4. To learn basics about nature and landscape: Analysis and assessment of the complex interactions between landscape elements, effects of current and future land use (ecosystem goods and services, landscape functions).
5. To identify and measure the characteristics of landscape.
6. To learn how to use spatial data in landscape planning.

**Content**
In this course, the following topics are discussed:
- Definition of the concept of landscape
- Relevance of landscape planning
- Landscape metrics
- Landscape change
- Methods, instruments and aims of landscape planning (policy)
- Socio-political questions of the future
- Environmental systems, ecological connectivity
- Ecosystem services
- Urban landscape services
- Practice of landscape planning
- Use of GIS in landscape planning

**Lecture notes**
No script. The documentation, consisting of presentation slides are partly handed out and are provided for download on Moodle.

**Prerequisites / notice**
The contents of the course will be illustrated in the associated course 103-0347-01 U (Landscape Planning and Environmental Systems (GIS Exercises)) or in Project LAND within the Experimental and Computer Lab (for Environmental Engineers). A combination of courses is recommended.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

#### Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

#### Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

#### Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management
Subject-specific Competencies
Analytical Competencies: fostered

Quantitative Vegetation Dynamics: Models from Tree to Globe

Abstract
Climate history and paleoclimatology explores how the major features of the earth's climate system have varied in the past, and the driving forces and feedbacks for these changes. The major topics include the earth's CO2 concentration and mean temperature, the size and stability of ice sheets and sea level, the amount and distribution of precipitation, and the ocean heat transport.

Objective
The student will be able to describe the natural factors leading to variations in the earth's mean temperature, the growth and retreat of ice sheets, and variations in ocean and atmospheric circulation patterns, including feedback processes. Students will be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geologic records. Students will be able to use data from climate proxies to test if a given hypotheses mechanism for the climate change is supported or refuted. Students will be able to compare the magnitudes and rates of past changes in the carbon cycle, ice sheets, hydrological cycle, and ocean circulation, with predictions for climate changes over the next century to millennia.

Content
The course spans 5 thematic modules:

1. Cyclic variation in the earth's orbit and the rise and demise of ice sheets. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth's ice sheets and the consequent effect on sea level? How do cyclic variations in the earth's orbit affect the size of ice sheets under modern climate and under past warmer climates? What conditions the mean size and stability or fragility of the large polar ice caps and is there evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? How stable or fragile is the ocean heat conveyor, past and present?

2. Feedbacks on climate cycles from CO2 and methane. What drives CO2 and methane variations over glacial cycles? What are the feedbacks with ocean circulation and the terrestrial biosphere?

3. Atmospheric circulation and variations in the earth's hydrological cycle - How variable are the earth's precipitation regimes? How large are the orbital scale variations in global monsoon systems?

4. Century-scale droughts and civil catastrophes. Will mean climate change El Nino frequency and intensity? What factors drive change in mid and high-latitude precipitation systems? Is there evidence that changes in water availability have played a role in the rise, demise, or dispersion of past civilizations?

5. How sensitive is Earth's long term climate to CO2 and cloud feedbacks? What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years?

The weekly two hour lecture periods will feature lecture on these themes interspersed with short interactive tasks to apply new knowledge. Over the semester, students will each present in class one debate based on two scientific articles of contrasting interpretations. With flexible scheduling, students will participate in a laboratory activity to generate a new paleoclimate record from stalagmites. Student teams will be supported by an individual tutorial meeting to assist in debate preparation and another to assist in the interpretation of the lab activity data.

Competencies
Subject-specific Competencies
Concepts and Theories: assessed
Techniques and Technologies: fostered

Method-specific Competencies
Analytical Competencies: assessed
Problem-solving: assessed

Social Competencies
Communication: assessed
Cooperation and Teamwork: assessed

Personal Competencies
Creative Thinking: fostered
Critical Thinking: fostered

701-1677-00L Quantitative Vegetation Dynamics: Models from Tree to Globe

Abstract
The course introduces basic concepts and applications of dynamic vegetation models at various temporal and spatial scales. Different modeling approaches and underlying principles are presented and critically discussed during the lectures. In the integrated exercise parts, students work in a number of small projects with some of the introduced models to gain practical experience.

Objective
Students will
- be enabled to understand, assess and evaluate the fundamental properties of dynamic systems using vegetation models as case studies
- obtain an overview of dynamic modelling techniques and their applications from the individual plant to the global level
- understand the basic assumptions of the various model types, which dictate the applicability and limitations of the respective model
- be enabled to work with such model types on their own
- appreciate the methodological basis for impact assessments of future climate change and other environmental changes on ecosystems.

Content
Models of individuals
- Deriving single-plant models from inventory measurements
- Plant models based on 'first principles'

Models at the stand scale
- Simple approaches: matrix models
- Competition for light and other resources as central mechanisms
- Individual-based stand models: distance-dependent and distance-independent
- Theoretical models

Models at the landscape scale
- Simple approaches: cellular automata
- Dispersal and disturbances (windthrow, fire, bark beetles) as key mechanisms
- Landscape models

Global models
- Sacrificing local detail to attain global coverage: processes and entities
- Dynamic Global Vegetation Models (DGVMs)
- DGVMs as components of Earth System Models

Lecture notes
Handouts will be available in the course and for download

Literature
Will be indicated at the beginning of the course

Prerequisites / notice
- Ideally basic experiences in modelling and systems analysis
- Basic knowledge of programming, ideally in R
- Good knowledge of general ecology, ideally of vegetation dynamics and forest systems

701-1346-00L Climate Change Mitigation: Carbon Dioxide Removal

Abstract
Future climate change can only kept within reasonable bounds when CO2 emissions are drastically reduced. In this course, we will discuss a portfolio of options involving the alteration of natural carbon sinks and carbon sequestration. The course includes introductory lectures, presentations from guest speakers from industry and the public sector, and final presentations by the students.

Objective
The goal of this course is to investigate, as a group, a particular set of carbon mitigation/sequestration options and to evaluate their potential, their cost, and their consequences.

W 3 credits

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### Content
From the large number of carbon sequestration/mitigation options, a few options will be selected and then investigated in detail by the students. The results of this research will then be presented to the other students, the involved faculty, and discussed in detail by the whole group.

### Lecture notes
None

### Literature
Will be identified based on the chosen topic.

### Prerequisites / notice
Exam: No final exam. Pass/No-Pass is assigned based on the quality of the presentation and ensuing discussion.

### Competencies

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### Lecture notes
A script and presentation slides for each exercise will be provided on Moodle.

### Literature
Will be named in the lecture.

### Prerequisites / notice
Basic GIS skills are strongly recommended.

### Competencies

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### Abstract
The course content of the lecture Landscape Planning and Environmental Systems (103-0347-00 V) will be illustrated in practical GIS exercises (e.g. habitat modelling, land use change, ecosystem services, connectivity).

### Objective
- Practical application of theory from the lectures
- Quantitative assessment and evaluation of landscape characteristics
- Learning useful applications of GIS for landscape planning
- Developing landscape planning measures for practical case studies
- Applications of GIS in landscape planning
- Landscape analysis
- Landscape structural metrics
- Modelling habitats and land use change
- Calculating urban ecosystem services
- Ecological connectivity

### Competencies

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<th>Method-specific Competencies</th>
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### Abstract
The lecture provides an overview of climate change in Europe, from a physical and atmospheric science perspective. It covers the following topics:
- Observational datasets, observation and detection of climate change;
- Underlying physical processes and feedbacks;
- Numerical and statistical approaches;
- Currently available projections.

### Objective
At the end of this course, participants should:
- Understand the key physical processes shaping climate change in Europe;
- Know about the methodologies used in climate change studies, encompassing observational, numerical, as well as statistical approaches;
- Be familiar with relevant observational and modeling data sets;
- Be able to tackle simple climate change questions using available data sets.

### Notes
- Autumn Semester 2024

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Data: 15.06.2024 12:39   Autumn Semester 2024   Page 2270 of 2653
**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies
- Decision-making
- Problem-solving

**Social Competencies**

- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Personal Competencies**

- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

---

**Content**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies

---

**Lecture notes**

Slides and lecture notes will be made available at
http://www.iac.ethz.ch/edu/courses/master/electives/european-climate-change.html

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**Prerequisites**

Participants should have a background in natural sciences, and have attended introductory lectures in atmospheric sciences or meteorology.

---

**Prerequisites / notice**

We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 18th 2023, justifying your motivation to enroll to this class. A selection of 20 students will be done on the basis of the letters.

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**Competencies**

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  - Self-awareness and Self-reflection
  - Self-direction and Self-management

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**Mineral Resources I**

**651-4037-00L**

**W** 3 credits 2G  C. Chelle-Michou

**Can be chosen as an elective course within the Bachelor.**

Prospective MSc-Students attending the module “Mineral Resources” should attend Mineral Resources I and II in the first year of their MSc studies.

**Abstract**

Principles of hydrothermal ore formation, using base metal deposits (Cu, Pb, Zn) in sedimentary basins to explain the interplay of geological, chemical and physical factors from global scale to sample scale. Introduction to orthonmagmatic ore formation (mostly Pt, Ni, PGE). Introduction to supergene residual deposits (Ni, Al).

**Objective**

- Understanding the fundamental processes of hydrothermal, magmatic and supergene ore formation, recognising and interpreting mineralised rocks in geological context
- Principles of hydrothermal ore formation: base metal deposits in sedimentary basins. Practical classification of sample suites by genetic ore deposit types
- Mineral solubility and ore deposition, principles & thermodynamic prediction using activity diagrams. Driving forces and structural focussing of hydrothermal fluid flow
- Introduction to supergene residual deposits with emphasis on Ni laterites and bauxites

**Lecture notes**

Notes handed out during lectures

**Literature**

Extensive literature list distributed in course

**Prerequisites / notice**

2 contact hours per lecture / week including lectures, exercises and practical study of samples, and small literature-based student presentations. Supplementary contact for sample practicals and exercises as required. Credits and mark based on participation in course (exercises, 50%) and 1h30 written exam in the last lecture of the semester (50%).

---

**Content**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies

---

**Lecture notes**

Slides and lecture notes will be made available at
http://www.iac.ethz.ch/edu/courses/master/electives/european-climate-change.html

---

**Prerequisites**

Participants should have a background in natural sciences, and have attended introductory lectures in atmospheric sciences or meteorology.

---

**Prerequisites / notice**

We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 18th 2023, justifying your motivation to enroll to this class. A selection of 20 students will be done on the basis of the letters.

---

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Case Studies

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<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>860-0011-00L</td>
<td>Complex Social Systems: Modeling Agents, Learning, and Games - With Coding Project</td>
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<td></td>
<td>Prerequisites: Good mathematical skills, basic programming skills, elementary probability and statistics.</td>
<td>W</td>
<td>6 credits</td>
<td>2S+2A</td>
<td>D. N. Dailisan, D. Helbing, D. Carpentras</td>
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Abstract

This course introduces mathematical and computational models to study techno-socio-economic systems and the process of scientific research. Students develop a significant project to tackle techno-economic challenges in application domains of complex systems. They are expected to implement a model and communicating their results through a seminar thesis and a short oral presentation.

Objective

The students are expected to know a programming language and environment (Python, Java or Matlab) as a tool to solve various scientific problems. The use of a high-level programming environment makes it possible to quickly find numerical solutions to a wide range of scientific problems. Students will learn to take advantage of a rich set of tools to present their results numerically and graphically.

Content

Students are expected to implement themselves models of various social processes and systems, including agent-based models, complex networks models, decision making, group dynamics, human crowds, or game-theoretical models.

Credit points are finally earned for the implementation of a mathematical or empirical model from the complexity science literature and the documentation in a seminar thesis.

Lecture notes

The lecture slides will be presented on the course web page after each lecture.

Literature

- Agent-Based Modeling https://link.springer.com/chapter/10.1007/978-3-642-24004-1_2
- Pedestrian, Crowd, and Evacuation Dynamics https://www.research-collection.ethz.ch/handle/20.500.11850/45424
- The hidden geometry of complex, network-driven contagion phenomena (relevant for modeling pandemic spread) https://science.sciencemag.org/content/342/6164/1337

Further literature will be recommended in the lectures.

Prerequisites / notice

- The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.
- Good programming skills and a good understanding of probability & statistics and calculus are expected.
- Students need to present a new subject, for which they have not earned any credit points before.
- Good scientific practices, in particular citation and quotation rules, must be properly complied with.
- Chatham House rules apply to this course. Materials may not be shared without previous written permission.
In the case study research paper, students apply skills and knowledge acquired in the social sciences courses of the ISTP curriculum to foster adaptability and flexibility.

Transport Planning Methods

Courses

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101-0417-00L Transport Planning Methods

Abstract

The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/policy by means of cost-benefit analysis.

Objective

- Knowledge and understanding of statistical methods and algorithms commonly used in transport planning
- Comprehend the reasoning and capabilities of transport models
- Ability to independently develop a transport model able to solve/answer planning problem
- Getting familiar with cost-benefit analysis as a decision-making supporting tool

Content

The course provides the necessary knowledge to develop models supporting the solution of given planning problems and also introduces cost-benefit analysis as a decision-making tool. Examples of such planning problems are the estimation of traffic volumes, prediction of estimated utilization of new public transport lines, and evaluation of effects (e.g. change in emissions of a city) triggered by building new infrastructure and changes to operational regulations.

To cope with that, the problem is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/policy by means of cost-benefit analysis. Interim lab sessions take place regularly to guide and support students with the applied part of the course.

Lecture notes

Moodle platform (enrollment needed)

Literature


860-0040-00L Case Study Research Paper in Science, Technology and Policy 1

Abstract

In the case study research paper, students apply skills and knowledge acquired in the social sciences courses of the ISTP curriculum to address a particular societal challenge.

Objective

Students are able to apply their problem-solving and analytical skills to address a particular societal challenge.

Content

Based on what they have learned, or are learning, in the companion course, and the skills and knowledge acquired in the social sciences courses of the ISTP curriculum, students identify a particular policy challenge to be addressed. Coached by the instructor of the companion course, or in exceptional cases by another ISTP professor, the develop and implement their research idea, according to the ISTP guidelines to this end. The result should be a research paper of around 4'000 words (all inclusive, except appendices) that will be graded by the supervisor of the associated case study paper. After successfully completing the companion course and the research paper, the student office will assign both courses to the category case studies.

Lecture notes

Moodle platform (enrollment needed)

Literature


860-0040-01L Case Study Research Paper in Science, Technology and Policy 2

Abstract

In the case study research paper, students apply skills and knowledge acquired in the social sciences courses of the ISTP curriculum to address a particular societal challenge.

Objective

Students are able to apply their problem-solving and analytical skills to address a particular societal challenge.

Content

Based on what they have learned, or are learning, in the companion course, and the skills and knowledge acquired in the social sciences courses of the ISTP curriculum, students identify a particular policy challenge to be addressed. Coached by the instructor of the companion course, or in exceptional cases by another ISTP professor, the develop and implement their research idea, according to the ISTP guidelines to this end. The result should be a research paper of around 4'000 words (all inclusive, except appendices) that will be graded by the supervisor of the associated case study paper. After successfully completing the companion course and the research paper, the student office will assign both courses to the category case studies.

Lecture notes

Moodle platform (enrollment needed)

Literature

Data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, there are serious risks that automated systems could replicate or amplify existing legal biases and rigidities. Given the stakes, these technologies force us to think carefully about notions of fairness and justice and how they should be applied.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is a criminal defendant to commit another crime? How much additional revenue will this new tax law collect? These are all tough questions at a technical level, but even tougher when you consider that governments typically need to employ indirect methods to get these things to happen. Arguably a government could simply pass a law that forbids people from using fossil fuels. But politically this is simply unrealistic, at least while so many people depend on fossil fuels in their daily lives.

It’s a complicated set of problems, especially the first of these, known as mitigation. Fundamentally this is because it means doing something that humanity has never really tried before at a planetary scale: deliberately altering the ways we produce, convert, and consume energy, which is at the heart of modern society. Modern society – the entire anthropocene – grew up on fossil fuels, and the huge benefits they offered in terms of energy that was inexpensive, easy to transport and store, and very dense in terms of its energy content per unit mass or volume. How to manage a society of over 7 billion people, at anything like today’s living standards, without the benefits of that energy, is a question for which there is no easy answer. There are also other challenges outside of energy. How do we build houses, office buildings, and infrastructure networks without cement, a substance that releases large amounts of CO2 as it hardens? How do we reverse the pace of deforestation, particularly in developing countries? How do we eliminate the GHG emissions from agriculture: the methane from cows’ bellies and rice paddies, together with the chemicals that enter the atmosphere from the application of fertilizer?

These are all tough questions at a technical level, but even tougher when you consider that governments typically need to employ indirect methods to get these things to happen. Arguably a government could simply pass a law that forbids people from using fossil fuels. But politically this is simply unrealistic, at least while so many people depend on fossil fuels in their daily lives. What is to be done? For this, one needs to turn to various ideas about how government can and should influence society. On the one hand are ideas suggesting that governments ought to do something about it; making sure that emissions of greenhouse gases (GHGs) stop within the next 20 to 30 years; helping people to adapt to the consequences of the climate change to which we have already committed ourselves; and, most controversially, perhaps taking measures to actively remove GHG’s from the atmosphere, or to alter the radiation balance of the Earth through solar engineering.

Ten Principles for Policy Making in the Energy Transition, by Laura Diaz Anadon et al.

Climate change is one of the defining challenges of our time, touching all aspects of the environment and of society. There is broad recognition (although with some dissent) that governments ought to do something about it; making sure that emissions of greenhouse gases (GHGs) stop within the next 20 to 30 years; helping people to adapt to the consequences of the climate change to which we have already committed ourselves; and, most controversially, perhaps taking measures to actively remove GHG’s from the atmosphere, or to alter the radiation balance of the Earth through solar engineering.

There are currently raging (of which the debate about whether climate change is actually real is probably the least complicated or interesting). We want to give students the ability to evaluate policy arguments made by politicians, experts, and academics with a critical eye, informed by a knowledge of history, an understanding of the theoretical underpinnings, and the results of empirical testing of different strategies. A student taking this course ought to be able to step into an NGO or government agency involved in climate policy analysis or political advocacy, and immediately be able to make an informed and creative contribution. Moreover, by experiencing the depth of this policy area, students should be able to appreciate the complexity inherent in all policy areas.

Climate Policy

This course provides an in-depth analysis of the theoretical underpinnings of different approaches to climate policy at the international and national levels, and how these different approaches have played out in practice. Students will learn how legislative frameworks have evolved over the last 25 years, and also be able to appreciate those frameworks critically.

It’s a complicated set of problems, especially the first of these, known as mitigation. Fundamentally this is because it means doing something that humanity has never really tried before at a planetary scale: deliberately altering the ways we produce, convert, and consume energy, which is at the heart of modern society. Modern society – the entire anthropocene – grew up on fossil fuels, and the huge benefits they offered in terms of energy that was inexpensive, easy to transport and store, and very dense in terms of its energy content per unit mass or volume. How to manage a society of over 7 billion people, at anything like today’s living standards, without the benefits of that energy, is a question for which there is no easy answer. There are also other challenges outside of energy. How do we build houses, office buildings, and infrastructure networks without cement, a substance that releases large amounts of CO2 as it hardens? How do we reverse the pace of deforestation, particularly in developing countries? How do we eliminate the GHG emissions from agriculture: the methane from cows’ bellies and rice paddies, together with the chemicals that enter the atmosphere from the application of fertilizer?

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The Research Studio has two main objectives:

1. Archaeology of Swiss Coloniality.

First, students will develop an ‘archaeology’ of the historical entanglements of Swiss industry with global colonialism. In this part, the studio work is understood as an archaeological venture, digging up traces of the past. Students will systematically probe the built environment of Switzerland for traces and influences of global colonialism and its aftermath. The result will be a catalogue of colonial entanglements, illustrating how they are inscribed into architectural and urban figures and how they continue to impact the urban fabric of Switzerland and its industry.

2. Processing Swiss Coloniality.

In a second step, students will attempt to ‘process’ the enduring impact of Swiss Coloniality. Based on the ‘Archaeology,’ students will explore the inherent logics of global colonialism in relation to Swiss industry as it impacts the present. The central idea is to avoid considering the past as a closed chapter, but as an ongoing process and condition of coloniality that still structures our present and future, which needs acknowledgement and dialogue. Students will be asked, using the tools of the architect, to explore strategies to represent these entanglements and suggest openings for repair where needed.

Based on these main objectives, this course will:

- offer students an overview of the most important historical and contemporary contributions to debates on postcolonial and decolonial theory and the entanglement of Switzerland’s industry with global colonialism;
- equip students to reflect critically upon the manifestations of Swiss Coloniality in the built environment with the help of both theoretical and historical perspectives;
- make students aware that the production of the city is not a neutral given but is always shaped by cultural values, assumptions, and expectations, which impact the everyday environment and, as such, condition inhabitants and users;
- help students to position themselves within current debates on cities, urban development, and urban life in relation to broader challenges such as sustainability and social inequality.

Content

Swiss Coloniality

Cities have never been isolated entities and have always existed by grace of the myriad connections with their hinterland. Throughout the past centuries, and especially since the 15th century onwards, these connections have become increasingly far-reaching across the globe, and the history of urban development in areas such as Europe has been intricately entwined with conditions and realities elsewhere. As such, urban history cannot be seen as entirely separate from global colonialism and its aftermath. While designing and constructing the architecture of the city, architects, urban designers, builders, and inhabitants also inevitably take part in the wider ecologies of material and immaterial flows that are shaped by and contribute to a global system of inequality. Not uncoincidentally, the metropole – a key term of colonial history – finds its roots in the political urban figure of the polis and identifies the center-periphery relationship between the ‘motherland’ and its hinterland. The metropole is the place from where power is exercised over foreign territories and the place that reaps the fruits of this exercising of power.

While Switzerland never had colonies of its own, it was nevertheless in many ways involved in and contributed to the history of global colonialism: by taking part in the economy sustained by colonialism, by financing and securing slave trade, by contributing to race-based science practices, etc. So, despite being a country without colonies, what if we consider Switzerland and its position in the world from the perspective of the colonial metropole? What would be the specific architectural and urban dimension of this figure of Metropole Switzerland? In raising such questions, in this Research Studio, we aim to focus on the entanglements of the architectural and urban histories of Switzerland and the history of global colonialism.

Starting to answer such questions requires a widened understanding of colonialism and its impact, which has been grasped with the notion of coloniality in recent debates. While colonialism refers to the historically specific phenomenon of one area of the world colonizing another, setting on foreign land, extracting its resources, and violently disciplining its inhabitants, the term coloniality refers to the more long-lasting processes and indirect effects that are the result of centuries of colonialism, and that mark a landscape of global inequality, even after the ‘official’ reign of colonialism has ended. In this sense, the disparity between the so-called ‘Global North’ and ‘Global South’, and the way in which a country such as Switzerland is still profiting from an advantageous position in this globally unequal world, can be considered the result of centuries of colonialism, and to be still part of a condition of coloniality. As this condition is a two-sided and mutually inflective phenomenon, to unravel the knot of Swiss coloniality, we not only aim to investigate how Switzerland was implicated in activities abroad but also, conversely, how these activities have impacted Switzerland. While in the fields of political, social and economic history, a revisionist effort is underway to reconsider/correct the image of Switzerland as a neutral country without colonies, in the field of architecture and urban history, however, we are yet to unravel the impact of this entanglement on the built environment, and, more widely, on the aesthetic, material and craft cultures of Swiss cities.
The overarching hypothesis of this Research Studio is that historical and theoretical research can profit profoundly from the use of the tools and knowledge of architects. On the one hand, the spatial, formal, material, and constructive knowledge gained throughout architectural studies will guide the historical research in the archives, in the library, and/or in the city itself and will allow students to articulate specifically architectural interpretations of the materials they find. On the other hand, the Studio explicitly asks students to employ specific architectural tools such as drawing, writing and model-making to explore the historical and theoretical realities that are being investigated. By actively reflecting on the composition of a varied set of analytical and interpretative drawings, texts, and models, students will probe the capacity of these means to act as tools for historical and theoretical research.

Within the general theme of Swiss Coloniality, students will be guided to identify their own subtheme, which will require exploring their own specific research methodologies. These architecture-specific methodologies will be strategically chosen to discuss specific aspects of society: political, economic, social, cultural, or otherwise. Thus, conjuring these 'autonomous' and 'heteronomous' dimensions of architecture, a new understanding of the city and our built environment is developed that allows us to answer (some of) the research questions mentioned previously.

### Research process

Students will be guided through three phases with different emphases: Definitions, Logics and Reinterpretations of Swiss Coloniality.

**The first phase, Definitions,** is focused on developing an understanding of what the notion of Swiss Coloniality can entail and how it relates specifically to industry and the production of the city. This phase will allow students to become familiar with the historical and current entanglements of Switzerland with global colonialism and, by closely examining its main actors, practices, and materials, will set the stage for students to develop their own, individual research project.

**The second phase, Logics,** is about understanding and demonstrating the inner workings and mechanisms of Swiss Coloniality. Each of the students will focus on one specific case – a material, a site, an actor, a practice, etc. – and will examine it closely through targeted archival and library research, as well as through drawing, writing, and model-making.

In the third phase, Reinterpretations, students will formulate and investigate a hypothesis regarding the entanglements of Swiss industry with global colonialism. Based on this hypothesis, students will position themselves in relation to Swiss Coloniality, its history and its enduring impact. The position statement can take the form of a written text, architectural drawings and/or models and will be presented in the form of a student-curated studio exhibition and an online adaptation of it.

Course syllabus and reader will be made available during the course's first week.

Enrollment will not take place through the D-ARCH website. To enroll for this Bachsemester please send an e-mail to sebastiaan.loosen@qta.arch.ethz.ch by Wednesday 6 September 2023, 8PM. If necessary, available places will be allocated firstly conform the A-B-C-studio priority system, and secondly, randomly. You will receive a confirmation by Thursday 7 September 2023, 12AM (noon). In case of over-applications, students who are not selected have the opportunity to choose a regular design studio through the D-ARCH website (enrollment ends on September 7, at 6 p.m.).

The Research Studio is self-dependent work and tutoring takes place on Tuesdays and Wednesdays.

Further course information on https://avermaete.arch.ethz.ch/researchstudio

### Literature

**Prerequisites / notice**

Students can register only once for a "Fachsemester" during the Master studies.

Enrollment will not take place through the D-ARCH website. To enroll for this Bachsemester please send an e-mail to sebastiaan.loosen@qta.arch.ethz.ch by Wednesday 6 September 2023, 8PM. If necessary, available places will be allocated firstly conform the A-B-C-studio priority system, and secondly, randomly. You will receive a confirmation by Thursday 7 September 2023, 12AM (noon). In case of over-applications, students who are not selected have the opportunity to choose a regular design studio through the D-ARCH website (enrollment ends on September 7, at 6 p.m.).

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### Competencies

**Subject-specific Competencies**

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**

- Analytical Competencies: assessed
- Decision-making: assessed
- Project Management: fostered
- Media and Digital Technologies: assessed
- Problem-solving: assessed

**Social Competencies**

- Communication: assessed
- Cooperation and Teamwork: assessed
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

**Personal Competencies**

- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: assessed

### Electives

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>351-0778-01L</td>
<td>Discovering Management (Pitch)</td>
<td>W</td>
<td>1 credit</td>
<td>1U</td>
<td>B. Clarysse, L. P. T. Vandeweghe</td>
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**Prerequisite:** Participation and successful completion of the module Discovering Management (351-0778-00L) is mandatory.

**Abstract**

This course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

**Objective**

The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.

**Content**

The exercise consists of delivering and submitting a "pitch" with a clear recommendation for one of the selected cases amongst those seen in Discovering Management, using your insights from Discovering Management, and an extra session on pitching.

Students have the option to either do this alone or in a group of two students.
Climate change, access to energy and other societal challenges are directly linked to the way we use and create energy. Both the 2015 United Nations Paris climate change agreement and the UN Sustainable Development Goals make a fast and extensive transition of the energy system necessary.

This lecture introduces the social and environmental challenges involved in the energy sector and discusses the implications of these challenges for the rate and direction of technical change in the energy sector. It compares the current situation with historical socio-technical transitions and derives the consequences for policy-making. It introduces theoretical frameworks and concepts for studying innovation and transitions. It then focuses on the role of policy and change in governing the energy transition, considering the role of political actors, institutions and policy feedback.

The grade will be determined by a final exam.
This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined.

The objectives in this course are to (1) gain an overview of important questions pertaining to international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions in this policy area and how to address them in a conceptually and methodologically meaningful and insightful way; (3) gain an overview of important global and regional environmental problems and how they are or could be solved.

The course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined, for example international efforts to reduce air pollution, manage international water resources, mitigate and adapt to global warming, protect the stratospheric ozone layer, address biodiversity challenges, deal with plastic waste, and prevent pollution of the oceans.

Questions and suggestions for the literature will be posted on the course web page (moodle). The course provides an introduction to ecosystem management, and in particular the importance of integrating ecology into management and decision making. This course will take place on campus (ETH Main Building, HG F.3). There will be no live-streaming, and the course is NOT in hybrid (on-campus plus online) format. However, the lecture will be recorded and the recordings will be made available via the Moodle platform for this course a few days after the respective lecture for students who are unable to attend in person. All electronic correspondence will take place via the ETH myStudies system and Moodle, so please make sure you are properly registered there with a functioning email account/address.

This course introduces the broad variety of conflicts that arise in projects focusing on sustainable management of natural resources. It explores case studies of ecosystem management approaches and considers their practicability, their achievements and possible barriers to their uptake.

Prequisites / notice
Teams of 2-3 students prepare a 2-3 page background reading for the group on a specific international organization and lead the discussion with representatives of that organization during the visit.

Contents
- Landscape ecology
- Protected area systems
- Community management

Objective
Students should be able to
a) propose appropriate and realistic solutions to ecosystem management problems that integrate ecological, economic and social dimensions across relevant temporal and spatial scales.

b) identify important stakeholders, their needs and interests, and the main conflicts that exist among them in the context of land and resource management.

Content
- Traditional management systems focus on extraction of natural resources, and their manipulation and governance. However, traditional management has frequently resulted in catastrophic failures such as, for example, the collapse of fish stocks and biodiversity loss. These failures have stimulated the development of alternative ecosystem management approaches that emphasise the functionality of human-dominated systems. Inherent to such approaches are system-wide perspectives and a focus on ecological processes and services, multiple spatial and temporal scales, as well as the need to incorporate diverse stakeholder interests in decision making. Thus, ecosystem management is the science and practice of managing natural resources, biodiversity and ecological processes, to meet multiple demands of society. It can be local, regional or global in scope, and addresses critical issues in developed and developing countries relating to economic and environmental security and sustainability.

This course provides an introduction to ecosystem management, and in particular the importance of integrating ecology into management systems to meet multiple societal demands. The course explores the extent to which human-managed terrestrial systems depend on underlying ecological processes, and the consequences of degradation of these processes for human welfare and environmental well-being. Building upon a theoretical foundation, the course will tackle issues in resource ecology and management, notably forests, agriculture and wild resources within the broader context of sustainability, biodiversity conservation and poverty alleviation or economic development. Case studies from tropical and temperate regions will be used to explore these issues. Dealing with ecological and economic uncertainty, and how this affects decision making, will be discussed. Strategies for conservation and management of terrestrial ecosystems will give consideration to landscape ecology, protected area systems, and community management, paying particular attention to alternative livelihood options and marketing strategies of common pool resources.
Competencies

Subject-specific Competencies
- Concepts and Theories
- Decision-making
- Problem-solving
- Project Management

Method-specific Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Social Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Personal Competencies
- Creativity
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Abstract
This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution.

Objective
To collect credit points, students must actively contribute and give an individual, circa 20-minute presentation in the seminar on a subject agreed upon with the lecturer. After the presentation, it will be discussed and graded.

Content
This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will also reflect on the question of how democracy could be digitally upgraded, and how citizen participation could contribute to innovation, sustainability, resilience, and quality of life. This includes questions around collective intelligence and digital platforms that support creativity, engagement, coordination and cooperation.

Literature
- Dirk Helbing, R. K. Dubey
  *An Analytical Theory of Traffic Flow (collection of papers)*

- Michael Batty, Kay Axhausen et al.
  *Smart cities of the future*

- Books by Michael Batty:
  - How social influence can undermine the wisdom of crowd effect
  - Evidence for a collective intelligence factor in the performance of human groups
  - Optimal incentives for collective intelligence
  - Collective Intelligence: Creating a Prosperous World at Peace
  - Big Mind: How Collective Intelligence Can Change Our World
  - Programming Collective Intelligence
  - Urban architecture as connective-collective intelligence. Which spaces of interaction?
  - Build digital democracy
  - How to make democracy work in the digital age
  - Digital Democracy: How to make it work?
  - Proof of witness presence: Blockchain consensus for augmented democracy in smart cities
  - Iterative Learning Control for Multi-agent Systems Coordination

- Decentralized Collective Learning for Self-managed Sharing Economies

Prerequisites / notice
- Students need to present a new subject, for which they have not earned any credit points before.
- Good scientific practices, in particular citation and quotation rules, must be properly complied with.
- Chatham House rules apply to this course. Materials may not be shared without previous written permission.
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

Abstract
The seminar aims at three-fold integration: (1) bringing modeling and computer simulation of techno-socio-economic processes and phenomena together with related empirical, experimental, and data-driven work, (2) combining perspectives of different scientific disciplines (e.g. sociology, computer science, physics, complexity science, engineering), (3) bridging between fundamental and applied work. Computational Social Science and Global Systems Science serve to better understand the emerging digital society with its close co-evolution of information and communication technology (ICT) and society. They make current theories of crises and disasters applicable to the solution of global-scale problems, taking a data-based approach that builds on a serious collaboration between the natural, engineering, and social sciences, i.e. an interdisciplinary integration of knowledge.

Objective
Participants of the seminar should understand how tightly connected systems lead to networked risks, and why this can imply systems we do not understand and cannot control well, thereby causing systemic risks and extreme events. They should also be able to explain how systemic instabilities can be understood by changing the perspective from a component-oriented to an interaction- and network-oriented view, and what fundamental implications this has for the proper design and management of complex dynamical systems.

Literature
- Ball: Why Society Is A Complex Matter
- Helbing: Social Self-Organization
- Helbing: Managing Complexity
- Colander/Kupers: Complexity and the Art of Public Policy
- Mitchell: Complexity
- Buckley: Society – A Complex Adaptive System
- Castellani/Hafferty: Sociology and Complexity Science
- Mikhailov/Calenbuhr: From Cells to Society
- Mainzer: Thinking in Complexity
- Sawyer: Social Emergence
- Books published by the Santa Fe Institute

Prerequisites / notice
Students need to present a new subject, for which they have not earned any credit points before.

Further literature will be recommended in the lectures.

Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Chatham House rules apply to this course. Materials may not be shared without previous written permission.
Concepts and Theories
Techniques and Technologies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management
Communication
Cooperation and Teamwork
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

363-0537-00L Resource and Environmental Economics

Objective
A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

Literature

400-0571-00L Urban Design III

Abstract
Students are introduced to a narrative of ‘Urban Stories’ through a series of three tools driven by social, governance, and environmental transformations in today’s urbanization processes. Each lecture explores one city’s spatial and organizational ingenuity born out of a particular place’s realities, allowing students to transfer these inventions into a catalog of conceptual tools.

Objective
How can students of architecture become active agents of change? What does it take to go beyond a building’s scale, making design-relevant decisions to the city rather than a single client? How can we design in cities with a lack of land, tax base, risk, and resilience, understanding that Zurich is the exception and these other cities are the rule? How can we discover, set rather than follow trends and understand existing urban phenomena activating them in a design process? The lecture series produces a growing catalog of operational urban tools across the globe, considering Governance, Social, and Environmental realities. Instead of limited binary comparing of cities, we are building a catalog of change, analyzing what design solutions cities have been developing informally incrementally over time, why, and how. We look at the people, institutions, culture behind the design and make concepts behind these tools visible. Students get first-hand information from cities where the chair as a Team has researched, worked, or constructed projects over the last year, allowing competent, practical insight about the people and topics that make these places unique. Students will be able to use and expand an alternative repertoire of experiences and evidence-based design tools, go to the conceptual core of them, and understand how and to what extent they can be relevant in other places. Urban Stories is the basic practice of architecture and urban design. It introduces a repertoire of urban design instruments to the students to use, test, and start their designs.
Urban form cannot be reduced to physical space. Cities result from social construction, under the influence of technologies, ecology, culture, the impact of experts, and accidents. Urban un-concluded processes respond to political interests, economic pressure, cultural inclinations, along with the imagination of architects and urbanists and the informal powers at work in complex adaptive systems. Current urban phenomena are the result of urban evolution. The facts stored in urban environments include contributions from its entire lifecycle, visible in the physical environment, and non-physical aspects. This imaginary city exists along with its potentials and problems and with the conflicts that have evolved. Knowledge and understanding, along with a critical observation of the actions and policies, are necessary to understand the diversity and instability present in the contemporary city and understand how urban form evolved to its current state.

How did cities develop into the cities we live in now? Urban plans, instruments, visions, political decisions, economic reasonings, cultural inputs, and social organization have been used to operate in urban settlements in specific moments of change. We have chosen cities that exemplify how these instruments have been implemented and how they have shaped urban environments. We transcribe these instruments into urban operational tools that we have recognized and collected within existing tested cases in contemporary cities across the globe.

This lecture series will introduce urban knowledge and the way it has introduced urban models and operational modes within different concrete realities, therefore shaping cities. The lecture series translates urban knowledge into operational tools, extracted from cities where they have been tested and become exemplary samples, most relevant for understanding how the urban landscape has taken shape. The tools are clustered in twelve thematic clusters and three tool scales for better comparability and cross-reflection.

The Tool case studies are compiled into a global urbanization toolbox, which we use as typological models to read the city and critically reflect upon it. The presented contents are meant to serve as inspiration for positioning in future professional life and provide instruments for future design decisions.

In an interview with a local designer, we measure our insights against the most pressing design topics in cities today, including inclusion, affordable housing, provision of public spaces, and infrastructure for all.

The learning material, available via https://moodle-app2.let.ethz.ch/ is comprised of:

- Toolbox 'Reader' with an introduction to the lecture course and tool summaries
- Weekly exercise tasks
- Infographics with basic information of each city
- Quiz question for each tool
- Additional reading material
- Interviews with experts
- Archive of lecture recordings
- Reading material will be provided throughout the semester.

### Literature

**851-0101-86L Complex Social Systems: Modeling Agents, Learning, W 3 credits 2S D. N. Dailisan, D. Carpentras, D. Helbing**

**Abstract**

This course introduces mathematical and computational models to study techno-socioeconomic systems and the process of scientific research. Students develop a significant project to tackle techno-socio-economic challenges in application domains of complex systems. They are expected to implement a model and to communicate their results through a project report and a short oral presentation.

**Objective**

See your own field of study in a wider context (“Science in Perspective”), e.g. see the psychological, social, economic, environmental, historical, ethical or philosophical connections and implications. Learn to think critically and out of the box. Question what you believe you know for sure. Get to know surprising, counterintuitive properties of complex (non-linearly interacting, networked, multi-component) systems. Learn about collaboration.

**Content**

By the end of the course, the students should be able to better understand the literature on complex social systems, develop their own models for studying specific phenomena and report results according to the standards of the relevant scientific literature by presenting their results both numerically and graphically.

At the end of the course, the students will deliver a report, computer code and a short oral presentation. To collect credit points, students will have to actively contribute and give a circa 30 minutes presentation in the course on a subject agreed with the lecturers, after which the presentation will be discussed. The presentation will be graded.

Students are expected to implement themselves models of techno-socio-economic processes and systems, particularly agent-based models, complex networks models, decision making, group dynamics, human crowds, or game-theoretical models. Credit points are finally earned for the implementation of a mathematical or empirical model from the complexity science literature, its presentation, and documentation by a project report.

**Lecture notes**

The lecture slides will be presented on the course Moodle after each lecture.

**Social Self-Organization**


Traffic and related self-driven many-particle systems

Reviews of Modern Physics 73, 1067
https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.73.1067

An Analytical Theory of Traffic Flow (collection of papers)

https://www.researchgate.net/publication/261629187

Pedestrian, Crowd, and Evacuation Dynamics

https://www.research-collection.ethz.ch/handle/20.500.11850/45424

The hidden geometry of complex, network-driven contagion phenomena (relevant for modeling pandemic spread)

https://science.sciencemag.org/content/342/6164/1337
The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.

Good programming skills and a good understanding of probability & statistics and calculus are expected.

Students need to present a new subject, for which they have not earned any credit points before.

Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Chatham House rules apply to this course. Materials may not be shared without previous written permission.

Prerequisites / notice

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for “Law & Tech (851-0732-06L, HS 2024)” and enroll.

Competencies

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Abstract

This course introduces students to scientific and technological developments that require regulation or enable legal innovation. We focus particularly on the challenges to current law posed by prominent near-future technologies.

Objective

The course is designed for a wide range of ETH students as well as for law students who are keen to deepen their understanding of cutting-edge technology. It offers an overview of key legal areas important for technology regulation, complemented by guest lectures on emerging technological trends.

In previous years, the course has featured esteemed speakers from various sectors, including industry leaders like Google, NGOs such as Digital Society Switzerland and The European Consumer Organization, regulatory bodies like the Swiss Competition Commission, and noted academics.

The course is open to ETH students through the Science in Perspective program of the Department of Humanities, Social and Political Sciences.

Content

The planned course outline is below.

- Overview of Law and Technology
- Fundamental Rights
- AI & Discrimination
- Landmark Big Tech Cases
- Regulation of Digital Platforms & Content Moderation
- Online Consumer Protection
- Law and Tech Scholarship Series

A number of recent regulations will be discussed, including the EU's AI Act, the Digital Services Act (DSA), and the Digital Markets Act (DMA), as well as emerging internet phenomena, like ChatGPT.

Prerequisites / notice

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for “International Engineering: from Hubris to Hope (151-8101-00L, HS 2024)” and enroll.

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Abstract

Since Europe surrendered their colonial assets, engineers from rich countries have returned to the African continent to address the real and perceived ills that they felt technology could solve. And yet, 70 years on, the promise of technology has largely failed to deliver widespread, substantive improvements in the quality of life. Why?
Objective

This course is meant for engineers who are interested in pursuing an ethical and relevant career internationally, and who are willing to examine the complex role that well-meaning foreigners have played and continue to play in the disappointing health outcomes that characterize much of the African continent.

After completing the course, participants will be able to
- critique the jargon and terms used by the international community, i.e. “development”, “aid”, “cooperation”, “assistance” “third world” “developing” “global south” “low and middle-income” and justify their own chosen terminology
- recognize the role of racism and white-supremacy in the development of the Aid industry
- understand the political, financial, and cultural reasons why technology and infrastructure have historically failed
- Debate the merits of international engineering in popular culture and media
- Propose improved SDG indicators that address current shortcomings
- Compare the engineering curricula of different countries to identify relative strengths and shortcomings
- Explain the inherent biases of academic publishing and its impact on engineering failure
- Analyse linkages between the rise of philanthropy and strategic priority areas
- Recommend equitable, just funding models to achieve more sustainable outcomes
- Formulate a vision for the international engineer of the future

Content

Role of international engineering during colonialism
- Transition of international engineering following colonialism
- White saviourism and racism in international engineering
- International engineering in popular culture
- The missing role of Engineering Education
- Biases in academic publishing
- The emerging role in Global Philanthropy
- The paradox of International funding

Literature


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Objective

Building a Robot Judge: Data Science for Decision-Making

W 3 credits 2V E. Ash

Does not take place this semester.
Particularly suitable for students of D-INFK, D-ITET, D-MTEC.

Abstract

This course explores the automation of decisions in the legal system. We delve into the machine learning tools needed to predict judge decision-making and ask whether techniques in model explanation and algorithmic fairness are sufficient to address the potential risks.

Objective

This course introduces students to the data science tools that may provide the first building blocks for a robot judge. While building a working robot judge might be far off in the future, some of the building blocks are already here, and we will put them to work.

Content

Data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, there are serious risks that automated systems could replicate or amplify existing legal biases and rigidities. Given the stakes, these technologies force us to think carefully about notions of fairness and justice and how they should be applied.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is a criminal defendant to commit another crime? How much additional revenue will this new tax law collect? Students will investigate and implement the relevant machine learning tools for making these types of predictions, including regression, classification, and deep neural networks models.

We then use these predictions to better understand the operation of the legal system. Under what conditions do judges tend to make errors? Against which types of defendants do parole boards exhibit bias? Which jurisdictions have the most tax loopholes? Students will be introduced to emerging applied research in this vein. In a semester paper, students (individually or in groups) will conceive and implement an applied data-science research project.

851-0685-00L Data and Society

W 3 credits 2V M. Leese

Abstract

This lecture series explores the multifaceted role of data in shaping contemporary society, governance, and individual lives. The course equips students with a critical understanding of how data is made, managed, and preserved, and its implications for societal norms and individual rights.

Objective

At the end of the term, students will be able to:
- reflect concepts and theories that capture the performativity of data
- reflect concepts and theories that capture the socio-technical nature of data
- assess the implications of data practices for social and political ordering
- identify key actors, sites, and domain contexts of data practices

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### Internship

The performance counts as electives.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>860-0600-00L</td>
<td>Internship - Short</td>
<td>W</td>
<td>6</td>
<td></td>
<td>external organisers</td>
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<tr>
<td>860-0700-00L</td>
<td>Internship - Long</td>
<td>W</td>
<td>12</td>
<td></td>
<td>external organisers</td>
</tr>
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</table>

#### Content
- The internship serves to make students familiar with policy analysis in a real world setting, for instance in a government agency, a NGO, a regulatory or public affairs division of a private sector firm, or a consulting firm focused on policy analysis.
- The short internship corresponds to a workload of 180 hours, to be accomplished within 3 months.
- The long internship corresponds to a workload of 360 hours, to be accomplished within 6 months.

#### Prerequisites / notice
- The internship can be started the earliest in the second semester. The internship needs to be approved by the study director. Therefore students need to hand in a short description to the study secretary before they start the internship.

### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>860-0900-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30</td>
<td>64D</td>
<td>Professors</td>
</tr>
</tbody>
</table>

#### Abstract
- The thesis should demonstrate the students ability to conduct independent research on the basis of the theoreticel and methodological knowledge acquired during the MSc program.

#### Objective
- The thesis should demonstrate the students ability to conduct independent research on the basis of the theoreticel and methodological knowledge acquired during the MSc program.

### Science, Technology, and Policy Master - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2285 of 2653
<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS  European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Core Subjects

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>651-7001-00L</td>
<td>Space System Engineering</td>
<td>O</td>
<td>14</td>
<td>14G</td>
<td>S. C. Stähler, Kehl, T. Zurbuchen</td>
</tr>
</tbody>
</table>

### Scientific Introductory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-7011-00L</td>
<td>Introduction to Planetary Science</td>
<td>W+</td>
<td>4</td>
<td>2G</td>
<td>M. Schönbachler, H. Busemann, C. Gillmann, A. Mittelholz</td>
</tr>
</tbody>
</table>

**Abstract**
This course aims to provide an understanding of the formation, evolution, composition, structure and dynamics of planetary bodies in our solar system and beyond, including new developments in the field and links to past, current and future space missions.

**Objective**
The goal of this course is to enable students to understand current knowledge and uncertainties regarding the evolution, composition, structure and dynamics of planets, moons, asteroids and comets in our solar system, as well as ongoing discoveries from space missions and planets around other stars.

**Content**
The main topics covered are: Orbital Dynamics and Tides, Solar Heating and Energy Transport, Chronology and Compositions (bulk and isotopic), Geochemical Concepts, Planetary Atmospheres, Planetary Surfaces, Planetary Interiors, Asteroids and Meteorites, Comets, Planetary Rings, Magnetic Fields and Magnetospheres, the Sun and Stars, Planet Formation, Exoplanets and Exobiology.

**The lectures introduce the basics of the terrestrial and giant planets, comets, and asteroids, gained from modern space missions and the study of extraterrestrial material from both the physical and geochemical perspectives. Students will practice making quantitative calculations relevant to various aspects of these topics through homework.**

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-7012-00L</td>
<td>The Physics of Space Weather</td>
<td>W+</td>
<td>2</td>
<td>3G</td>
<td>L. Harra, to be announced</td>
</tr>
</tbody>
</table>

**Abstract**
The physics of solar flares, coronal mass ejections and the solar wind and how they are triggered and transport through the solar system is described. The impact of the Sun’s activity and its activity cycle on the Earth and our technology will be outlined. The students will use real spacecraft data in the exercise classes to track space weather events and their impact.

**Objective**
The main goal of the course is to give the students an overview of physical phenomena that lead to impacts on the Earth and our technical infrastructure from the Sun. The areas described are at the forefront of scientific research internationally, and is an area known as ‘space weather’. The current status and reliability of space weather predictions will be reviewed.

**Content**
There will be 2 lectures given each week for 7 weeks followed by an exercise class. The exercise class will track the lectures and the students will use spacecraft data to determine their own space weather impacts from different solar storms.

**Competencies**
Concepts and Theories fostered

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0675-00L</td>
<td>Earth Observation</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>I. Hajnsek, P. Bernhard</td>
</tr>
</tbody>
</table>

**Abstract**
The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for bio/geophysical environmental parameter estimation.

**Objective**
The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for bio/geophysical environmental parameter estimation. Students should know at the end of the course:

1. Basics of measurement principle
2. Fundamentals of image acquisition
3. Basics of the sensor-specific geometries
4. Sensor-specific determination of environmental parameters

**Content**
Die Lehrveranstaltung gibt einen Einblick in die heutige Erdbeschichtigung mit dem folgenden skizzierten Inhalt:

1. Einführung in die Fernerkundung von Luft- und Weltraum gestützten Systemen
2. Einführung in das Elektromagnetische Spektrum
3. Einführung in optische Systeme (optisch und hyperspektral)
4. Einführung in Mikrowellen-Technik (aktiv und passiv)
5. Einführung in atmosphärische Systeme (meteo und chemisch)
6. Einführung in die Techniken und Methoden zur Bestimmung von Umweltparametern
7. Einführung in die Anwendungen zur Bestimmung von Umweltparametern in der Hydrologie, Glaziologie, Forst und Landwirtschaft, Geologie und Topographie

**Lecture notes**
Folien zu jedem Vorlesungsblock werden zur Verfügung gestellt.

**Literature**
Ausgewählte Literatur wird am Anfang der Vorlesung vorgestellt.

### Deep Track Courses

#### Aerospace Engineering

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0187-02L</td>
<td>Satellite Geodesy</td>
<td>W+</td>
<td>4</td>
<td>3G</td>
<td>M. Alchinger-Rosenberger</td>
</tr>
</tbody>
</table>

**Abstract**

**Objective**
- Sicherheit im Umgang mit Koordinaten-, Referenz- und Zeitsystemen
- Grundlegendes Verständnis der Berechnung von Satellitenbahnen
- Grundlegendes Verständnis der geodätischen Weltraumverfahren und deren Stärken und Schwächen
- Kenntnis der wichtigsten Prozesse, die für Änderungen in der Geometrie, der Rotation und dem Schwerfeld der Erde verantwortlich sind.
- Erkennen der Anwendungsmöglichkeiten der Satellitengeodäsie für interdisziplinäre Aufgaben (System Erde).

**Content**
- Koordinatensysteme, Transformationen
- Referenz- und Zeitsysteme
- Grundlagen Satellitenbahnen
- Weltraumverfahren: VLBI, SLR, DORIS, Altimetrie
- Schwerefeldmissionen
- Kombination der Weltraumverfahren zur Bestimmung der Geometrie, Orientierung sowie des Schwerfeldes der Erde
- Interdisziplinäre Anwendungen (Meteorologie, Klimatologie, Hydrologie, etc.)

**Lecture notes**
103-0187-01L  Space Geodesy  W-  6 credits  4G  B. Soja

Abstract

Objective
After this course, the students should be able to
- Describe the major observation techniques in space geodesy
- Describe the necessary modeling and analysis approaches to derive geodetic products of highest quality
- Select the appropriate space geodetic data for scientific investigations
- Analyze the space geodetic data for scientific purposes
- Interpret the scientific results

Content
Overview of GNSS, Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser Ranging (SLR/LLR), Satellite Radar Altimetry with the basic principles, the instruments and observation equations.

Modelling of the station motions and the estimation of station coordinates. Basics of wave propagation in the atmosphere. Signal propagation in the ionosphere and troposphere for the different observation techniques and the determination of atmospheric parameters.

Equation of motion of the unperturbed and perturbed satellite orbit. Osculating and mean orbital elements. General and special perturbation theory and the determination of satellite orbits.

Lecture notes
Script M. Rothacher "Space Geodesy"

Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: fostered
  - Problem-solving: assessed
- Social Competencies
  - Communication: fostered
- Personal Competencies
  - Creative Thinking: fostered
  - Critical Thinking: assessed
  - Self-awareness and Self-reflection: fostered

151-0563-01L  Dynamic Programming and Optimal Control  W+  4 credits  2V+1U  R. D'Andrea

Abstract
Introduction to Dynamic Programming and Optimal Control.

Objective
Covers the fundamental concepts of Dynamic Programming & Optimal Control.

Content
Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

Literature
Prerequisites / notice
Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

151-1116-00L  Introduction to Aircraft and Car Aerodynamics  W+  4 credits  3G  M. Immer, F. Schröder

Abstract

Objective
An introduction to the basic principles and interrelationships of aircraft and automotive aerodynamics.
To understand the basic relations of the origin of aerodynamic forces (ie lift, drag). To quantify the aerodynamic forces for basic configurations of aircraft and car components. Illustration of the intrinsic problems and results using examples. Using experimental and theoretical methods to illustrate possibilities and limits.

Content
Aircraft aerodynamics: atmosphere, aerodynamic forces (ascending force: profile, wings, Resistance, residual resistance, induced resistance); thrust (overview of the propulsion system, aerodynamics of the propellers), introduction to static longitudinal stability.

Lecture notes
Preparation materials & slides are provided prior to each class

Literature
Aircraft Aerodynamics:
- Schlichting,H. und Truckenbrodt, E: Aerodynamik des Flugzeugs (Bd I und II), Springer Verlag, 1960
- Hoerner, S.F.: Fluid Dynamic Lift, Hoerner Fluid Dynamics, 1975

Vehicle Aerodynamics
The main learning objectives of this course are: 1. Understand the thermodynamic, fluid-dynamic and chemical kinetics fundamentals of combustion and reactive processes in energy and materials technology. 2. Predict relevant parameters for combustion systems, such as laminar and turbulent flame speeds, adiabatic flame temperature or quenching distance. 3. Understand the causal relations of relevant combustion parameters such as the pressure influence on the laminar flame speed. 4. Analyze the challenges of developing sustainable combustion technologies based on carbon-neutral synthetic fuels.
Content

Reaction kinetics, fuel oxidation mechanisms, premixed and diffusion laminar flames, two-phase-flows, turbulence and turbulent combustion, pollutant formation, development of sustainable combustion technologies for power generation, shipping and aviation.  

Lecture notes

No script available. Instead, material will be provided in lecture slides and the following text book (which can be downloaded for free) will be followed:


Teaching language, assignments and lecture slides in English

Literature


151-0215-00L Fundamentals of Acoustics W+ 4 credits 3G  N. Noiray, B. Van Damme

Abstract

This course provides an introduction to acoustics. It focusses on fundamental phenomena of airborne and structure-borne sound waves. The lecture combines theoretical principles with practical insights and interpretations.

Objective

This course is proposed for Master and PhD students interested in getting knowledge in acoustics. Students will be able to understand, describe analytically and interpret sound generation, absorption and propagation.

Content

First, magnitudes characterizing sound propagation are reviewed and the constitutive equations for acoustics are derived. Then the different types of sources (monopole/dipole/quadrupole, punctual, non-compact) are introduced and linked to the noise generated by turbulent flows, coherent vortical structures or fluctuating heat release. The scattering of sound by rigid bodies is given in basic configurations. Analytical, experimental and numerical methods used to analyze sound in ducts and rooms are presented (Green functions, Galerkin expansions, Helmholtz solvers). The second part covers elastic wave phenomena, such as dispersion and vibration modes, in infinite and finite structures.

Lecture notes

Handouts will be distributed during the class

Literature

Books will be recommended for each chapter

151-0368-00L Aeroelasticity W+ 4 credits 2V+1U  M. Righi

Abstract

Introduction to the basics and into the methods of Aeroelasticity. An overview of the main static and dynamic phenomena arising from the interaction between structural and aerodynamic loads.

Objective

The course will provide a basic physical understanding of flow-structure interaction focused on lifting bodies such as wings. You will get to know the most important phenomena in the static and dynamic aeroelasticity, as well as a presentation of the most relevant analytical and numerical prediction methods.

Content

Introduction to steady and unsteady thin airfoil theory, extension to three dimension wing aerodynamics, strip theory, overview of numerical methods available (panel methods, CFD).

Introduction to unsteady aerodynamics (theory): Theodorsen and Wagner functions. Unsteady aerodynamics observed from numerical experiments (CFD). Generation of simplified mathematical models.

Presentation of steady aeroelasticity: equations of equilibrium for the typical section, aeroelastic deformation, effectiveness of the aeroelastic system, stability (definition), divergence condition, role played by a control surface, control effectiveness, sweep angle, aeroelastic tailoring of bending-torsion coupling. Ritz model to model beams, use of FEM, modal condensation, choice of generalized coordinates.


Numerical aeroelasticity (Test Cases extracted from the latest AIAA Aeroelastic Prediction Workshops). Generation of Reduced Order Models from CFD data (in some cases though Machine Learning).

Aeroelasticity of modern aircraft: assessment of the effects induced by the control surfaces and control systems (Aeroservoelasticity), active controlled aircraft, flutter-suppression systems, certification (EASA, FAA).

Planning and execution of Wind Tunnel experiments with aeroelastic models. Live-execution of an experiment in the WT of the ETH.

Lecture notes

A script in English language is available.

Literature

Bisplinghoff Ashley, Aeroelasticity


Competencies

Subject-specific Competencies Concepts and Theories fostered

Techniques and Technologies fostered

Method-specific Competencies Analytical Competencies fostered

Media and Digital Technologies fostered

Problem-solving fostered

Personal Competencies Creative Thinking fostered

Critical Thinking fostered

Integrity and Work Ethics fostered

151-0532-00L Nonlinear Dynamics and Chaos I W+ 4 credits 4G  G. Haller

Abstract

Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

Objective

This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.
Understanding the physics of failures and failure mechanisms enables reliability analysis and serves as a practical guide for electronic devices design, integration, systems development and manufacturing. The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.

**Lecture notes**

The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

**Prerequisites / notice**

- Prerequisites: Analysis, linear algebra and a basic course in differential equations.

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### 227-0377-10L

**Physics of Failure and Reliability of Electronic Devices and Systems**

**W+** 3 credits 2V

*I. Shorubalko, M. Held*

**Abstract**

Understanding the physics of failures and failure mechanisms enables reliability analysis and serves as a practical guide for electronic devices design, integration, systems development and manufacturing. The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.

**Objective**

Provide an understanding of the physics of failure and reliability. Introduce the degradation and failure mechanisms, basics of failure analysis, methods and tools of reliability testing.

**Content**

Summary of reliability and failure analysis terminology; physics of failure: materials properties, physical processes and failure mechanisms; failure analysis: basics and properties of instruments; quality assurance of technical systems (introduction); introduction to stochastic processes; reliability analysis; component selection and qualification; maintainability analysis (introduction); design rules for reliability, maintainability, reliability tests (introduction).

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### 227-0124-00L

**Embedded Systems**

**W+** 6 credits 4G

*M. Magno*

**Abstract**

An embedded system is a combination of hardware and software, either fixed in function or programmable, that is designed for a specific application scenario or for a specific task within a larger system. They are part of industrial machines such as agricultural and manufacturing equipment, automotive systems, medical equipment, household appliances, sensor networks, and the Internet of Things.

**Objective**

Understanding the specific requirements and problems that arise in embedded system applications.

Understanding the firmware structure of a microcontroller and an embedded system; memory architecture and memory map, internal and external peripherals, low-power and low-energy design as well as instruction sets and computational accelerators.

Understanding the firmware structure of a microcontroller and an embedded system; low-level instruction set, hardware-software interfaces, communication between components, embedded real-time operating systems, real-time scheduling, shared resources, low-power and low-energy programming as well as computational accelerators.

Using formal models and methods for designing and optimizing embedded systems.

Gaining experience with practical applications of the C programming language, embedded real-time operating systems, and debug functionalities of the associated design environment to design, implement, and verify embedded firmware.

Through project-based activities, students will gain substantial experience in applying the C programming language in the context of embedded systems. Projects will involve developing and implementing firmware, utilizing embedded real-time operating systems, and exploring the debugging functionalities within design environments. This hands-on approach aims to bridge the gap between theoretical knowledge and practical application, allowing students to experience the full lifecycle of embedded system development from design to implementation and verification.

**Content**

This lecture focuses on the design of embedded systems using formal models and methods.

Besides the theoretical lecture, the course contains laboratory sessions where students transfer the learned theoretical aspects into praxis by programming a microcontroller and interfacing it with sensors and actuators. Students will be exposed to a commercial microcontroller, and the development board extend with a custom-designed embedded systems educational platform.

Specifically, the following topics will be covered in the course: hardware and software structures of embedded systems, low-level instruction set, memory architecture and memory map, peripherals, hardware-software interfaces, communication between components, firmware design methodologies, firmware design using the C programming language, embedded real-time operating systems, real-time scheduling, shared resources, low-power, and low-energy designs as well as computational accelerators.

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### Space Communication

**Number** 227-0121-00L

**Abstract**

The course teaches the fundamentals of digital communication systems. The main topics are analog and digital modulation, signals and linear time-invariant systems, baseband and passband representations, continuous-time and discrete-time channels, noise, inter-symbol interference, detection theory, as well as the basics of forward error correction and information theory.
After attending the lectures, participating in the exercise sessions, and working on the homework problems (which include MATLAB coding assignments), the students will be able to:
- understand the fundamentals of digital communication systems
- explain the principles of modulation, demodulation, detection, and error correction
- analyze error rates of simple digital communication systems
- implement simple MATLAB simulations to calculate error rates

The course focuses on the fundamentals of digital communication systems. The course starts with analog modulation and discusses the main building blocks of modern digital communication systems. The topics include:
- essential components of digital communication systems
- analog and digital modulation
- baseband and passband representation; up- and down-conversion
- communication channels as LTI systems
- discretizing communication systems; sampling and quantization
- noise, signal-to-noise ratio (SNR), and interference
- detection theory and error rates
- basics of forward error correction
- basics of information theory
- orthogonal frequency-division multiplexing (OFDM)
- building blocks of modern communication systems

The exercises cover theoretical aspects as well as the basics of software-based communication-system modeling in MATLAB.

Lecture notes
Lecture notes will be distributed electronically at the beginning of the semester.


Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Problem-solving assessed

Personal Competencies
- Critical Thinking fostered
- Integrity and Work Ethics fostered

Objective
After completing this course, a student will understand the challenges of space flight imposed on communication components and systems, the available existing solutions of those problems, the main components of communications systems suitable for a spacecraft, and future technologies capable of enabling ultra-fast RF/mm-Wave, THz, and Laser communication links.

Content
- Space missions: scenarios and challenges on flight equipment
- Space communications: architectures, assets, payloads, link budgets, and use cases.
- Electromagnetic waves: radiation, operating principles of antennas, antenna types, and antenna parameters.
- RF electronics and antenna arrays architecture for SATCOM: low-noise amplifiers, beam forming, spatial filtering, and design examples.
- Laser communication links for free-space communication, architectures and implementation
- Microwave photonics for space applications: analog photonic links, optical generation and distribution of RF signals, and advanced RF filtering using photonic techniques.
- Communication channels: channel modeling, incl. atmospheric effects, Doppler, synchronization tracking, beam forming, tracking and finding.
- Signal modulation: modulation formats, adaptive optics, phase noise, and quantum key distribution (QKD).
- Outlook for emerging use-cases (ranging, time-, nav- and position-transfer (PNT))

Lecture notes
Lecture notes, Matlab programs, exercises and their solutions will be handed out.
Earth Observation

### 103-0187-01L  Space Geodesy

**Abstract**

**Objective**

- Describe the major observation techniques in space geodesy
- Describe the necessary modeling and analysis approaches to derive geodetic products of highest quality
- Select the appropriate space geodetic data for scientific investigations
- Analyze the space geodetic data for scientific purposes
- Interpret the scientific results

**Content**
Overview of GNSS, Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser Ranging (SLR/LLR), Satellite Radar Altimetry with the basic principles, the instruments and observation equations.

The course will provide the basics and principles of Radar Remote Sensing (specifically Synthetic Aperture Radar (SAR)) and its imaging techniques for the use of environmental parameter estimation.

**Literature**

**Prerequisites / notice**
Bachelor Studies of Electrical Engineering or Physics.
The rationale behind the structure of the course follows the idea that radar imaging and radar/SAR interferometry are closely related and that a basic understanding of the radar imaging concept is helpful to understand and interpret interferometric radar data for various applications.

The course starts with the real-aperture radar case and a first introduction to the concept of radar interferometry with applications to topographic mapping and mapping of surface displacements.

Based on that, the 2-D imaging concept used in synthetic aperture radar imaging is treated.

Then, we expand further on radar and SAR interferometric (InSAR) concepts and processing steps for single interferograms and stacks of interferograms also using persistent scatterer interferometry (PSI) to measure deformation based on time series of interferometric SAR data.

Finally, the 3-D radar imaging case (SAR tomography) is put into context with PSI/InSAR time series as an extension of the more classical interferometric approaches thereby closing the circle around the strongly related concepts of SAR imaging and interferometry.

Lecture notes/handouts for each topic will be provided online.

Additional reading material:

https://doi.org/10.1007/0-306-47633-9

It is highly recommended that the student has previously taken the following courses:
102-0617-00L: Basics and Principles of Radar Remote Sensing
and
102-0617-01L: Methodologies for Image Processing of Remote Sensing Data

Planetary Science

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<tr>
<th>Number</th>
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<td>103-0187-01L</td>
<td>Space Geodesy</td>
<td>W+</td>
<td>6</td>
<td>4G</td>
<td>B. Soja</td>
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Abstract


Objective

After this course, the students should be able to
- Describe the major observation techniques in space geodesy
- Describe the necessary modelling and analysis approaches to derive geodetic products of highest quality
- Select the appropriate space geodetic data for scientific investigations
- Analyze the space geodetic data for scientific purposes
- Interpret the scientific results

Content

Overview of GNSS, Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser Ranging (SLR/LLR), Satellite Radar Altimetry with the basic principles, the instruments and observation equations.

Equation of motion of the unperturbed and perturbed satellite orbit. Osculating and mean orbital elements. General and special perturbation theory and the determination of satellite orbits.

Lecture notes

Script M. Rothacher “Space Geodesy”

Competencies

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402-0398-00L                  Cosmic Dust in the Solar System: From Science Case to Mission Design

Abstract

This course provides students with a basic understanding of the science of cosmic dust in the solar system and how to measure it with space-based satellites and instrumentation. The lectures include the physical processes of both interplanetary and interstellar dust, trajectory simulations (i.e. orbital dynamics), in situ measurement techniques, and mission design aspects.

Objective

Cosmic dust is an important building block for planets and towards life. This course provides students with a basic understanding of the science of cosmic dust in the solar system, and how to measure it with space-based satellites and instrumentation. The lectures include the physical processes of both interplanetary and interstellar dust, trajectory simulations (i.e. orbital dynamics), in situ measurement techniques, and mission design aspects.

At the end of the course, students are able to classify the different types of dust in the solar system, and to relate them to their sources, sinks, their importance for planetary science and astronomy, physical processes, and appropriate measurement techniques. They will be able to simulate dust trajectories and use them to gain insight in how orbital dynamics and the space environment shape them. Students can design a basic concept of a space mission for dust measurements. The skills taught in this course will be useful to students in a broader way for planetary sciences.
Content
1. Introduction, course outline, historical notes, interstellar and interplanetary dust, dust in the solar system, sources, sinks, importance for science
2. Dust instrumentation and observables: ground-based, space-based and sample return techniques, calibration of dust instruments in the lab
3. Dust dynamics: recap basic aspects of orbital dynamics, the SPICE toolkit, types of orbits
4. Dust dynamics: space environment, dust processes and implications (e.g. in the early solar system), dust charging, consequences for dynamics, comparison with spacecraft dynamics
5. Dust models and dust data analysis: types of models and their limitations, data analysis
6. Mission design aspects: orbits, mission design limitations, advantages, disadvantages, instrument accommodation, example missions

Lecture notes
Slides will be provided before each lecture.

Literature
Interplanetary dust (freely available online)
https://link.springer.com/book/10.1007/978-3-642-56428-4

Cosmic dust from the laboratory to the stars (ETH Library)

Prerequisites / notice
The exercise solutions are performed in the Julia programming language.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered

Personal Competencies
- Creative Thinking fostered
- Critical Thinking fostered

Planet Formation
W+ 4 credits 2V
J. Szulágyi

Abstract
This course reviews the formation processes of terrestrial- and gaseous planets, and their moons. It provides a basic understanding on how our Solar System came to be, and how other planetary systems form, as well as how/when planets & moons can be habitable places for life.

Objective
Overview the state of the art planet- and moon formation models and identify open questions in the field. Understanding the formation process of planetary systems, and the formation of habitable worlds.

Content
1) Planet types
2) The Solar System planets
3) Extrasolar Planets
4) The protoplanetary disk where planets are forming. The initial conditions for planet formation.
5) The formation of the building blocks of planets (so-called "planetesimals")
6) Terrestrial Planet formation
7) Formation models of giant planets
8) Formation of moons
9) Evolution of planetary systems, orbital evolution of planets, resonances, planet-disk interactions
10) Origin of life, habitability, astrobiology

Literature
Astrophysics of Planet Formation
Armitage, Philip J.; Second edition – 2020
https://eth.swisscovery.slsp.ch/permalink/41SLSP_ETH/lshl64/alma99117212978705503

Prerequisites / notice
No prerequisites.
Max. 20 participants.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies fostered
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication assessed
- Cooperation and Teamwork fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

Earth - A (Unique?) Habitable Planet
W+ 6 credits 2V+1U
S. P. Quanz

Abstract
While thousands of extrasolar planets are known to orbit stars other than the Sun, Earth is - until now - the only planet known to be habitable. This lecture takes an interdisciplinary view on Earth as a habitable planet, how it formed, evolved, allowed life to flourish, and how its future might look like. Would we be able to identify another Earth-like planet amongst the population of exoplanets?

Objective
Attending students will
• understand Earth place in the cosmos
• learn tools to discern the history of Earth and other planets
• explore the origin and co-evolution of Earth and life
• put Earth in context with extrasolar planets

Autumn Semester 2024
This lecture focuses on our home planet - Earth - from an interdisciplinary perspective. As the search for habitable - and potentially even inhabited - extrasolar planets is one of the most dynamic research fields in modern astrophysics, understanding what makes a planet habitable is a topic of increasing importance; and a highly interdisciplinary topic. In broadbrushes, this lecture will discuss the building blocks of planetary systems and their formation, how we can learn about the history of Earth and other planets, what major epochs we can identify over the course of Earth's 4.5 billion year history, when life arose on Earth and what impact it had on Earth's evolution, how the future Earth might look like, and - last but certainly not least - how we can search for an Earth-like planet in our cosmic neighbourhood and what our chances are to be successful.

651-4037-00L  Mineral Resources I

Can be chosen as an elective course within the Bachelor.

Prospective MSc-Students attending the module "Mineral Resources" should attend Mineral Resources I and II in the first year of their MSc studies.

Abstract

Principles of hydrothermal ore formation, using base metal deposits (Cu, Pb, Zn) in sedimentary basins to explain the interplay of geological, chemical and physical factors from global scale to sample scale. Introduction to orthonmagmatic ore formation (mostly Cr, Ni, PGE). Introduction to supergene residual deposits (Ni, Al).

Objective

Understanding the fundamental processes of hydrothermal, magmatic and supergene ore formation, recognising and interpreting mineralised rocks in geological context.

Content

(a) Principles of hydrothermal ore formation: base metal deposits in sedimentary basins. Practical classification of sample suites by genetic ore deposit types

Mineral solubility and ore deposition, principles & thermodynamic prediction using activity diagrams. Driving forces and structural focussing of hydrothermal fluid flow

(b) Introduction to orthonmagmatic ore formation. Chromite, Ni-Cu sulphides and PGE in layered mafic intrusions. Distribution coefficients between silicate and sulphide melts. Carbonatites and pegmatite deposits.

(c) Introduction to supergene residual deposits with emphasis on Ni laterites and bauxites

Lecture notes

Notes handed out during lectures

Literature

Extensive literature list distributed in course

Prerequisites / notice

2 contact hours per lecture / week including lectures, exercises and practical study of samples, and small literature-based student presentations. Supplementary contact for sample practicals and exercises as required. Credits and mark based on participation in course (exercises, 50%) and 1100 written exam in the last lecture of the semester (50%).

Competencies

Subject-specific Competencies

Concepts and Theories fostered

Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies fostered

Problem-solving fostered

Social Competencies

Communication fostered

Cooperation and Teamwork fostered

Personal Competencies

Creative Thinking fostered

Critical Thinking assessed

Integrity and Work Ethics assessed

Self-direction and Self-management fostered

651-4015-00L  Earthquakes I: Seismotectonics

W+  3 credits  2G  A. P. Rinaldi

Abstract

If you're interested in knowing more about the relationship between seismicity and plate tectonics, this is the course for you. (If you're not that interested, but your program of study requires that you complete this course, this is also the course for you.)

Objective

The aim of the course is to obtain a basic understanding of the physical process behind earthquakes and their basic mathematical description. By the conclusion of this course, we hope that you will be able to:

- describe the relationship between earthquakes and plate tectonics in a more sophisticated and complete way
- explain earthquake source representations of varying complexity;
- address earthquakes in the context of different tectonic settings;
- explain the statistical behaviour of global earthquakes
- describe and connect the ingredients for a seismotectonic study

Content

The course features a series of 14 meetings, in which we review some fundamentals of continuum mechanics and tensor analysis required for a complete understanding of the relation between earthquakes and plate tectonics. Its main goal is to help you understand deformation at the small scale (fault) to the scale of plate tectonics. We will tell you about several ways to represent an earthquake source; we'll present these in order of increasing sophistication. You will enjoy (at least) a computer/class exercise and a guest lecture.

Topics covered in the course include:

- review of stress and deformation in the Earth, stress and strain tensors, rheology and failure criteria, fault stresses, friction and effects of fluids
- earthquake focal mechanisms; relationship between stress fields and focal mechanisms;
- seismic moment and moment tensors;
- crustal deformation from seismic, geologic, and geodetic observations;
- earthquake stress drop, scaling, and source parameters;
- global earthquake distribution; current global earthquake activity;
- different seismotectonic regions; examples of earthquake activity in different tectonic settings.

Lecture notes

Course notes will be made available on a designated course web site. Most of the topics discussed in the course are available in the book mentioned below.

Literature


Prerequisites / notice

Basic knowledge of continuum mechanics and rock mechanics, as well as notion of tensor analysis is strongly suggested. We recommend to have taken the course Continuum Mechanics (generally taught during the Fall semester).

This course will be taught in fall 2017 and it will be followed by Earthquakes 2: Source Physics in Spring 2018.

The course will be evaluated in a final written test covering the topics discussed during the lectures.

The course will be worth 3 credit points, and a satisfactory total grade (4 or better) is needed to obtain 3 ECTS.

The course will be given in English.

651-4041-00L  Sedimentology I: Physical Processes and Sedimentary Systems

W+  3 credits  2G  V. Picotti
The sedimentary record of sea-level change fostered the students to learn basic concepts of modern sedimentology and stratigraphy in the context of sequence stratigraphy and sea level change. They discuss the advantages and pitfalls of the method and look beyond. In particular we pay attention to introducing the importance of considering entire sediment routing systems and understanding their functioning.

Details on the program will be handed out during the first lecture.

We will study traces in the lithosphere that have been left behind by organisms during the course of Earth history and mineral components, which were built through biological processes or used as sources of energy and nutrients by organisms. Traces of life from the past will be compared with the development of the diversity of today’s organisms.

The course will allow you to ask questions about the origin and the evolution of life on Earth, to understand contemporary hypotheses and create new methods of developing them further. Theory is supplemented with observations in the field, exercises and the application of simple mathematical models. The course will enable you to integrate geological knowledge into topics that will be taught in subsequent earth science courses and into the current understanding of Earth history. You will learn to better understand modern geological settings and, if necessary, to recommend biochemically well-founded and responsible interventions or protective measures.

The course focuses on (a) geobiological cycles that play major roles in Earth history in aquatic and terrestrial ecosystems, (b) biosynthetic and metabolic processes, which are essential for life, (c) organisms which regulate and maintain geochemical cycling, and (d) chemical signals of past life in the geological record.

Accordingly, we must understand
- how biological cells and its components are built from essential elements and molecules,
- how cells function and which life styles organisms developed,
- where organisms can exist and which factors select for their presence,
- where biologically usable forms of energy come from, and under which conditions they can be exploited,
- how biological metabolism can change environmental conditions and composition,
- how biological products can lead to signals preserved in the rock record, and how biomolecules and elements are altered in sedimentary deposits,
- how organic and inorganic components are cycled through the biosphere, and how biogeochemical cycles function,
- how "biological innovations" evolved and changed in response to environmental changes.

Applied Case Studies, which supplement and illustrate the contents:
- Scientific applications of geobiological knowledge are found in fields like Microbial Ecology, Geochemistry, Palaeontology, Sedimentology, Petrology, Ocean Research, Environmental Sciences, Astrobiology and Archaeology.
- Practical applications of geobiological knowledge are needed in fields like stabilisation of existing and design of safe waste repositories, surveilling ground water resources, sewage treatment, exploitation of and prospecting for fossil carbon sources, soil remediation, mineral exploration and teaching, forensic science and medicine.
- Geobiology is a topical subject in Earth and planetary science.

Examining our planet's evolution through the lens of life sciences, we will review the evidence left by the rocks and explore its context using questions of what, when and where aspects.

The course will emphasise a hands-on learning approach rather than extensive theory, and will begin with an introduction to programming in MATLAB.

651-4143-00L Geobiology Students registering for the course confirm having read and accepted the terms and conditions for excursions and field courses of D-ERDW: https://www.ethz.ch/content/dam/ethz/special-interest/erdw/department/dokumente/studium/exkursionen/AGB_ERDW_Exkursionen_dt.pdf

Abstract

We will study traces in the lithosphere that have been left behind by organisms during the course of Earth history and mineral components, which were built through biological processes or used as sources of energy and nutrients by organisms. Traces of life from the past will be compared with the development of the diversity of today’s organisms.

Objective

The students learn basic concepts of modern sedimentology and stratigraphy in the context of sequence stratigraphy and sea level change. They discuss the advantages and pitfalls of the method and look beyond. In particular we pay attention to introducing the importance of considering entire sediment routing systems and understanding their functioning.

Details on the program will be handed out during the first lecture.

We will study traces in the lithosphere that have been left behind by organisms during the course of Earth history and mineral components, which were built through biological processes or used as sources of energy and nutrients by organisms. Traces of life from the past will be compared with the development of the diversity of today’s organisms.

Objective

The students learn basic concepts of modern sedimentology and stratigraphy in the context of sequence stratigraphy and sea level change. They discuss the advantages and pitfalls of the method and look beyond. In particular we pay attention to introducing the importance of considering entire sediment routing systems and understanding their functioning.
A provisional week-by-week schedule (subject to change) is as follows:

Week 1: Introduction to the finite difference approximation to differential equations. Introduction to programming in Matlab. Solving of 1D Poisson equation.


Week 3: Solving momentum and continuity equations in case of constant viscosity using stream function/vorticity formulation.


Weeks 5: Conservative finite differences for the momentum equation. "Free slip" and "no slip" boundary conditions. Solving momentum and continuity equations in case of variable viscosity using pressure-velocity formulation with staggered grid.


Week 7: Advection in 2-D with Marker-in-cell method. Combining flow calculation and advection for buoyancy driven flow.


Week 9: Solving 2D heat conservation equation in case of constant thermal conductivity with explicit and implicit approaches.

Week 10: Solving 2D heat conservation equation in case of variable thermal conductivity with implicit approach. Temperature advection with markers. Creating thermomechanical code by combining mechanical solution for 2D buoyancy driven flow with heat diffusion and advection based on marker-in-cell approach.

Week 11: Implementation of radioactive, adiabatic and shear heating to the thermomechanical code.

Week 12: Programming of solution of coupled solid-fluid momentum and continuity equations for the case of melt percolation in a rising mantle plume.


Week 14: Final project description for slab breakoff modeling.

GRADING will be based on weekly programming homeworks (50%) and a term project (50%) to develop an application of their choice to a more advanced level.

**Literature**

**Competencies**

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**Physics of Planetary Interiors**

**W+** 3 credits 2G A. Khan

**Abstract**
Planetary science encompasses the study of the physical and chemical nature of planetary bodies both in the Solar System and in extrasolar systems. The formation of planets, the forces that shaped their orbits and the processes that mold their interiors are part of planetary science. Understanding these complex phenomena requires knowledge from various geo- and astrophysically-related fields.

**Objective**
The goal of this course is to provide students with quantitative understanding of planetary science. The emphasis in this course will be on theoretical development of the fundamentals needed for understanding planetary materials, planetary formation and evolution, and planetary interiors.

**Content**
The course will loosely be divided into ~14 lectures on various topics to be held by the main lecturer. In addition to the lectures, the students will solve a number 'take-home' problems and will hand in reports.

Topics that will be covered in the course include:

1. Elasticity
2. Equations of state
3. Thermodynamics applied to mantle materials
4. Harmonicity and anharmonicity
5. Tidal potential, gravity and figure of a planet
6. Planetary rotation, precession and nutation
7. Orbital evolution and tidal dissipation
8. Heat
9. Free oscillations of a planet

**Prerequisites / notice**
Completion of "651-4130-00 Mathematical Methods" is required.
Completion of "651-4013-00L Potential Field Theory" is required.
Completion of "651-4096-00L Inverse Theory for Geophysics I: Basics" would be helpful.

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**Tectonics**

**W+** 3 credits 2V W. Behr, S. Willett
Abstract
Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales. Evaluation of plate tectonic and other orogenic processes through the study of reference examples of taken in Alps-Himalaya orogenic system.

Objective
Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales. Assessment of mechanisms responsible for plate movements (the Earth as a heat transfer machine, dynamics of earth mantle, plate driving forces) and subsequent large-scale structures (oceanic basins and cycle of the oceanic lithosphere, convergence and mountain systems and continental growth, etc) through theoretical and experimental information. Evaluation of plate tectonic and other orogenic processes through the study of reference examples of taken in Alps-Himalaya orogenic system.

Content
Plate tectonic frame work; earth cooling and mantle-plate interaction, three kinds of plate boundaries and their roles and characteristics, cycle of oceanic lithosphere, longfifty and growth of continents, supercontinents. Rheology of layered lithosphere and upper mantle. Obduction systems Collisions systems Extensional systems Basin evolution Passive and active continental margin evolution

Literature

651-4025-00L  Rock Mechanics and Rock Engineering  W+  4 credits  4V  P. A. Selvadurai
Abstract
This course focusses on the principles (fundamentals) and basic concepts of rock mechanics and rock engineering (e.g. tunnelling, rock slope stability).

Objective
The course aims to introduce the fundamentals and basic concepts of rock mechanics and generic rock engineering. The student shall understand how rocks behave at different scales, under various artificial loads and in the shallow subsurface (a few km below ground). The link between rock mechanics, geology, hydrogeology and tectonics (i.e. the conditions under which the rock formed) will be clearly established.

Content
The student shall understand basic principles of rock mechanics and rock engineering. In addition, the student shall learn how to apply the results from lab and field investigations to simple engineering problems. This knowledge is required for subsequent integration courses (Landslide Analysis and Hazard Mitigation; Engineering Geology of Underground Excavations).

701-0475-00L  Atmospheric Physics  W+  3 credits  2G  U. Lohmann
Abstract
This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation, especially prediction of showers and severe convective storms, and optical phenomena

Objective
Students are able to explain the mechanisms of cloud and precipitation storm formation using knowledge of thermodynamics and cloud microphysics. - to interpret precipitation radar images - to evaluate the significance of clouds and aerosol particles for artificial weather modification.

Content
In the course "Atmospheric Physics", the competencies of process understanding, system understanding and data analysis & interpretation are taught, applied and examined. Measurement methods are taught as well.

Content
The course starts with introducing selected concepts of thermodynamics for atmospheric processes: The students learn the concept of the thermodynamic equilibrium and derive the Clausius-Claypon equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Students also learn to use thermodynamic charts (tephigrams) and to identify cloud base, cloud top, available convective energy in radiosonde ascents. Atmospheric mixing processes are introduced as a basis for fog formation. The concept of an air parcel is used to understand convection. Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

With these basics, the different forms of precipitation (convective vs. stratiform) are discussed and how they can be identified in radar images. Students will also learn under which conditions severe convective storms (especially supercells with tornadoes) can form.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

Lecture notes
Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=20400
Literature
Lohmann, U., Lüönd, F. and Mahrt, F., An Introduction to Clouds:
From the Microscale to Climate, Cambridge Univ. Press, 391 pp., 2016.

An electronic version of this book can be obtained via the ETH library.

Prerequisites / notice
We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments.

There is a additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies fostered

Method-specific Competencies
- Analytical Competencies assessed
- Problem-solving assessed

Social Competencies
- Communication assessed

Personal Competencies
- Critical Thinking assessed
- Self-direction and Self-management assessed

701-1241-00L Atmospheric Remote Sensing W+ 3 credits 2G J. Gröbner, S. Kazantzis

Abstract
The course will provide advanced physical understanding on the fundamentals of passive and active remote sensing, measuring sensors and retrieval methods. A series of diverse remote sensing applications will be presented, including measurements/retrievals of various atmospheric composition parameters (ozone, aerosols, clouds, others) from surface based and satellite based instruments.

Objective
Main objectives of the course and what the students will be able to explain and use at the end of it are:
- The major atmospheric laws used for the retrieval of atmospheric composition and solar radiation parameters
- Ground based and satellite based retrieval examples for major atmospheric constituents
- Practical and experimental aspects on measuring atmospheric aerosols through the use of relevant instrumentation
- Explore major atmospheric measurement databases and use of the available data
- Interpretation of measurement and retrieval related results on atmospheric composition and solar radiation based on using combined retrieval data products

Content
Atmospheric passive and active remote sensing is connected with a large number of applications including: atmospheric composition, Earth-atmosphere radiative balance, atmospheric and weather prediction model assimilation, agriculture, energy and health related applications and many others.

The proposed lesson is divided in three sections including exercises:
- Fundamentals of remote sensing
- Sensors (surface based and satellites) and retrieval methods
- Applications

The first aim of the lecture is to provide an in-depth understand of the physical aspects and basic laws on the fundamentals of remote sensing to the students. The lectures will provide a basic to intermediate understanding of radiative transfer of electromagnetic radiation through the atmosphere, covering the spectrum from UV to thermal. Examples of atmospheric components that will be addressed are: ozone, aerosols, greenhouse gases, clouds, water vapor.

In addition, measuring sensors used from the surface or from satellites and the relevant retrieval methods based on passive and active remote sensing of atmospheric composition will be presented (e.g. Spectroradiometers, filter radiometers, Lidars and others).

Finally, we aim to demonstrate a series of diverse remote sensing applications, including atmospheric composition measurements and retrievals from surface- and satellite-based instruments, including calibration and validation aspects.

The exercises will be embedded in the overall course lectures to provide hands-on experience with the measurements and retrieval methods conducting measurements and organising small field experiments. Also with the use of atmospheric datasets available from specific instruments (e.g. satellite sensors) and networks (e.g. AERONET, GAWPFR).

More specific the course include:
- 3 introductory courses on climate variables, sensors, solar measurements and radiative transfer basics
- 7 courses including remote sensing techniques on solar UV measurements, total column ozone, trace gases, greenhouse gases, aerosols, cloud retrievals and lidar active remote sensing
- 3 exercises:
  a. Conducting sun photometric measurements in the field and retrieve aerosol optical depth, including a visit in Davos, World Calibration Center
  b. Exploring ground and satellite based solar UV, Ozone and aerosol measurements
  c. Using radiative transfer modeling tools

Finally, students are involved on presenting scientific literature on subjects they are interested in.

All exercises are conducted in student-forming teams

Lecture notes
Lecture slides will be provided via Moodle before every lecture.

Prerequisites / notice
none
Abstract
This course offers a systematic introduction to statistical and machine learning methods with focus on applications in atmospheric and climate science. Focus is on the theoretical and mathematical basis of supervised statistical learning (advanced regression, nonparametric methods) and their application in practice with hands-on exercises.

Objective
Students:
- Understand the theoretical basis of machine learning
- Are familiar with overarching concepts such as bias-variance trade-off, cost-functions, hyper parameters, cross-validation
- Have good command of the theoretical basis of selected machine learning tools
- Are able to select the appropriate statistical learning tools to tackle atmospheric and climate research problems
- Can apply methods of statistical learning in atmospheric and climate research
- Data in atmospheric and climate research (data types, observations, models)
- Exploring properties of atmospheric and climate data (data in space and time, multivariate data)
- Concepts of supervised learning (bias variance trade-off, overfitting, cross-validation)
- Advanced linear regression (multiple linear regression, regularization)
- Non-linear regression (local linear regression, regression trees, gradient boosting, random forests, neural networks)
- Bootstrapping
- Keynote speakers showcasing recent topics in statistical learning and high-level applications for atmospheric and climate research

Literature

Prerequisites / notice
- Knowledge of introductory statistics
- Overview on the climate system
- Basic experience in a programming language

Course is limited to 30 participants.

Exercises will be in the R for most of the sessions and in Python for deep learning.
This course is a hands-on introduction to self-driving cars using the Duckietown platform.

Each student is given a mobile wheeled robot and throughout the class must configure and program.

Objective
This course includes the basics of modeling, perception, planning, control, and learning for self-driving cars. The focus is on the integration and co-design of components and behaviors rather than algorithmic dept.

The objective of the class is to give the student a pragmatic view of what it takes to design and operate a fleet of self-driving cars or any other large robotic systems.

Content
Perception, planning, modeling, and control, leveraging primarily on vision data.

Lecture notes
Lecture notes, primarily in the form of slides and tutorials, will be accessible from Moodle.

Prerequisites
Students should have taken a basic course in probability theory, computer vision, and control systems, and should be familiar and comfortable with programming (Python), Linux, and Git utilization.

In introduction to ROS will be given, but it's strongly advised that students have prior exposure to and experience with ROS to effectively navigate through the homework assignments and the final project

Method-specific Competencies
- Robots
- Hybrid systems with nonholonomic constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

151-0325-00L Planning and Decision Making for Autonomous Robots

Abstract
Planning safe and efficient motions for robots in complex environments, often shared with humans and other robots, is a difficult problem combining discrete and continuous mathematics, as well as probabilistic, game-theoretic, and ethical/regulated aspects. This course will cover the algorithmic foundations of motion planning, with an eye to real-world implementation issues.

Objective
The students will learn how to design and implement state-of-the-art algorithms for planning the motion of robots executing challenging tasks in complex environments.

Content

Lecture notes
Course notes and other education material will be provided for free in an electronic form.

Additional materials can also be accessed from the EdX MOOC called “Self-driving cars with Duckietown”.

Prerequisites
Students should have taken basic courses in optimization, control systems, probability theory, and should be familiar with modern programming languages and practices (e.g., Python, and/or C/C++). Previous exposure to robotic systems is a definite advantage.

Method-specific Competencies
- Robots
- Hybrid systems with nonholonomic constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

151-0371-00L Advanced Model Predictive Control

Abstract
Model predictive control (MPC) has established itself as a powerful control technique for complex systems under state and input constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

Objective
Design, implement and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.

Content
Topics include:
- Nominal MPC for uncertain systems (nominal robustness)
- Robust MPC
- Stochastic MPC
- Review of regression methods
- Set-membership Identification and robust data-driven MPC
- Bayesian regression and stochastic data-driven MPC
- MPC as safety filter for reinforcement learning

Lecture notes
Lecture notes will be provided.

Prerequisites
Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control in Spring Semester) strongly recommended.

Background in linear algebra and stochastic systems recommended.

151-0563-01L Dynamic Programming and Optimal Control

Abstract
This course is a hands-on introduction to self-driving cars using the Duckietown platform.

Each student is given a mobile wheeled robot and throughout the class must configure and program.

Objective
This course includes the basics of modeling, perception, planning, control, and learning for self-driving cars. The focus is on the integration and co-design of components and behaviors rather than algorithmic dept.

The objective of the class is to give the student a pragmatic view of what it takes to design and operate a fleet of self-driving cars or any other large robotic systems.

Content
Perception, planning, modeling, and control, leveraging primarily on vision data.

Lecture notes
Lecture notes, primarily in the form of slides and tutorials, will be accessible from Moodle.

Prerequisites
Students should have taken a basic course in probability theory, computer vision, and control systems, and should be familiar and comfortable with programming (Python), Linux, and Git utilization.

In introduction to ROS will be given, but it's strongly advised that students have prior exposure to and experience with ROS to effectively navigate through the homework assignments and the final project

Method-specific Competencies
- Robots
- Hybrid systems with nonholonomic constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

151-0325-00L Planning and Decision Making for Autonomous Robots

Abstract
Planning safe and efficient motions for robots in complex environments, often shared with humans and other robots, is a difficult problem combining discrete and continuous mathematics, as well as probabilistic, game-theoretic, and ethical/regulated aspects. This course will cover the algorithmic foundations of motion planning, with an eye to real-world implementation issues.

Objective
The students will learn how to design and implement state-of-the-art algorithms for planning the motion of robots executing challenging tasks in complex environments.

Content

Lecture notes
Course notes and other education material will be provided for free in an electronic form.

Prerequisites
Students should have taken basic courses in optimization, control systems, probability theory, and should be familiar with modern programming languages and practices (e.g., Python, and/or C/C++). Previous exposure to robotic systems is a definite advantage.

Method-specific Competencies
- Robots
- Hybrid systems with nonholonomic constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

151-0371-00L Advanced Model Predictive Control

Abstract
Model predictive control (MPC) has established itself as a powerful control technique for complex systems under state and input constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

Objective
Design, implement and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.

Content
Topics include:
- Nominal MPC for uncertain systems (nominal robustness)
- Robust MPC
- Stochastic MPC
- Review of regression methods
- Set-membership Identification and robust data-driven MPC
- Bayesian regression and stochastic data-driven MPC
- MPC as safety filter for reinforcement learning

Lecture notes
Lecture notes will be provided.

Prerequisites
Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control in Spring Semester) strongly recommended.

Background in linear algebra and stochastic systems recommended.
Real-World Robotics - A Hands-On Project Class

151-0615-00L

Learning Objective 1: High-Level System Design
System and product design combined with requirement generation and verification are essential for this robotics project. The students will apply previously acquired system design knowledge and methods to a hands-on challenge.

Learning Objective 2: Robot Design and Simulation
Students will gain experience implementing and simulating robotic systems using modern design, modelling, and simulation techniques such as CAD and Isaac Gym. These techniques are essential in any design process to understand the expected system behaviour. This requires a thorough understanding of the system’s kinematics, dynamics, material, actuation principle, and physical limitations. Students will learn the theory and limitations behind modelling and simulation software.

Learning Objective 3: Robot Fabrication
Students will learn to use the previously designed CAD models for successful robot fabrication. Additionally, the iterative nature of the process will allow them to develop their critical thinking skills in assessing the limitations of their design as well as possible sources for improvements. Building the robot will equip students with essential skills for using robots in the real world.

Learning Objective 4: Control, Integration, and Testing
Students can directly apply the knowledge acquired in their baseline control courses. They will gain theoretical knowledge on how to model and develop intelligent control algorithms. Perception methods and alternative machine-learning techniques will be taught. They will gain experience in testing their robots' performance in both hard- and software to enhance their design and suggest future improvements.

Learning Objective 5: Robot production
Students will learn how to choose between state-of-the-art industrial production processes to manufacture a soft robot, by understanding their limitations and requirements. They will also learn how to optimize the robot design to account for a specific production process.

During this course, the students will divide into teams and each group will independently develop an articulated robotic arm to solve a real-world robotic challenge, which will take place at the end of the course. The students will learn the key theoretical concepts required to model, manufacture, control and test a soft robot, along with developing the programming, hardware and engineering skills through hands-on workshops.

This course is composed of tutorials, which will be available on the course website where the lecturer will provide all the necessary theoretical input, focus talks where robotic experts will present a particular aspect of the manipulator in detail, and workshops where the students will have the possibility to hands-on learn how to implement the solutions required to solve their challenge. Finally, there will be time slots to autonomously work on the manufacturing and development of the team's robot and an online forum will be available to help the students throughout the entire course.

This course is divided into 5 parts:

Part 1: Challenge introduction
- Identify the functional requirements necessary for the final challenge
- Evaluate the existing manipulator designs to optimize them for the specific task

Part 2: Robot Design
- Develop a CAD model based on the high-level system design.
- Integrate motors, pneumatics components and other required materials in the design

Part 3: Robot Fabrication
- Come up with a fabrication method and plan using the presented fabrication skills.
- Fabricate the robot and its actuators based on the CAD model.
- Evaluate, modify, and enhance the fabrication approach.

Part 4: Soft Robot Simulation
- Simulate the soft manipulator through a simulation framework
- Optimize the simulation parameters to reflect the experimental setup

Part 5: Control, Integration, and Testing
- Formulate the dynamic skills needed for real-life application.
- Develop traditional and learning-based control algorithms and test them in simulation.
- Integrate controller design into the fabricated robot.
- Build, test, fail, and repeat until the soft robot works as desired in simple tasks.
- Upgrade and validate the robot for performance in real-world conditions and verify requirements.

Part 6: Product development
- Propose a manufacturing process to bring the robot from a prototype to the final product
- Optimize the robot for production

Lecture notes
All class materials, including slides, tutorials, and supporting literature can be found on the class webpage (rwr.ethz.ch) and on Moodle, supported by discussion and Q&A forums. Focus talks, Q&A sessions, and workshops will happen on Monday between 14:00 and 16:00.

Literature
Prerequisites / notice

Students are expected to have attended introductory courses in dynamics, control systems and robotics.

The registration to this course is limited to 40 students. For this reason, it is required to apply through the following module: https://forms.gle/2Fk8KLHra/7miAekk8

The graded semester performance consists of the final team performance in the class challenge, a final team presentation and report, weekly Moodle quizzes, and attendance at the focus talks and workshops.

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed

Decision-making assessed

Problem-solving assessed

Project Management assessed

Social Competencies

Communication assessed

Cooperation and Teamwork assessed

Personal Competencies

Adaptability and Flexibility assessed

Creative Thinking assessed

Critical Thinking assessed

Abstract

For a robot to be autonomous, it has to perceive and understand the world around it. This course introduces you to the key computer vision algorithms used in mobile robotics, such as feature extraction, structure from motion, dense reconstruction, tracking, image retrieval, event-based vision, and visual-inertial odometry. In this context, the algorithms behind Hololens, Oculus Quest, and the NASA Mars rovers.

Objective

Learn the fundamental computer vision algorithms used in mobile robotics, in particular: filtering, feature extraction, structure from motion, multiple view geometry, dense reconstruction, tracking, image retrieval, event-based vision, and visual-inertial odometry and Simultaneous Localization And Mapping (SLAM) (the algorithms behind Hololens, Facebook-Oculus Quest, and the NASA Mars rovers).

Content

Each lecture will be followed by a lab session where you will learn to implement a building block of a visual odometry algorithm in Matlab.

By the end of the course, you will integrate all these building blocks into a working visual odometry algorithm.

Lecture notes

Lecture slides will be made available on the course official website: http://rpg.ifi.uzh.ch/teaching/html

Literature


Prerequisites / notice

Note: If you are interested in taking UZH courses, you must register as an incoming mobility student at UZH. For details, see as follows:

UZH course enrollment for ETH student at University of Zurich (UZH) > Mobility within Switzerland – Incoming > Module Mobility: The easiest way to take individual modules/courses to supplement your studies at your home university is with module mobility. This option is not available to students who have dropped out of their home university or have been definitely excluded or banned from the relevant program > Application and Deadlines: Applications are submitted via the UZH application portal (https://www.uzh.ch/cms/en/studies/application/chi/mobility.html).

Step-by-step guidelines on how ETH students can register for this course, are given on the official course website: https://rpg.ifi.uzh.ch/teaching/html

ATTENTION: When you book the course at UZH, you are automatically registered for the exam at UZH and you can unregister until the October deadline. After registering for the course, you as an ETH student need to check out your **UZH email account** to receive the related information from the lecturer.

151-0632-00L Vision Algorithms for Mobile Robotics (University of Zurich) W+ 6 credits 2V+2U D. Scaramuzza

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student:

UZH Module Code: DINF2039

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cms/en/studies/application/deadline s.html

Abstract

We will provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing.

Objective

The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems. The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

Content

The course consists of three parts: First, we will refresh and deepen the student’s knowledge in kinematics, dynamics, and rotations of multi-body systems. In this context, the learning material will build upon the courses for mechanics and dynamics available at ETH, with the particular focus on their application to robotic systems. The goal is to foster the conceptual understanding of similarities and differences among the various types of robots. In the second part, we will apply the learned material to classical robotic arms as well as legged systems and discuss kinematic constraints and interaction forces. In the third part, focus is put on modeling fixed wing aircraft, along with related design and control concepts. In this context, we also touch aerodynamics and flight mechanics to an extent typically required in robotics. The last part finally covers different helicopter types, with a focus on quadrotors and the coaxial configuration which we see today in many UAV applications. Case studies on all main topics provide the link to real applications and to the state of the art in robotics.

Prerequisites / notice

The contents of the following ETH Bachelor lectures or equivalent are assumed to be known: Mechanics and Dynamics, Control, Basics in Fluid Dynamics.

151-0851-00L Robot Dynamics W+ 4 credits 2V+2U M. Hutter, R. Siegwart, J. Tordesillas Torres

Abstract

We will provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing.

Objective

The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems. The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

Content

The course consists of three parts: First, we will refresh and deepen the student’s knowledge in kinematics, dynamics, and rotations of multi-body systems. In this context, the learning material will build upon the courses for mechanics and dynamics available at ETH, with the particular focus on their application to robotic systems. The goal is to foster the conceptual understanding of similarities and differences among the various types of robots. In the second part, we will apply the learned material to classical robotic arms as well as legged systems and discuss kinematic constraints and interaction forces. In the third part, focus is put on modeling fixed wing aircraft, along with related design and control concepts. In this context, we also touch aerodynamics and flight mechanics to an extent typically required in robotics. The last part finally covers different helicopter types, with a focus on quadrotors and the coaxial configuration which we see today in many UAV applications. Case studies on all main topics provide the link to real applications and to the state of the art in robotics.

Prerequisites / notice

The contents of the following ETH Bachelor lectures or equivalent are assumed to be known: Mechanics and Dynamics, Control, Basics in Fluid Dynamics.

151-1116-00L Introduction to Aircraft and Car Aerodynamics W+ 4 credits 3G M. Immer, F. Schröder

Abstract


Objective

An introduction to the basic principles and interrelationships of aircraft and automotive aerodynamics.

To understand the basic relations of the origin of aerodynamic forces (i.e., lift, drag). To quantify the aerodynamic forces for basic configurations of aircraft and car components.

Illustration of the intrinsic problems and results using examples.

Using experimental and theoretical methods to illustrate possibilities and limits.
Content

Aircraft aerodynamics: atmosphere, aerodynamic forces (ascending force: profile, wings. Resistance, residual resistance, induced resistance); thrust (overview of the propulsion system, aerodynamics of the propellers), introduction to static longitudinal stability.


Lecture notes

Preparation materials & slides are provided prior to each class

Literature

Aircraft Aerodynamics:
- Schlichting, H. und Truckenbrodt, E: Aerodynamik des Flugzeuges (Bd I und II), Springer Verlag, 1960
- Hoerner, S.F.: Fluid Dynamic Lift, Hoerner Fluid Dynamics, 1975

Vehicle Aerodynamics

151-0623-00L ETH Zurich Distinguished Seminar in Robotics, Systems and Controls

W+ 1 credit 1S
B. Nelson, M. Hutter, R. Katzschmann, C. Menon, R. Riener, R. Siegwart

Abstract

This course consists of a series of seven lectures given by researchers who have distinguished themselves in the area of Robotics, Systems, and Controls.

Objective

Obtain an overview of various topics in Robotics, Systems, and Controls from leaders in the field. Please see http://www.msrl.ethz.ch/education/distinguished-seminar-in-robotics--systems---controls--151-0623-0.html for a list of upcoming lectures.

Content

This course consists of a series of seven lectures given by researchers who have distinguished themselves in the area of Robotics, Systems, and Controls. MSc students in Robotics, Systems, and Controls are required to attend every lecture. Attendance will be monitored. If for some reason a student cannot attend one of the lectures, the student must select another ETH or University of Zurich seminar related to the field and submit a one page description of the seminar topic. Please see http://www.msrl.ethz.ch/education/distinguished-seminar-in-robotics--systems---controls--151-0623-0.html for a suggestion of other lectures.

Prerequisites / notice

Students are required to attend all seven lectures to obtain credit. If a student must miss a lecture then attendance at a related special lecture will be accepted that is reported in a one page summary of the attended lecture. No exceptions to this rule are allowed.

227-0124-00L Embedded Systems

W+ 6 credits 4G
M. Magno

Abstract

An embedded system is a combination of hardware and software, either fixed in function or programmable, that is designed for a specific application scenario or for a specific task within a larger system. They are part of industrial machines such as agricultural and manufacturing equipment, automotive systems, medical equipment, household appliances, sensor networks, and the Internet of Things.

Objective

Understanding the specific requirements and problems that arise in embedded system applications.

Understanding the hardware structure of a microcontroller and an embedded system; memory architecture and memory map, internal and external peripherals, low-power and low-energy design as well as instruction sets and computational accelerators.

Understanding the firmware structure of a microcontroller and an embedded system; low-level instruction set, hardware-software interfaces, communication between components, embedded real-time operating systems, real-time scheduling, shared resources, low-power and low-energy programming as well as computational accelerators.

Using formal models and methods for designing and optimizing embedded systems.

Gaining experience with practical applications of the C programming language, embedded real-time operating systems, and debug functionalities of the associated design environment to design, implement, and verify embedded firmware.

Through project-based activities, students will gain substantial experience in applying the C programming language in the context of embedded systems. Projects will involve developing and implementing firmware, utilizing embedded real-time operating systems, and exploring the debugging functionalities within design environments. This hands-on approach aims to bridge the gap between theoretical knowledge and practical application, allowing students to experience the full lifecycle of embedded system development from design to implementation and verification.

Content

This lecture focuses on the design of embedded systems using formal models and methods.

Besides the theoretical lecture, the course contains laboratory sessions where students transfer the learned theoretical aspects into praxis by programming a microcontroller and interfacing it with sensors and actuators. Students will be exposed to a commercial microcontroller, and the development board extend with a custom-designed embedded systems educational platform.

Specifically, the following topics will be covered in the course: hardware and software structures of embedded systems, low-level instruction set, memory architecture and memory map, peripherals, hardware-software interfaces, communication between components, firmware design methodologies, firmware design using the C programming language, embedded real-time operating systems, real-time scheduling, shared resources, low-power, and low-energy designs well as computational accelerators.

Lecture notes

Lecture material, publications, exercise sheets, and laboratory documentation will be available on the course's Moodle page.

Literature


Prerequisites / notice

Prerequisites: C programming, circuit theory, digital logic, binary number representations.

Competencies

Recommended: basic knowledge of assembly programming and computer architecture.

Image Analysis and Computer Vision

227-0447-00L

W+ 6 credits 3V+1U
E. Konukoglu, E. Erdil, F. Yu

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

assessed

assessed

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Students will learn about the fundamentals of autonomous cars and of the computer vision models and methods these cars use to analyze
This course introduces the core computer vision techniques and algorithms that autonomous cars use to perceive the semantics and
C. Sakaridis
Lecture slides are provided in PDF format.
Computer Vision and Artificial Intelligence for
Abstract
Objective
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience
Content
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image
processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is
considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then
turns to image discretization, necessary to process images by computer.
The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear
filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic
information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific
objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based
approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are
given.

Lecture notes
Prerequisites
Prerequisites:
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux.
The course language is English.
227-0560-00L
Computer Vision and Artificial Intelligence for
Autonomous Cars  
Up until FS2022 offered as Deep Learning for Autonomous Driving
Abstract
This course introduces the core computer vision techniques and algorithms that autonomous cars use to perceive the semantics and
game of their driving environment, localize themselves in it, and predict its dynamic evolution. Emphasis is placed on techniques
tailored for real-world settings, such as multi-modal fusion, domain-adaptive and outlier-aware architectures, and multi-agent methods.
Objective
Students will learn about the fundamentals of autonomous cars and of the computer vision models and methods these cars use to analyze
their environment and navigate themselves in it. Students will be presented with state-of-the-art representations and algorithms for semantic, geometric and temporal
visual reasoning in automated driving and will gain hands-on experience in developing computer vision algorithms and architectures for
solving such tasks.

After completing this course, students will be able to:
1. understand the operating principles of visual sensors in autonomous cars
2. differentiate between the core architectural paradigms and components of modern visual perception models and describe their logic and
the role of their parameters  
3. systematically categorize the main visual tasks related to automated driving and understand the primary representations and algorithms
which are used for solving them
4. critically analyze and evaluate current research in the area of computer vision for autonomous cars
5. practically reproduce state-of-the-art computer vision methods in automated driving
6. independently develop new models for visual perception
Content
The content of the lectures consists in the following topics:
1. Fundamentals
(a) Fundamentals of autonomous cars and their visual sensors
(b) Fundamental computer vision architectures and algorithms for autonomous cars

2. Semantic perception
(a) Semantic segmentation
(b) Object detection
(c) Instance segmentation and panoptic segmentation

3. Geometric perception and localization
(a) Depth estimation
(b) 3D reconstruction
(c) Visual localization
(d) Unimodal visual/ldar 3D object detection

4. Robust perception: multi-modal, multi-domain and multi-agent methods
(a) Multi-modal 2D and 3D object detection
(b) Visual grounding and verbo-visual fusion
(c) Domain-adaptive and outlier-aware semantic perception
(d) Vehicle-to-vehicle communication for perception

5. Temporal perception
(a) Multiple object tracking
(b) Motion prediction

The practical projects involve implementing complex computer vision architectures and algorithms and applying them to real-world, multi-
modal driving datasets. In particular, students will develop models and algorithms for:
1. Semantic segmentation and depth estimation
2. Sensor calibration for multi-modal 3D driving datasets
3. 3D object detection using lidars

Lecture notes
Lecture slides are provided in PDF format.
Prerequisites
Students are expected to have a solid basic knowledge of linear algebra, multivariate calculus, and probability theory, and a basic
background in computer vision and machine learning. All practical projects will require solid background in programming and will be based
on Python and libraries of it such as PyTorch.
### System Identification

**Abstract**
Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.

**Objective**
To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.

**Content**
- Introduction to modeling: Black-box and grey-box models; Parametric and non-parametric models; ARX, ARMAX (etc.) models.
- Predictive, open-loop, black-box identification methods. Time and frequency domain methods. Subspace identification methods.
- Optimal experimental design, Cramer-Rao bounds, input signal design.
- Parametric identification methods. On-line and batch approaches.

**Literature**

**Prerequisites / notice**
- Control systems (227-0216-00L) or equivalent.

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### Advanced Machine Learning

**Abstract**
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

**Content**
- The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.
- Topics covered in the lecture include:
  - Fundamentals:
    - What is data?
    - Bayesian Learning
    - Computational learning theory
  - Supervised learning:
    - Ensembles: Bagging and Boosting
    - Max Margin methods
    - Neural networks
  - Unsupervised learning:
    - Dimensionality reduction techniques
    - Clustering
    - Mixture Models
    - Non-parametric density estimation
    - Learning Dynamical Systems
- No lecture notes, but slides will be made available on the course webpage.

**Literature**

**Prerequisites / notice**
- The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.
- PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

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### Human Computer Interaction

**Abstract**
The course provides an introduction to the field of human-computer interaction, emphasising the central role of the user in system design. Through detailed case studies, students will be introduced to different methods used to analyse the user experience and shown how these can inform the design of new interfaces, systems and technologies.

**Objective**
The goal of the course is that students should understand the principles of user-centred design and be able to apply these in practice. As well as understand the basic notions of Computational Design in a HCI context.
Content

The course will introduce students to several methods of analysing the user experience, showing how these can be used at different stages of system development from requirements analysis through to usability testing.

Students will get experience of designing and carrying out user studies as well as analysing results. The course will also cover the basic principles of interaction design. Practical exercises related to touch and gesture-based interaction will be used to reinforce the concepts introduced in the lecture. To get students to further think beyond traditional system design, we will discuss issues related to ambient information and awareness.

263-5210-00L Probabilistic Artificial Intelligence

W+ 8 credits

A. Krause

Abstract

This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective

How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit “intelligent” behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content

Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice

Solid basic knowledge in statistics, algorithms and programming.

The material covered in the course “Introduction to Machine Learning” is considered as a prerequisite.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Decision-making

Social Competencies

Communication

Personal Competencies

Creative Thinking

Critical Thinking

Integrity and Work Ethics

263-5902-00L Computer Vision

W+ 8 credits

3V+1U+3A

M. Pollefeys, S. Tang, F. Yu

Abstract

The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective

The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve these.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

Prerequisites / notice

It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

376-1504-00L Physical Human Robot Interaction (pHRI)

W+ 4 credits

2V+2U

O. Lambercy, P. Wolf

Abstract

This course focuses on the emerging, interdisciplinary field of physical human-robot interaction, bringing together themes from robotics, real-time control, human factors, haptics, virtual environments, interaction design and other fields to enable the development of human-oriented robotic systems.

Objective

The objective of this course is to give an introduction to the fundamentals of physical human-robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and de- sign safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1) Identify critical human factors in physical human-robot interaction and use these to derive design requirements;
2) Compare and select mechatronic components that optimally fulfill the defined design requirements;
3) Derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;
4) Design control hardware and software and implement and test human-interactive control strategies on the physical setup;
5) Characterize and optimize such systems using both engineering and psychophysical evaluation metrics;
6) Investigate and optimize one aspect of the physical setup and convey and defend the gained insights in a technical presentation.

Content

This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in device design for humans such as transparency and stability analysis, safety hardware and procedures. The course is organized into lectures that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical human-robot interaction, laboratory sessions and lab visits.

Students will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. Here the salient features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic paddle (https://relab.ethz.ch/downloads/open-hardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

Lecture notes

Will be distributed on Moodle before the lectures.
### Literature


### Prerequisites / notice

- **Notice:** The registration is limited to 26 students.
- **Prerequisites:** The students are expected to have basic control knowledge from previous classes.
- **Registration:** http://www.relab.ethz.ch/education/courses/phri.html

### Competencies

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<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Problem-solving</th>
<th>Project Management</th>
<th>Communication</th>
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<tr>
<td>Subject-specific Competencies</td>
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### Elective Courses

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<td>227-0417-00L</td>
<td>Information Theory I</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>A. Lapidoth</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.</td>
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<tr>
<td>Objective</td>
<td>The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity.</td>
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<tr>
<td>Content</td>
<td>The fundamentals of Information Theory including Shannon's source coding and channel coding theorems</td>
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<tr>
<td>Literature</td>
<td>T.M. Cover and J. Thomas, Elements of Information Theory (second edition)</td>
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<tr>
<td>227-0146-00L</td>
<td>Data Conversion System Design</td>
<td>W</td>
<td>6</td>
<td>2+V+2U</td>
<td>T. Burger, G. Cervelli, R. Reutemann</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course provides a thorough treatment of integrated data conversion systems from system level specifications and trade-offs, over architecture choice down to circuit implementation.</td>
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<tr>
<td>Objective</td>
<td>Data conversion systems are substantial sub-parts of many electronic systems, e.g. the audio conversion system of a home-cinema systems or the base-band front-end of a wireless modem. Data conversion systems usually determine the performance of the overall system in terms of dynamic range and linearity. Students will learn the underlying principles of data conversion and be introduced to the different methods and circuit architectures to implement such a conversion. The conversion methods such as successive approximation or algorithmic conversion are explained based on their operation principle accompanied with the appropriate mathematical calculations, including effects of non-idealties in some cases. After successful completion of the course students should understand the concept of an ideal ADC, know all major converter architectures, their principle of operation and what governs their performance.</td>
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Data: 15.06.2024 12:39 | Autumn Semester 2024 | Page 2309 of 2653
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Fostered
- Analytical Competencies

227-0116-00L VLSI 1: HDL Based Design for FPGAs

This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:

- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.

This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:

- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.

Prerequisites:
Basics of digital circuits.

Examination:
In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details:
https://lis-students.ee.ethz.ch/lectures/vlsi-i/

252-1411-00L Security of Wireless Networks

This course discusses physical layer aspects of wireless communication and a wide range of security-related topics in the domain of wireless technologies. It mainly targets computer science students. Though useful, a background in signal processing or physical layer concepts is not required. A basic understanding of security (e.g. as taught in 252-0211.00L Information Security) is recommended.

After this course, students should be able to describe and classify security goals of and attacks on various wireless networks and technologies, with an emphasis on physical layer aspects.

- Introduction to wireless communication
- Physical layer security schemes
- Spreading techniques and their application in jamming-resilient communication and Global Navigation Satellite Systems (GNSSs)
- Secure ranging with Ultra-Wide Band (UWB)
- Security aspects of cellular networks, WiFi, and Bluetooth Low Energy (BLE)
Quantum Information Processing I: Concepts

402-0448-01L

This theory part QIP I together with the experimental part 402-0448-02L QIP II (both offered in the autumn semester) combine to the core course in experimental physics "Quantum Information Processing" (totally 10 ECTS credits). This applies to the Master's degree programme in Physics.

Abstract
The course covers the key concepts and formalism of quantum information processing. Topics include quantum algorithms, quantum error correction, quantum cryptography, and quantum metrology, with an emphasis on the power of quantum information processing beyond that of classical information processing. The formalism of quantum states, measurements, and channels is developed in detail.

Objective
By the end of the course students are able to explain the basic mathematical formalism of quantum mechanics and apply it to quantum information processing problems. They are able to adapt and apply these concepts and methods to analyze and discuss quantum algorithms and other quantum information-processing protocols.

Content
The topics covered in the course will include quantum circuits, gate decomposition and universal sets of gates, efficiency of quantum circuits, quantum algorithms (Shor, Grover, Deutsch-Josza,...), stabilizer-based quantum error correction, fault-tolerant designs, the BB84 quantum key distribution protocol, and simple methods of quantum metrology.

Lecture notes
Will be provided.

Literature
Quantum Computation and Quantum Information
Michael Nielsen and Isaac Chuang
Cambridge University Press

Prerequisites / notice
A good understanding of finite dimensional linear algebra is recommended.

Competencies

<table>
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<td>Adaptable and Flexibility</td>
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<td>Critical Thinking</td>
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Science in Perspective

Recommended Science in Perspective (Type B) for D-EAPS

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Master's Thesis

Key for Hours

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>V lecture</th>
<th>G lecture with exercise</th>
<th>U exercise</th>
<th>S seminar</th>
<th>K colloquium</th>
<th>P practical/laboratory course</th>
<th>A independent project</th>
<th>D diploma thesis</th>
<th>R revision course / private study</th>
</tr>
</thead>
</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Thematische Schwerpunkte:
Skript unter: https://moodle-app2.let.ethz.ch/course/view.php?id=117

This course looks into scientific theories and also empirical

A. Thoma

Title

1. LV Semestereinführung

Folien werden zur Verfügung gestellt.

ECTS

Implementation of practical sport into general teacher training with planning, execution and evaluation of the topics from all sport-specific

Designing Educational Environments in Physical Education (EW2 Sport)

Compulsory course requirements for EW2 Sport: This course is required to be taken prior to EW4 Sport "Outdoor Education: Concepts and Practice" (871-0242-02L)

Abstract

Students learn principles of teaching beyond classroom and regular PE-Lessons:
- Planning and organizing camps and events
- Teaching the "Ergänzungsfach Sport"
- Long-term-curricula in PE

As a practical part students design the Outdoor event in EW4 of the following term

Objective

Students know
- How to plan events and camps
- To assess curricula critically and to use them properly
- How to combine theoretical and practical issues in the 'Ergänzungsfach'

Content

1. LV Semestersteuerung
2. LV Planung Outdoor-Weekend
3. LV Auswertung Outdoor-Event
4. LV Planung Event
5. LV Event-Präsentationen / Schlussveranstaltung

Prerequisites / notice

EW2 is compulsory requirement for EW4 Sport

871-0240-00L Human Learning (EW1)

This lecture is only apt for students who intend to enrol in the programs "Teaching Diploma" or "Teaching Certificate". It is about learning in childhood and adolescence.

Abstract

This course looks into scientific theories and also empirical studies on human learning and relates them to the school.

Objective

Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

Content

Thematische Schwerpunkte:

Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen

Lernformen:

Literature


Prerequisites / notice

This lecture is only apt for students who intend to enrol in the programs "Lehrdiplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.

Subject Didactics in Sport

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

871-0240-00L Human Learning (EW1)

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Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

Content

Thematische Schwerpunkte:

Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen

Lernformen:

Literature


Prerequisites / notice

This lecture is only apt for students who intend to enrol in the programs "Lehrdiplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.

Subject Didactics in Sport

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

557-0315-00L Sports Didactics I

Simultaneous enrolment in Introductory Internship Sports - course 557-0210-00L - is compulsory. Prerequisite: Professional Exercises (557-0215-00L) passed.

Abstract

Practical implementation in sports of general didactics, with the planning, implementation and evaluation of topics from all the sport-specific areas of tuition in secondary school Level II.

Objective

The students:
- Implement the objectives of general didactics in respect of the different types of sport at school.
- master the planning, implementation and evaluation of topics from all the sports-specific areas of tuition.
- gain an overview of the preparation necessary for the different requirements placed on a sports teacher at secondary school Level II.
- try out different teaching structures, such as the lesson, teaching unit, block periods and extra units in sport in addition to those on the timetable.

Content

Implementation of practical sport into general teacher training with planning, execution and evaluation of the topics from all sport-specific areas of the education at this level in Section II.

Lecture notes

Skript unter: https://moodle-app2.let.ethz.ch/course/view.php?id=117>
The teaching practice takes in 50 sessions. The teaching practice lasts 4-6 weeks. It gives students the opportunity to implement the theoretical background in practice. By teaching sports lessons, they improve their teaching skills and classroom management and learn how to interact with pupils. Together with their supervisor, they develop an ability of critical reflection of their tasks.

### Professional Training in Sport

**Important:** You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>557-0210-00L</td>
<td>Introductory Internship Sports</td>
<td>O</td>
<td>3</td>
<td>6P</td>
<td>A. Thoma, further lecturers</td>
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<td></td>
<td>Simultaneous enrolment in Sports Didactics I (557-0315-00L) OR Sports Didactics II (557-0316-00L) is compulsory, depending on which of the Sports Didactics courses is taken first.</td>
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<td>Prerequisite: Professional Exercises (557-0215-00) passed.</td>
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<td>During the introductory teaching practice, the students sit in on 3 lessons given by the teacher responsible for their teaching practice, and teach 7 lessons themselves. The students are given observation and reflection assignments by the teacher responsible for their teaching practice.</td>
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<td>Right at the start of their training, students acquire initial experience with the observation of teaching, the establishment of concepts for teaching and the implementation of teaching. This early confrontation with the complexity of everything that teaching involves helps students decide whether they wish to and, indeed, ought to, continue with the training. It forms a basis for the subsequent pedagogical and subject-didactics training.</td>
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<td>Students observe 3 and teach 7 lessons, supervised by experienced teachers.</td>
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<td>Lecture notes</td>
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<td></td>
<td>Disler P., Did-Methodische Modelle in der Ausbildung, Dissertation in 2004, 152</td>
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<td></td>
<td>Loosch E., Allgemeine Bewegungsllehre, Limpert Verlag Wiebelsheim 1999</td>
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<td></td>
<td>Roth K. &amp; K. Willenmzik, Bewegungswissenschaft, Rowohlt Verlag Reinbek 1999</td>
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<td>Röthig P., Sportwissenschaftliches Lexikon, Schorndorf Verlag 2003</td>
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<td>Röthig P. &amp; s. Grösing (Hrsg.) Bewegungsllehre, Kursbuch 3, Wiesbaden 1990/3</td>
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<tr>
<td>557-0208-00L</td>
<td>Teaching Internship Sports</td>
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<td>17P</td>
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<td>Takes normally place at the end of the studies, before the examination lessons are conducted.</td>
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<td>The teaching practice takes in 50 sessions. The teaching practice lasts 4-6 weeks. It gives students the opportunity to implement the contents of their specialist-subject, educational science and subject-didactics training in the classroom. Students also conduct work assignments in parallel to their teaching practice.</td>
<td></td>
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<tr>
<td></td>
<td>Students use their disciplinary skills and educational knowledge for teaching. They know how to judge topics of their subject and can present them in class. Teaching and classroom management in practice is the main target of this course; students have to find a balance between instruction and self-determined activity of their pupils. Together with their supervisors, they learn to assess their tasks and achievements.</td>
<td></td>
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<tr>
<td></td>
<td>Content</td>
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</tr>
<tr>
<td></td>
<td>Students apply their theoretical background in practice. By teaching sports lessons, they improve their teaching skills and classroom management and learn how to interact with pupils. Together with their supervisor, they develop an ability of critical reflection of their tasks.</td>
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<tr>
<td></td>
<td>Lecture notes</td>
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<tr>
<td></td>
<td>see moodle 00 - Lehreidiplom Sport</td>
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</tr>
</tbody>
</table>
Partial Teaching Internship Sport

Students use their disciplinary skills and educational knowledge for teaching. Further lecturers

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 3 ECTS Educational Science</td>
</tr>
<tr>
<td>- 4 ECTS Specialized Courses with Educational Focus</td>
</tr>
<tr>
<td>- 2 ECTS Examination Lessons</td>
</tr>
</tbody>
</table>

**Abstract**

The teaching practice takes in 30 Sessions. It lasts 4-6 weeks. It gives students the opportunity to implement the contents of their specialist-subject, educational science and subject-didactics training in the classroom. Students also conduct work assignments in parallel to their teaching practice.

**Objective**

Students use their disciplinary skills and educational knowledge for teaching. They know how to judge topics of their subject and can present them in class. Teaching and classroom management in practice is the main target of this course; students have to find a balance between instruction and self-determined activity of their pupils. Together with their supervisors they learn to assess their tasks and achievements.

**Content**

Students apply their theoretical background in practice. By teaching sports lessons they improve their teaching skills and classroom management and learn how to interact with pupils. Together with their supervisor they develop an ability of critical reflection of their tasks.

**Literature**

Disler P. Dida-Methodische Modelle in der Ausbildung, Dissertation in 2004, 152
Loosch E., Allgemeine Bewegungslehre, Limpert Verlag Wiesbaden 1999
Roth K. & K. Willemcziz, Bewegungswissenschaft, Rowohlt Verlag Reinbek 1999
Röthig P. Sportwissenschaftliches Lexikon, Schorndorf Verlag 2003
Röthig P. & s. Grössing (Hrsg.) Bewegungslehre, Kursbuch 3, Wiesbaden 1990/3

---


**Specialized Courses in Respective Subject with Educational Focus I**

At least 6 CP's must be obtained in this category.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1033-00L</td>
<td>History of Sports</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>M. Gisler</td>
</tr>
</tbody>
</table>

**Abstract**

Comprehension for development and changes of sports from the ancient world to the present. Description of sports in services of national idea, from education and health promotion from the middle of the 18th century till this day.

**Objective**

Understanding for the development and adaptation of sports from the ancient world to present times.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2314 of 2653
Subject area of educational psychology

Development of pedagogical-psychological competences for the optimisation of future teaching activities.

The lectures set out to:

Ein Skript für die aktuelle Veranstaltung wird abgegeben.

Critical Thinking

Selected materials for the lecture are available on the Moodle platform.


Concepts and Theories

These lectures deal with the current changes in society and sport and provide an overview of the many different problems and perspectives

Sociology of Sport

Teaching materials for the individual lectures are provided to the students via moodle.

C. Herrmann

This lecture is intended as an introduction to sport psychology and imparts knowledge on selected areas of the subject.

Pedagogical application of research projects for schools

4A

Sport Psychology

Mentored Work Specialised Courses in the Respective Mentored Work Specialised Courses in the Respective

557-0205-00L

Objective

Development of pedagogical-psychological competences for the optimisation of future teaching activities.

Content

- Subject area of educational psychology
- Motivating students in physical education
- Building self-efficacy and strengthen the self-concept
- Promoting positive emotions and a positive attitude to anxiety
- Encouraging self-directed learning
- Leading classes and promoting cooperation
- Communicating with students efficiently
- Reflecting your own expectations critically
- Handling gender issues sensitively
- Promoting inclusion / Strengthening social and moral development
- Dealing with difficult students
- Evaluating achievements of students

Lecture notes

Teaching materials for the individual lectures are provided to the students via moodle.

Literature


Sport Pedagogy

W 2 credits 2V C. Herrmann

Abstract

The teacher-student interaction presents a complex psychosocial event, demonstrating the need for a psychological extension of the classical social science / sports pedagogical perspective. Therefore, this lecture will be focused on "pedagogical-psychological aspects of competence development in the context of a multi-perspective physical education".

Objective

Development of pedagogical-psychological competences for the optimisation of future teaching activities.

Content

- Subject area of educational psychology
- Motivating students in physical education
- Building self-efficacy and strengthen the self-concept
- Promoting positive emotions and a positive attitude to anxiety
- Encouraging self-directed learning
- Leading classes and promoting cooperation
- Communicating with students efficiently
- Reflecting your own expectations critically
- Handling gender issues sensitively
- Promoting inclusion / Strengthening social and moral development
- Dealing with difficult students
- Evaluating achievements of students

Lecture notes

Teaching materials for the individual lectures are provided to the students via moodle.

Literature


Sport Psychology

W 2 credits 2V H. Gubelmann

Abstract

This lecture is intended as an introduction to sport psychology and imparts knowledge on selected areas of the subject.

Objective

Students are given insight into different work areas of sport psychology. In order to understand what «sport psychology» is, it is necessary to explain the essence and tasks of sport psychology and what it relates to, and to work out an underlying basis for key topics, such as cognition and emotions. Students' expertise is furthered by presenting and providing more in-depth treatment of additional topics of sport psychology. Selected intervention forms are intended to provide insight into applied sport psychology and ensure that mental processes and their impact in sport can be recognised. Case studies and practical exercises (e.g. objective training) are intended to prompt students to reflect to a greater extent on the forms in which sport psychology can be applied in their practice of sports and to integrate these in their teaching.

Content

Main Topics
- Introduction to sport psychology
- Cognitions in sports: mental rehearsal and mental training
- Emotions and stress
- Motivation: goal-setting in sports
- Career and career transition in elite sport
- Coach-Athlete-Interaction
- Psychological aspects of sport-injury rehabilitation
- Group dynamics in sport

Lecture notes

Instructional materials for each course will be made available to students. All lecture materials will be available to students on Moodle.

Literature


Sociology of Sport

W 2 credits 2V R. Bürgi

Abstract

These lectures deal with the current changes in society and sport and provide an overview of the many different problems and perspectives of sport sociology.

Objective

The lectures set out to:
- present the different dimensions, functions and interrelationships of present-day sport
- provide an introduction to the central theories and models of (sport) sociology
- show how far sport reflects society and how it changes and becomes more differentiated in the process
- take current examples to highlight the sociological view of sport.

Content

Sport and social change: developments and trends
The economy and the media: commercialisation, logic, dependencies
Conflicts and politics: sports organizations, doping, violence
Social inequalities and distinctions: social impact, health and sport, sport and gender

Lecture notes

Selected materials for the lecture are available on the Moodle platform.

Literature


Competencies

Subject-specific Competencies
- Concepts and Theories assessed

Method-specific Competencies
- Analytical Competencies assessed

Social Competencies
- Sensitivity to Diversity assessed

Personal Competencies
- Critical Thinking assessed

Mentored Work Specialised Courses in the Respective O

557-0205-00L

Objective

Pedagogical application of research projects for schools

Introduction of sports pedagogical oriented research projects. Competency to a youth friendly movement and sports education. Competent 'pedagogical application' of research projects in the field of movement and sport. Feed in of scientific findings to school lesson settings.
Objective
The students combine and apply general educational aims with a general and specific background of research projects.
They know different educational concepts of the above mentioned, recognise its strengths and weaknesses and are able to apply concepts appropriate to the situation.
They are interested in the (thought-) processes of education and research in sports in Switzerland.
They use their knowledge of research matters to guide educational thought-processes.
They are interested in processes of research in sports.
They approach the research interest of their pupils with the knowledge of sports psychology, sports sociology, sports pedagogy, and sports history.

Content
Die Studierenden wenden die Bewegungs- und Lernziele des Sportunterrichts aus den kantonalen Lehrplänen im Unterricht an und können diese begründen.
Sie interessieren sich für die Prozesse der Forschung Im Sport
Sie erlernen anhand von Projektaufgaben die didaktische Anwendung der Sportpsychologie, Sportssoziologie, Sportpädagogik und Sportgeschichte und ziehen daraus Konsequenzen für den situativ-variabel orientierten Unterricht.
Sie setzen ihr Wissenschaftswissen ein, um bei den Lernenden Denkprozessen anzustoßen und zu begleiten.

Lecture notes
Skript unter: https://moodle-app2.let.ethz.ch/course/view.php?id=117>

Literature

Prerequisites / notice
Auswahl von 2 aus 4 Angeboten:
a) Motor-Learning im Sport (Fachbereich Sportpsychologie)  
- Vorlesung  
- Praktische Umsetzung von Forschungsprojekten für die Schule
b) Sport im Spannungsfeld zwischen Ethik und Kommerz  (Fachbereich Sportssoziologie)  
- Vorlesung  
- Praktische Umsetzung von Forschungsprojekten für die Schule
c) Mehrperspektivität im Sportunterricht (Fachbereich Sportpädagogik)  
- Vorlesung  
- Praktische Umsetzung von Forschungsprojekten für die Schule
d) Historische Entwicklung der Lehr und Lernmodell im Sportunterricht (Fachbereich Sportgeschichte)  
- Vorlesung  
- Praktische Umsetzung von Forschungsprojekten für die Schule
Alle Wahlfachangebote beinhalten:  
- Sportwissenschaftliche Fachpraxis  
- Praktische Umsetzung der Erkenntnisse für die Schule

Specialized Courses in Respective Subject with Educational Focus II
At least 6 CP's must be obtained in this category. Further courses must be chosen from the "Sports Practice: In-depth Education".

Compulsory Elective Courses
At least 6 CP's must be acquired in this category. Further courses must be chosen from "Sports Practice: In-depth Education and Specialized Education".

Sports Practice
The Teaching Diploma in Sports will only be granted to students holding a Master, Diploma or Licentiate degree in Human Movement Sciences and Sports or Health Sciences and Technology. Additionally, a Sports Practice encompassing 56 CP's is required. The Sports Practice can be partly conducted during the Bachelor and Master programmes in Sports.

Assessments

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>557-0101-00L</td>
<td>Assessment Polysports</td>
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<tr>
<td></td>
<td>Compulsory for Teaching Diploma Sports.</td>
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</tbody>
</table>

Abstract
Successful completion of the course “Assessment Polysports” is requirement for access to further practical sport courses. Basic skills in ball games, athletics, gymnastics, fitness, and dance are repeated and tested.

Lecture notes
During the semester the documents are steadily available electronically

Basic Education

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>557-0424-01L</td>
<td>Fitness I</td>
<td>W</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Prerequisite: Assessment Polysport passed (or Assessment I or II or III).</td>
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</tbody>
</table>

Abstract
Basic education in fitness: to acquire abilities and skills in the areas of strength, endurance, mobility, aerobics and prophylaxis

Objective
To gain knowledge of practical basics in the area of fitness
To obtain abilities and skills in the area of fitness such as strength, endurance, flexibility, aerobic dance, prevention

Content
- Prophylaktisches Fitnesstraining: Muskikondi
- Fitnessstest in Kraft und Ausdauer
- - Grundlagen Krafttraining
- - Haltung und Beweglichkeit
- - Fitnessstrends (Crossfit, TRX)
- - Anwendungen für die Schule

Lecture notes
Sie wird im Unterricht abgegeben

Literature
- Taschenatlas der Anatomie, Bewegungsapparat, W.Platzer, Thieme Verlag
- Optimales Training, J.Weineck, Erfangen, Spitta Verlag
- Sportbiologie, J.Weineck, Erfangen, Perimed Verlag
- Sportanatomie, J.Weineck, Erfangen, Perimed Verlag
- ASVZ Trainingslehre, erhältlich in Polybuchhandlung ETH
To get to know and understand the basics of movement (core movements) and its respective actions and functions on apparatuses, on the

M. Ferrari

Learning the basic elements in drills and games, learning (pre-)tactical elements (1-1, getting open, 2-2, backdoor cut, frontdoor cut, 3-3, - Schwimmen: Erwerben und festigen der Schwimmtechniken Rücken, Brust und Kraul sowie Grundform Delfin. Erwerben und Festigen


M. Perk

All kind of swimming:

Basketball I

The students should be able to:

Apparatus Gymnastics and Trampoline I

- acquire and consolidate apparatus related core movements as well as apply and create such combinations
- utilize their own strength as well as the resulting impact in a differentiate way in order to precisely move the swinging, flying, falling and twisting body
- gain orientation safety and room orientation while twisting and flying
- gain sensitivity for social competences (e.g. to assist, to observe, to advise) within a small group.

- structural relationships within rotations (tumaround, handsprings and free somersaults)
- core poses as motor basic training
- variety of position modifications in handstands
- core movements and combinations on parallel bars, high bar, floor and in swinging rings
- different forms of vaulting as well as springing in movements like handstands and somersaults

Compulsory for Teaching Diploma Sports.

Abstract

To get to know and understand the basics of movement (core movements) and its respective actions and functions on apparatuses, on the floor and in acrobatics as well as to create individual and cooperative combinations according to qualitative criteria.

Objective

The students should be able to:

Content

- Schwimmen: Erwerben und festigen der Schwimmtechniken Rücken, Brust und Kraul sowie Grundform Delfin. Erwerben und Festigen

- Wasserball: Erwerben und festigen Dribbeln, Wassertreten, Ballaufnahme und Werfen, Spielformen Wasserball.
- Artistic Swimming: Erwerben und festigen Wassertreten, Paddeln, einzelne Grundfiguren.
- Basic education in swimming: swimming, diving, water polo and artistic swimming

Compulsory for Teaching Diploma Sports.

Abstract

All kind of swimming:

- learns to know and understand the individual basic techniques
- improvement of technical skills and crafts

Objective

Content

- Schwimmen: Erwerben und festigen der Schwimmtechniken Rücken, Brust und Kraul sowie Grundform Delfin. Erwerben und Festigen

- Wasserball: Dribbeln, Wassertreten, Ballaufnahme und Werfen, Spielformen Wasserball.
- Artistic Swimming: Einzelne Grundfiguren.

Lecture notes

Wird abgegeben

Literature

- Swimsports.ch: Schweizerische Tests im Schwimmsport

Prerequisites / notice

Assessment Polysport passed (or Assessment I, II or III).

Assessment Polysport passed (or Assessment I, II or III).

Basketball I

Prerequisites: Assessment Polysports passed (or Assessment I, II or III).

Basketball-Basics:

Basic technical skills: dribbling/ballhandling, passing, shooting, footwork and defense related to the specific Basketball rules.

Tactical skills: 1 on 1, give & go, hand-off, pick & roll, pick & pop and the application of these skills in a game 3 on 3 on one basket.

Objective

The students know the technical basic Basketball elements (dribbling, changes of hand, stops, starts, footwork, pass, shot, defense), they can demonstrate them and use them correctly in a game situation 3 on 3 on one basket.

The students know the tactical Basketball elements (1 on 1, give & go, hand-off, pick & roll, pick & pop) and can apply these skills in a game 3 on 3 on one basket.

The students know the main rules of the game.

Content

Learning the basic elements in drills and games, learning (pre-)tactical elements (1-1, getting open, 2-2, backdoor cut, frontdoor cut, 3-3, give & go, hand-off, pick & roll, pick & pop, spacing) and assemble them into systems, that can be used in a game situation 3 on 3 on one basket.

Lecture notes

available on Moodle

Literature


manual for monitors of the Swiss Youth & Sports program (available through the "Jugend & Sport" office, german / french / italian)

Chervet, Michel: Basketball. Fundamental skills for offensive play. Video (german / french). Magglingen, BASPO, 2003 (CHF 34.-). Order at video@baspo.admin.ch
Competencies

Subject-specific Competencies
- Concepts and Theories fostered
- Techniques and Technologies fostered

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication assessed
- Cooperation and Teamwork assessed
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility assessed
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

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557-0514-03L  Soccer I

Prerequisites: Assessment Polysports passed (or Assessment I, II or III).
Compulsory for Teaching Diploma Sports.

W 2 credits 2G  H. A. Russheim, P. C. Humbel

Abstract
Acquisition/consolidation basic skills for soccer.
Support and development the individual conditions/talent/skill and introduction of basic methods will be treated.

Objective
Acquisition/consolidation basic skills in soccer
Support and development the individual conditions/talent/skill want to be at the centre of attention.
The introduction of basic methods complete the aim of the course.

Content
Technique:
- Dribble, short passport play, get the ball under control, shot,
- Individual tactics:
  - offensive/defensive 1vs1; keep ball in own rows
- various contests in support of different techniques and tactics

Prerequisites / notice
1. Prerequisites:
- Small being able in soccer.
- Readiness to train.
2. Additional material
- wearing soccer shoes is mandatory
- wearing shin guards is mandatory

Competencies

Social Competencies
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Self-presentation and Social Influence fostered

Personal Competencies
- Creative Thinking fostered
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

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557-0522-01L  Handball I

Prerequisites: Assessment Polysports passed (or Assessment I, II or III).
Compulsory for Teaching Diploma Sports.

W 2 credits 2G  F. Lüchinger

Abstract
Learn by playing - from three-a-side to four-a-side games.
Game development takes place over the zone play of the game (2/1) or 3/2 to the game 4/4 (6/6).
The introduced technical elements form the requirements for the tactically-orientated zone plays and are exclusively trained in the execution and formation steps.

Objective
The students improve their personal skills and demonstrate the game in teams as well as groups of 4 against 4.
They deepen the development of the game
They improve their personal skills with an individual emphasis on game and practice.

Content
Spielend Handball lernen - Über das Spiel zum Spiel (Vom Spiel 3/3 zum Spiel 4/4)
Techniktraining ist Sache der Studierenden.
Die individuelle Grundschulung wird mit Lernkontrollen überprüft (Kontrollblätter).
Alle ausgewählten Formen müssen als Lernkontrolle durchführbar sein.

Lecture notes
Lehrunterlagen können von der Homepage abgerufen werden.
In-depth Education

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>557-0542-01L</td>
<td>Volleyball I 🎾</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>M. Attinger, N. Beeler</td>
</tr>
</tbody>
</table>

**Prerequisites / notice**

Prüfungen Inhalte: Die Prüfungsinhalte werden während des Semesters erarbeitet und am Ende des Semesters online schriftlich zur Verfügung gestellt.

**Literature**

- Spielerziehung O. Buholzer SHV (online verfügbar)
- Spielen lernen M. Ochsenbein/O. Buholzer SHV (online verfügbar)
- Technik lernen O. Buholzer SHV (online verfügbar)
- Spielen Handball lernen A. Emrich Limpert

**Prerequisites**

- Polysport passed (or Assessment I or II or III).

**Abstract**

Acquire technical and tactical abilities in the game of volleyball

**Objective**

- Experience and use of various aspects of volleyball as a teamplayer
- Various forms of warmups and tournament setups

**Content**

- Techniques and tactics of indoor-volleyball (1:1 to 6:6)
- Various warmups and tournament setups

**Lecture notes**

Published during the semester on "moodle"

**Literature**

- Volleyball, Training & Coaching", Czimek & DVV, 2017
- "Volleyball spielen”, Foerster (BASPO), 2016
- "Volleyball verstehen”, Schnyder-Benoit (BASPO), 2016
- "Volleyball Grundlagen” Papageorgiou/Spitzley 2005

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories assessed
  - Techniques and Technologies assessed
  - Analytical Competencies fostered
  - Decision-making fostered
  - Problem-solving fostered

- Method-specific Competencies
  - Communication fostered
  - Cooperation and Teamwork assessed
  - Leadership and Responsibility fostered
  - Self-presentation and Social Influence assessed
  - Sensitivity to Diversity fostered

- Social Competencies
  - Adaptability and Flexibility assessed
  - Creative Thinking fostered
  - Critical Thinking fostered
  - Integrity and Work Ethics fostered
  - Self-awareness and Self-reflection fostered
  - Self-direction and Self-management fostered

- Personal Competencies
  - Adaptability and Flexibility assessed
  - Creative Thinking fostered
  - Critical Thinking fostered
  - Integrity and Work Ethics fostered
  - Self-awareness and Self-reflection fostered
  - Self-direction and Self-management fostered

**557-0603-01L Snowsports I - Ski 🎿**

Only for BSc / MSc HST / Teaching Diploma Sports

100% presence is required!

**Abstract**

Education in the disciplines of winter sports.
- J+S Education possibility
- Transfer Offpist
- Transfer Nordic Cross

**Objective**

The students:
- Experience the different winter sports.
- Gain an understanding of how to ski off-piste.
- Transfer: Input Nordic Cross!

**Content**

- To apply and vary personal technique of alpine skiing
- To acquire and vary personal technique of cross-country skiing
- Competition in ski-jumping, and giant slalom
- To gain an understanding in how to ski off-piste
- To gain Nordic Cross

**557-0603-02L Snowsports I - Snowboard 🛡️**

Only for BSc / MSc HST / Teaching Diploma Sports

100% presence is required!

**Abstract**

Education in the disciplines of winter sports.
- J+S Education possibility
- Transfer Offpist
- Transfer Nordic Cross

**Objective**

The students:
- Experience the different winter sports!
- Gain an understanding of how to ski off-piste!
- Gain an understanding of how to Nordic Cross.

**Content**

- To apply and vary personal technique of snowboarding
- To acquire and vary personal technique of cross-country skiing
- Competition in ski-jumping, and giant slalom
- To gain an understanding in how to ski off-piste
- To gain an understanding in how to Nordic Cross

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2319 of 2653
Athletics II

Prerequisites: Athletics I attended.

Compulsory for Teaching Diploma Sports. 80% active participation required.

Abstract
The athletics level 2 course focuses on methodological and didactic aspects of disciplines taught in the level 1 course. Pole vault is introduced as a new and additional discipline. Central elements required for passing the course don't include skill assessments or athletic performance tests but rather didactical contributions.

Objective
The level II courses focus on methodological concepts and didactics. The goal is to learn how to teach the specific sport at high school level. The didactical aspects are often conveyed through new skills and elements. It is not required to have passed the level I course, but it is mandatory to have attended it previously.

Content
- Specific warm-up for athletics
- Core elements of all disciplines
- Acquiring of technical pole vault skills
- Learning how to support an athlete during pole vaulting
- Keys to a successful baton handoff
- Written assignment on a movement observation task
- How to modulate intensity with task variations
- Developing feedback skills

Lecture notes
No script

Literature
J+S Kernlehrmittel
J+S Broschüre Leichtathletik verstehen & Leichtathletik vermitteln
J+S Leichtathletik Manual Kinder und Jugendliche

Prerequisites / notice
It is not required to have passed the level I course, but it is mandatory to have attended it previously.

Competencies
Subject-specific Competencies
- Concepts and Theories
  - fostered
Method-specific Competencies
- Analytical Competencies
  - fostered
- Decision-making
  - fostered
- Problem-solving
  - fostered
Social Competencies
- Leadership and Responsibility
  - fostered
Personal Competencies
- Self-awareness and Self-reflection
  - fostered

Handball II

Prerequisites: Handball I attended.

Compulsory for Teaching Diploma Sport. 80% active participation required.

Abstract
Recognizing and experiencing important aspects of the game and preparing them for your own lessons with the help of didactic-methodical concepts.

Objective
The level II courses focus on methodological concepts and didactics. The goal is to learn how to teach the specific sport at high school level. The didactical aspects are often conveyed through new skills and elements. It is not required to have passed the level I course, but it is mandatory to have attended it previously.

You will know and experience the most important aspects of teaching handball and prepare them for teaching with the help of didactic-methodical concepts.

You will know and experience different forms of assessment for the school.

You will improve your individual skills in technique and tactics.

Content
You will learn and discuss the didactic-methodological concepts to adapt exercises and the game in the sense of physical education and sport and to develop them further with a class.

You will learn and discuss different forms of assessment for the school.

You will improve your individual skills in technique and tactics.

Prerequisites / notice
It is not required to have passed the level I course, but it is mandatory to have attended it previously.

80% presence required.

Gymnastics / Acrobatics II

Prerequisites: Attended basic education
- "Apparatus Gymnastics and Trampoline I" (557-0433-00L); and
- "Acrobatics I" (557-0432-01L).

Compulsory for Teaching Diploma Sport. 80% active participation required.

Abstract
Recognizing and experiencing important aspects of the game and preparing them for your own lessons with the help of didactic-methodical concepts.

Objective
The level II courses focus on methodological concepts and didactics. The goal is to learn how to teach the specific sport at high school level. The didactical aspects are often conveyed through new skills and elements. It is not required to have passed the level I course, but it is mandatory to have attended it previously.

You will know and experience the most important aspects of teaching handball and prepare them for teaching with the help of didactic-methodical concepts.

You will know and experience different forms of assessment for the school.

You will improve your individual skills in technique and tactics.

Content
You will learn and discuss the didactic-methodological concepts to adapt exercises and the game in the sense of physical education and sport and to develop them further with a class.

You will learn and discuss different forms of assessment for the school.

You will improve your individual skills in technique and tactics.

Prerequisites / notice
It is not required to have passed the level I course, but it is mandatory to have attended it previously.

80% presence required.
80% active participation required.

**Abstract**
Acquirement and Application of classic as well as modern forms of movement on different apparatuses and on the trampoline.

**Objective**
The level II courses focus on methodological concepts and didactics. The goal is to learn how to teach the specific sport at high school level. The didactical aspects are often conveyed through new skills and elements. It is not required to have passed the level I course, but it is mandatory to have attended it previously.

The students should be able to:
- enhance their repertoire on apparatus specific movements
- deepen their existing store of movements
- improve their individual performance competencies
- realize and comprehend transfer characteristics within the movement learning process
- work up methodically and didactically a chosen skill
- gain sensitivity for social competences (e.g. to assist, to observe, to advise) within a small group
- compose and present to music within a group of three a creative performance

**Content**
- further core movements and its combinations on different apparatuses
- handsprings and (free) somersaults back- and forwards, respectively twists back- and forwards on different apparatuses
- creative and cooperative composition in a threesome accompanied by music
- vault springs and touching down springs (stuetz springs) to overcome obstacles in an artful way (Freerunning)
- integrated theoretical coherences of the qualitative movement learning process
- conveyance of methodical and didactical principles as well as topic specific criteria
- functional warm-up with regard to specific contents

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### 557-0544-00L Floorball II

**Prerequisite:** Floorball I attended.

**Compulsory for Teaching Diploma Sports.**

80% active participation required.

**Objective**
Learning the methodology and the didactics for teaching floorball and guiding floorball games at high school level.

The level II courses focus on methodological concepts and didactics. The goal is to learn how to teach the specific sport at high school level. The didactical aspects are often conveyed through new skills and elements. It is not required to have passed the level I course, but it is mandatory to have attended it previously.

Prerequisites / notice
80% presence required.

**Competencies**
- Method-specific Competencies
- Analytical Competencies
  - Decision-making
  - Self-awareness and Self-reflection
- Personal Competencies

---

### 557-0602-00L Badminton II

**Prerequisite:** Badminton I (557-0601-00L) attended.

**Mandatory for Teaching Diploma Sports.**

80% active participation required.

**Objective**
In this course you will build up and experience different tactical and technical exercise forms for classes. At the same time you will be able to deepen your own badminton skills.

The level II courses focus on methodological concepts and didactics. The goal is to learn how to teach the specific sport at high school level. The didactical aspects are often conveyed through new skills and elements. It is not required to have passed the level I course, but it is mandatory to have attended it previously.

Prerequisites / notice
80% presence required.

---

### Education Acquired Outside ETH

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>557-0450-00L</td>
<td>Life Saving Rescue Test Plus Pool SLRG</td>
<td>O</td>
<td>2</td>
<td></td>
<td>external organisers</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Acquisition of course attendance Brevet Basis Pool and Brevet Plus Pool SLRG.</td>
<td></td>
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</tr>
<tr>
<td><strong>Objective</strong></td>
<td>To recognize danger in, on and around water knowledge and handling of life saving equipment rescue and towing techniques orientation under water to rescue a person basis knowledge in anatomy and first aid</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Prerequisites: please consult <a href="http://www.slrg.ch">www.slrg.ch</a></td>
<td></td>
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</tbody>
</table>

| 557-0451-00L | First Responder Level 2 IVR                                     | O    | 2    |       | external organisers|
| **Abstract** | Acquisition of the certificate "Ersthelfer Stufe II IVR." |

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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2321 of 2653
Objective
- To be able to judge an injured person and to apply life saving actions
- To carry out wound treatment with actual bandage
- To list the characteristics of a sprain, strain, dislocation and to apply first-aid interventions
- To carry out fixed bandages with common material
- To explain the function of the cardiovascular system
- To name the symptoms of poisoning
- To list the signs of acute illness
- To put together the content of a first-aid box
- To carry out safety interventions in daily situations.

Content
* Hautverletzungen
* Wundinfektion / Blutvergiftung
* Stürze im Alltag (Verstauchungen, Prellungen, Quetschungen)
* Sportverletzungen, Knochenbrüche
* Herzkreislaufterstörungen
* Alltagskrankheiten in der Familie

Prerequisites / notice
Prerequisites: please consult www.samariter.ch

 Compensation Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>557-0603-01L</td>
<td>Snowsports I - Ski</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>C. Elmiger-Schnyder, further lecturers</td>
</tr>
<tr>
<td></td>
<td>Only for BSc / MSc HST / Teaching Diploma Sports</td>
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<tr>
<td></td>
<td>100% presence is required!</td>
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<td></td>
<td>Registration via Study Administration necessary.</td>
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<tr>
<td></td>
<td>Compulsory for Teaching Diploma Sports.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>Education in the disciplines of winter sports.</td>
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<tr>
<td></td>
<td>- J+S Education possibility</td>
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<tr>
<td></td>
<td>- Transfer Offpist</td>
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<tr>
<td></td>
<td>- Transfer Nordic Cross</td>
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<td></td>
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<tr>
<td>Objective</td>
<td>The students:</td>
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<tr>
<td></td>
<td>- experience the different winter sports.</td>
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<tr>
<td></td>
<td>- gain an understanding of how to ski off-piste.</td>
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<tr>
<td></td>
<td>- Transfer: Input Nordic Cross!</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Content</td>
<td>- To apply and vary personal technique of alpine skiing</td>
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<tr>
<td></td>
<td>- To acquire and vary personal technique of cross-country skiing</td>
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<tr>
<td></td>
<td>Competition in ski-jumping, and giant slalom</td>
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<tr>
<td></td>
<td>- To gain an understanding in how to ski off-piste</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>- To gain Nordic Cross</td>
<td></td>
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</tr>
</tbody>
</table>

| 557-0603-02L  | Snowsports I - Snowboard  | W    | 2    | 2G    | C. Elmiger-Schnyder, further lecturers |
|               | Only for BSc / MSc HST / Teaching Diploma Sports |      |      |       |                          |
|               | 100% presence is required! |      |      |       |                          |
|               | Registration via Study Administration HST necessary. |      |      |       |                          |
|               | Compulsory for Teaching Diploma Sports. |      |      |       |                          |
| Abstract      | Education in the disciplines of winter sports. |      |      |       |                          |
|               | - J+S Education possibility |      |      |       |                          |
|               | - Transfer Offpist |      |      |       |                          |
|               | - Transfer Nordic Cross |      |      |       |                          |
| Objective     | The students: |      |      |       |                          |
|               | - experience the different winter sports! |      |      |       |                          |
|               | - Gain an understanding of how to ski off-piste! |      |      |       |                          |
|               | - Gain an understanding of how to Nordic Cross. |      |      |       |                          |
| Content       | - To apply and vary personal technique of snowboarding |      |      |       |                          |
|               | - To acquire and vary personal technique of cross-country skiing |      |      |       |                          |
|               | Competition in ski-jumping, and giant slalom |      |      |       |                          |
|               | - To gain an understanding in how to ski off-piste |      |      |       |                          |
|               | - To gain Nordic Cross |      |      |       |                          |

| 557-0605-01L  | Snowsports II - Ski       | W    | 2    | 2G    | C. Elmiger-Schnyder, further lecturers |
|               | Prerequisite: Basic course Snowsports I - Ski passed. |      |      |       |                          |
|               | 100% presence is required! |      |      |       |                          |
|               | Registration via Study Administration HST necessary. |      |      |       |                          |
| Abstract      | Specialization training: Acquisitions of special skills, getting to know the performance factors and training methods in the areas of Snowsports. |      |      |       |                          |
| Objective     | Snow sports Skiing: |      |      |       |                          |
|               | - To deepen and expand experience and skills in snow sports and in the personal competency of technique of the chosen snow sport. |      |      |       |                          |
| Content       | Snow sports skiing: |      |      |       |                          |
|               | - General and specific education of personal competency in technique of the chosen snow sport. |      |      |       |                          |
| Prerequisites / notice | Requirement: Basic course in Snowsport I completed. |      |      |       |                          |

| 557-0605-02L  | Snowsports II - Snowboard | W    | 2    | 2G    | C. Elmiger-Schnyder, further lecturers |
|               | Prerequisite: Basic course Snowsports I - Snowboard passed. |      |      |       |                          |
|               | 100% presence is required! |      |      |       |                          |
|               | Registration via Study Administration HST necessary. |      |      |       |                          |
| Abstract      | Specialization training: Acquisitions of special skills, getting to know the performance factors and training methods in the areas of Snowsports. |      |      |       |                          |
| Objective     | Snow sports (Snowboarding): |      |      |       |                          |
|               | - To deepen and expand experience and skills in snow sports and in the personal competency of technique of the chosen snow sport. |      |      |       |                          |
Snow sports (snowboarding):
- General and specific education of personal competency in technique of the chosen snow sport: Park, Piste and Off-Piste

Requirement: Basic course in Snowsport I completed.

557-0605-03L  Snowsports II - Telemark  W  2 credits  2G  C. Elmiger-Schnyder, further lecturers

Prerequisite: Basic course Snowsports I (Ski or Snowboard) passed. 100% presence is required!

Registration via Study Administration HST necessary.

Abstract
Specialization training: Acquisitions of special skills, getting to know the performance factors and training methods in the areas of Snowsports.

Objective
Snow sports:
- To deepen and expand experience and skills in snow sports and in the personal competency of technique of the chosen snow sport.
- To expand skills to the area of telemark

Content
Snow sports:
- General and specific education of personal competency in technique of the chosen snow sport.
- Telemark as an extra experience in the framework of technique on slope, park and off-piste.

Prerequisites / notice
Requirement: Basic course in Snowsport I completed.

557-0605-04L  Snowsports II - Off-Piste  W  2 credits  2G  C. Elmiger-Schnyder, further lecturers

Prerequisite: Basic course Snowsports I (Ski or Snowboard) passed. 100% presence is required!

Registration via Study Administration necessary.

Abstract
Specialization training: Acquisitions of special skills, getting to know the performance factors and training methods in the areas of Snowsports.

Objective
Off-piste education:
- Planning and realization of back-country skiing
- Handling of the environment
- Avalanche prophylaxis

Content
Off-piste education:
- Planning and realization of back-country skiing
- Handling of the environment
- Avalanche prophylaxis

Prerequisites / notice
Requirement: Basic course in Snowsport I completed.

Additional Requirements in Sports Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0203-00L</td>
<td>Movement and Sport Biomechanics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>W. R. Taylor, R. List</td>
</tr>
<tr>
<td>Abstract</td>
<td>Learning to view the human body as a (bio-)mechanical system. Making the connections between everyday movements and sports activity with injury, discomfort, prevention and rehabilitation.</td>
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</tr>
<tr>
<td>Objective</td>
<td>Students are able to describe the human body as a mechanical system. They analyse and describe human movement according to the laws of mechanics.</td>
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<tr>
<td>Content</td>
<td>Movement- and sports biomechanics deals with the attributes of the human body and their link to mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.</td>
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<tr>
<td>Lecture notes</td>
<td>Is available within the Moodle</td>
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</tr>
<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>fostered</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Personal Competencies</td>
<td>Analytical Competencies</td>
<td>fostered</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Problem-solving</td>
<td>fostered</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

376-0207-00L  Exercise Physiology  W  4 credits  3G  C. Spengler, F. Gabe Beltrami

Abstract
This course provides an overview over molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interactions of the different systems influencing factors, e.g. genetics, gender, age, altitude/depth, heat/cold, with respect to performance and health.

Objective
The aim of this course is to understand molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interaction of the different systems regarding health-relevant aspects and performance in healthy people and persons with selected diseases. Furthermore, students will understand the influence of genetics, gender, age, altitude/depth, heat and cold on the named factors.

Content
History of Exercise Physiology, research methods, fibertype heterogeneity and its functional significance, neural control of muscle force, molecular nad cellular mechanisms of muscle adaptation to resistance, endurance and stretching exercise, interindividual variability in the response to training, cardiorespiratory and metabolic responses to acute and chronic exercise, sex differences relevant to exercise performance, exercise in hot and cold environment, children and adolescents in sport and exercise, exercise at altitude and depth, aging and exercise performance, exercise for health, exercise in the context of disease.

Lecture notes
Online material is provided during the course.

Literature
Wird in der Vorlesung bekannt gegeben.

Prequisites / notice
Anatomy and Physiology I + II

376-1033-00L  History of Sports  W  2 credits  2V  M. Gisler

Abstract
Comprehension for development and changes of sports from the ancient world to the presence. Description of sports in services of national idea, from education and health promotion from the middle of the 18th century till this day.

Objective
Understanding for the development and adaptation of sports from the ancient world to present times.
Conduct physical performance tests and measurements that are typically used to assess performance of athletes and/or patients and that

Analytical Competencies

Primärliteratur:


Content

Development of pedagogical-psychological competences for the optimisation of future teaching activities.

Objective

Main Topics

- Introduction to sport psychology
- Cognitions in sports: mental rehearsal and mental training
- Emotions and stress
- Motivation: goal-setting in sports
- Career and career transition in elite sport
- Coach-Athlete-Interaction
- Psychological aspects of sport-injury rehabilitation
- Group dynamics in sport

Content

- Group dynamics in sport

Lecture notes

Teaching materials for the individual lectures are provided to the students via moodle.

Literature

Sociology of Sport


376-1117-00L Sociology of Sport

Objective

The lectures set out to:
- present the different dimensions, functions and interrelationships of present-day sport
- provide an introduction to the central theories and models of (sport) sociology
- show how far sport reflects society and how it changes and becomes more differentiated in the process
- take current examples to highlight the sociological view of sport.

Competencies

Subject-specific Competencies
Concepts and Theories

Method-specific Competencies
Analytical Competencies

Social Competencies
Sensitivity to Diversity

Personal Competencies
Critical Thinking

376-0130-00L Laboratory Course in Exercise Physiology

Abstract

Conduct physical performance tests and measurements that are typically used to assess performance of athletes and/or patients and that

Objective

Gain hands-on experience in exercise physiology and consolidate knowledge on physiological adaptations to different types and degrees of

physical activity and climatic influences. Learn fundamental assessment techniques of the muscular system, the cardio-respiratory system
and of whole-body performance, learn scientifically correct data analysis and interpretation of results. Insight into today's Sports Medicine.
Content

Lecture notes

Literature

Prerequisites / notice

376-0225-00L Critical Appraisal of Evidence for Exercise in Health

Abstract

Objectives

Content

Competencies

Literature

376-1651-00L Clinical and Movement Biomechanics

Abstract

Objective

Content

Competencies

376-6403-00L Nutrition and Performance

Abstract

Objective

Content

Lecture notes

Literature

Prerequisites / notice

376-0208-00L Molecular and Cellular Biology of Exercise and Muscle Regeneration - Practical Aspects

Abstract

Prerequisites:

Laboratory Course in Molecular Biology (376-0006-02L)
Objective

The objective of this course is to introduce students into current research topics and outstanding questions in skeletal muscle biology. Also, the course will give students hands-on experience in respect to the tools needed to perform basic molecular biology research in the field of exercise and skeletal muscle biology. Students will learn how to translate a scientific question in muscle biology into a small scientific project. They will learn how to design an experiment and to analyze and critically interpret experimental data.

Content

The course will consist of 4 main research themes and the anticipated 16 students will be divided into 4 subgroups of 4 students each one will focus on one of the following research topics:

Topic 1: Molecular pathways that control muscle stem cell self-renewal and differentiation
Topic 2: Genome engineering to correct genetic mutations that cause muscle diseases
Topic 3: Muscle fiber composition, force production and insulin sensitivity
Topic 4: Amino acid sensitivity in skeletal muscle following exercise

The course will be organized into 7 sessions, each approx. 4 hours: the first 2 sessions will be theoretical and include an introductory lectures by the professors in addition to a journal club presentation by the students. This journal club aims to provide theoretical and scientific background that will be used to identify outstanding research questions. This will be followed by 4 practical sessions (hands-on experience) and 1 final evaluation session.

For the journal club, each group of students will receive a peer-review article that is highly relevant to the respective group’s research topic. Each of the 4 groups will present and discuss the article in a journal club format to the rest of the participants the following week. During the four practical sessions, students will gain hands-on experiences and learn different lab techniques related to molecular biology of exercise and muscle regeneration. Each group will be presented with a research objective that is related to their topic, and perform in collaboration with teaching assistants a set of experiments that aim to address the research objective. At the final evaluation session, each group of students will present their results and identify follow-up research questions and hypothesis based on their experimental achievements.

Select practical methods that the proposed course will teach include:

i. Group 1: tissue culture, isolation of muscle stem cells via FACS, differentiation of muscle stem cell into muscle fibers, small molecules screens, quantitative analysis of muscle cell proliferation and fusion, Immunofluorescence.
ii. Group 2: tissue culture, differentiation of muscle stem cells into muscle fibers, guide RNA design and Crispr-Cas9 gene editing of genetic mutations that cause muscle diseases in muscle stem cells and fibers. Immunofluorescence and PCR.
iii. Group 3: ex vivo assessment of muscle force characteristics, cryosectioning of muscle tissue, immunofluorescence and western blot.
iv. Group 4: tissue culture of muscle stem cells, isolation of muscle stem cells and differentiation into muscle fibers, amino acid stimulation of muscle fibers, Western blot.

Prerequisites / notice

Prerequisites:

376-0006-02L Laboratory Course in Molecular biology

Key for Type

<table>
<thead>
<tr>
<th>W+</th>
<th>Eligible for credits and recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

Key for Hours

| V  | lecture                            |
| G  | lecture with exercise              |
| U  | exercise                           |
| S  | seminar                            |
| K  | colloquium                         |
| P  | practical/laboratory course        |
| A  | independent project                |
| D  | diploma thesis                     |
| R  | revision course / private study    |

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Core Courses First Year Examinations

### Examination Block 1

*Students are free to take the exam either in German or in French. They may choose between 853-0723-00L 'Introduction to Torts, Contract and Insurance Law' or 851-0709-00L 'Introduction to Civil Law' (French)*

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0723-00L</td>
<td>Introduction to Torts, Contracts and Insurance Law</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>C. von Zedtwitz</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to Torts, Contracts and Insurance Law</td>
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<tr>
<td>Objective</td>
<td>The course shall make sure that the participants are fit to make the adequate decisions when encountering legal questions and issues in their career.</td>
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<tr>
<td>Content</td>
<td>In order to achieve this goal, legal problems and issues will be presented to the participants and then discussed in class.</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>The course 'Introduction au Droit civil' (851-0709-00) provides an introduction to the law of Contracts and Torts in French.</td>
<td></td>
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</tr>
<tr>
<td>851-0709-00L</td>
<td>Introduction to Civil Law</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>H. Peter</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course Private Law focuses on the Swiss Code of Obligations (contracts, torts) and on Property Law (ownership, mortgage and easements). In addition, the course will provide a short overview of Civil Procedure and Enforcement.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Teaching of the principles of law, particularly private law. Introduction to law.</td>
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</tr>
<tr>
<td>Content</td>
<td>Le cours de droit civil porte notamment sur le droit des obligations (droit des contrats et responsabilité civile) et sur les droits réels (propriété, gages et servitudes). De plus, il est donné un bref aperçu du droit de la procédure et de l'exécution forcée.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Literature</td>
<td>Editions officielles récentes des lois fédérales, en langue française (Code civil et Code des obligations) ou italienne (Codice civile e Codice delle obbligazioni), disponibles auprès de la plupart des librairies.</td>
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<td></td>
<td>Sont indispensables:</td>
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<tr>
<td></td>
<td>- le Code civil et le Code des obligations;</td>
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<td></td>
<td>Sont conseillés:</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>- Nef, Urs Ch.: Le droit des obligations à l'usage des ingénieurs et des architectes, trad. Bovay, J., éd. Payot, Lausanne</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Boillod, J.-P.: Manuel de droit, éd Slatkine, Genève</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Remarques:</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>- Le cours de droit civil et le cours de droit public (2e sem.) sont l'équivalent des cours &quot;Recht I&quot; et &quot;Recht II&quot; en langue allemande et des exercices y relatifs.</td>
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<tr>
<td></td>
<td>- Les examens peuvent se faire en français ou en italien.</td>
<td></td>
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<tr>
<td></td>
<td>- Examen au 1er propédeutique; convient pour travail de semestre.</td>
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<tr>
<td></td>
<td>- Con riassunti in italiano. E possibile sostenere l'esame in italiano.</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>851-0577-00L</td>
<td>Principles of Political Science</td>
<td>O</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>T. Bernauer, C. Brügge, S. Rhein</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course deals with basic questions, concepts, theories, methods, and empirical findings of political science.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>This course deals with basic questions, concepts, theories, methods, and empirical findings of political science.</td>
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</tbody>
</table>
The lectures "Leadership I" (WS) and "Leadership II" (SS) have been designed as a two-semester lecture series, but may also be followed independently of one another or in reverse order. "Leadership I" covers the following fields: leadership basics, leadership theories and leadership styles, the concept of leadership responsibility and the role of communication in practical leadership. The aim of this lecture is to give students an introductory overview of relevant topics regarding leadership research and practice, thus enabling them to gain a deeper understanding of the leadership phenomenon. Students should understand different concepts of leadership in the complex interaction between individuals, groups, organizations, contexts, and situations. They should grasp the concept of leadership responsibility (leadership ethics) and be able to derive consequences for leadership in practical situations.

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical Competencies</td>
<td>Problem-solving</td>
<td>fostered</td>
</tr>
<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
</tr>
<tr>
<td>Cooperation and Teamwork</td>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td>Negotiation</td>
<td>fostered</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
</tbody>
</table>

The aim of this course is to provide an introduction to relevant topics in leadership research and practice, enabling students to gain a deeper understanding of the leadership phenomenon. Students should understand different concepts of leadership in the complex interaction between individuals, groups, organizations, contexts, and situations. They should grasp the concept of leadership responsibility (leadership ethics) and be able to derive consequences for leadership in practical situations. They should recognize the fundamental importance of communication in leadership situations and receive input that enables them to communicate adequately in specific situations.
### Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>351-1034-00L</td>
<td>Microeconomics</td>
<td>O</td>
<td>3</td>
<td>2V</td>
<td>A. Fetz, M. Gysler</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
<td></td>
<td></td>
<td>Not for students belonging to D-MTEC!</td>
</tr>
<tr>
<td></td>
<td>Introduction to the economic decisions of households and firms, and their coordination through markets. Analysis of different market structures and of situations in which markets may lead to socially undesirable outcomes.</td>
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<tr>
<td></td>
<td><strong>Objective</strong></td>
<td></td>
<td></td>
<td></td>
<td>Understanding of basic microeconomic models. Ability to apply these models to real world economic situations.</td>
</tr>
<tr>
<td></td>
<td><strong>Content</strong></td>
<td></td>
<td></td>
<td></td>
<td>Economics as a science, division of labour and welfare (concept of comparative advantage), supply and demand (market equilibrium, elasticity), households (preferences, demand), firms (technology, cost analysis, profit maximisation, supply), perfect competition, monopoly and oligopoly, externalities, public goods, information, factor markets and income distribution</td>
</tr>
<tr>
<td></td>
<td><strong>Lecture notes</strong></td>
<td></td>
<td></td>
<td></td>
<td>via email</td>
</tr>
<tr>
<td></td>
<td><strong>Literature</strong></td>
<td></td>
<td></td>
<td></td>
<td>Mankiw, G. and Taylor M. (2023): Economics, Cengage Learning</td>
</tr>
<tr>
<td></td>
<td><strong>Prerequisites / notice</strong></td>
<td></td>
<td></td>
<td></td>
<td>Course macroeconomics in the spring term</td>
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</table>

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
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<tr>
<td></td>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Social Competencies</td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
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<tr>
<td></td>
<td></td>
<td>Customer Orientation</td>
<td>fostered</td>
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<td></td>
<td></td>
<td>Leadership and Responsibility</td>
<td>assessed</td>
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<tr>
<td></td>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>fostered</td>
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<tr>
<td></td>
<td></td>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Personal Competencies</td>
<td>Adaptable and Flexibility</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Creative Thinking</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<tr>
<td></td>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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<tr>
<td></td>
<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>History Part One: Europe (The Cradle of Modernity, Britain, 1789-1914)</th>
<th>O</th>
<th>3</th>
<th>2V</th>
<th>H. Fischer-Tiné</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
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<td>A range of fundamental processes have transformed European societies in the course of the 19th and the 20th centuries. This lecture series looks at several key aspects of these modernization processes and asks about their continuing relevance for our times. The regional focus lies on where these processes took place for the first time.</td>
</tr>
<tr>
<td></td>
<td><strong>Objective</strong></td>
<td></td>
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<td></td>
<td>At the end of this lecture course, students can: (a) highlight the most important changes in the &quot;long nineteenth century&quot; in Britain (b) explain their long-term effects (also for other European countries) and (c) relate these changes to global developments today.</td>
</tr>
<tr>
<td></td>
<td><strong>Content</strong></td>
<td></td>
<td></td>
<td></td>
<td>The thematic foci include: Industrialization, urban growth, democratization and mass politics, shifting gender roles and ideals, and the emergence of consumerism and leisure culture.</td>
</tr>
<tr>
<td></td>
<td><strong>Lecture notes</strong></td>
<td></td>
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<td></td>
<td>Power Point Slides and references will be made available in digital form during the course of the semester.</td>
</tr>
<tr>
<td></td>
<td><strong>Literature</strong></td>
<td></td>
<td></td>
<td></td>
<td>Mandatory and further reading will be listed on the course plan that is made available as from the first session.</td>
</tr>
<tr>
<td></td>
<td><strong>Prerequisites / notice</strong></td>
<td></td>
<td></td>
<td></td>
<td>This lecture series does not build upon specific previous knowledge by the students.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Social Competencies</td>
<td>Sensitivity to Diversity</td>
<td>fostered</td>
</tr>
<tr>
<td></td>
<td>Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Military Psychology and Pedagogy I</th>
<th>O</th>
<th>4</th>
<th>2V+3U</th>
<th>H. Annen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>Examine the fundamentals of the two sciences and establish links with military life. Discuss various schools of thought in psychology and focus on content and process theories of motivation. Explore characteristics of pedagogical thinking and discuss the values of military education with reference to the young adult serving in the armed forces.</td>
</tr>
</tbody>
</table>

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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2329 of 2653
Objective
- Becoming acquainted with basic psychological views of human behaviour and experience
- Knowing content- and process theories of motivation and being able to transfer them to the military context
- Knowing the possibilities and limitations of military education and deriving consequences

Content
Overall, the objective is to become acquainted with the basics of both scientific areas and to make references to military practice. Military psychology is a branch of applied psychology, consequently selected aspects of psychological principles will be covered. Military pedagogy hasn't yet established itself firmly as an independent scientific discipline, it nevertheless can draw on a deep-seated tradition in Switzerland. Thus, the great importance that has been attached to the discussion of education in Swiss society and academia will be taken into account.

Subjects:
- History of military psychology
- Introduction to psychological thinking
- Motivational theories
- Defence-, service-, operational- and combat motivation
- Swiss military pedagogy
- Education as defining feature of pedagogic thinking and acting

This course is completed by a compulsory one week course between terms.

Literature
- Annen, H., Steiger, R. & Zwyzgurt, U.: Gemeinsam zum Ziel, Huber, Frauenfeld 2004 (provided as pdf)
- Stadelmann, J.: Führung unter Belastung, Huber, Frauenfeld 1998 (provided as pdf)

The lecture is supported by a virtual learning environment containing relevant documents (presentations and texts) and information to further literature.

Competencies
Subject-specific Competencies

Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Social Competencies

Leadership and Responsibility assessed
Self-presentation and Social Influence assessed

Personal Competencies

Critical Thinking assessed
Self-awareness and Self-reflection assessed

Remaining Core Courses of the Bachelor Programme

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0205-00L</td>
<td>Proseminar I: Political Methodology</td>
<td>O</td>
<td>3</td>
<td>2S</td>
<td>A. Levis, E. Henninger</td>
</tr>
</tbody>
</table>

Abstract
Teaching of formal requirements of scientific work (philosophy of science with a focus on the social sciences); literature reviews and the basics of conducting independent research on short as well as simple topics; basics of conceptualizing research designs for politically relevant questions and hypotheses.

Objective
1) Understanding the goal and the basic procedures of (empirical social sciences) scientific work (philosophy of science, theory building, research design, as well as the correct employment of sources, data and literature).
2) Identification of relevant research questions.
3) Creating a common basis for a thorough and systematic analysis of these.

Content
Political Methodology I seeks to introduce students to the basics of scientific work and procedures in the social sciences, which in turn shall allow them - also in conjunction with Political Methodology II - to conduct work that fulfills satisfactory standards of research quality throughout their further studies.

With regard to Political Methodology I, this seminar primarily focuses on the philosophy and theory of (empirical social) sciences, its structure, and procedures. The seminar emphasizes substantive contents and ways of presenting them, research and conceptual work. Additionally, it deals with the basis of establishing research designs with politically relevant questions and hypotheses.

Literature

Prerequisites / notice
Each student will be graded by two exercises (50% each).

1) Source analysis and acquisition: based upon a research question that will be given by the lecturer, the student shall collect a comprehensive list of the relevant literature and summarize that with her/his own words.

2) Critical analysis of sources: based upon a research article that the student chooses on her/his own, the student shall write a critical analysis of that, which mirrors frame and structure of scientific writing

Submission dates will be communicated in the first meeting.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0064-00L</td>
<td>Military Sociology I</td>
<td>O</td>
<td>3</td>
<td>2V</td>
<td>T. Szvircsev Tresch, S. De Rosa, T. Ferst</td>
</tr>
</tbody>
</table>

Abstract
Beside of the most important terms of sociology, demographic changes and the related value and structure change will be analysed. The second part focuses on organizational sociology. Thirdly, the course examines to which extent armed forces can be considered as organizations like any other and to which extent they constitute a special case from an organizational and normative point of view.

Objective
Recognize and explain current changes (social change) in modern society (individualisation, pluralisation); describe demographic changes in Switzerland; explain the structures of societies; define issues and fields of research in modern military sociology and explain the foundations of organisational sociology; explain the military in terms of organisational sociology and identify specific traits of the military as an organisation.

Content
Societal change; organizations as societal phenomena; aims, structures, environments of organizations; specifics of the military as an organization; impacts of technological and societal changes on the armed forces in modern societies.

Literature
A reader with a set of texts will be handed out.
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: assessed
- Problem-solving: fostered
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: fostered

Languages

First Foreign Language

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0405-00L</td>
<td>English, Part I</td>
<td>O</td>
<td>3 credits</td>
<td>4G</td>
<td>S. Schweizer</td>
</tr>
</tbody>
</table>

Abstract
Teaching is focused on the acquisition of general English in the four classical skills, i.e. speaking, listening comprehension, reading comprehension and writing. The goal is to reach level B2 or C1 depending on the linguistic proficiency of the students.

Objective
This three-semester English course should enable the participants to successfully use the English language in an international military setting.

Content
- Read, analyse and write military and civilian documents
- Listening comprehension using current radio or TV reports
- Practise speaking through group discussions and short presentations
- Systematic revision and extension of key grammar points
- Systematic acquisition of general and military vocabulary

3. Semester

Remaining Core Courses of the Bachelor Programme

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0001-00L</td>
<td>Conflict Research I: Political Violence</td>
<td>O</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>A. Juon</td>
</tr>
</tbody>
</table>

Abstract
Introduction to research on political violence in domestic and international politics. This course covers the causes and solutions to different types of political violence including interstate wars, civil wars, terrorism or social protests.

Objective
Knowledge on different types of political violence and their causes.

Content
- This course offers an introduction to research on the causes and solutions to political violence in domestic and international politics. First, we discuss the definitions and concepts used in conflict research, the data and methods commonly applied and their historical development. Second, we focus on interstate wars and examine in this context state formation, nationalism and democracy. The third part of the course focuses on different types of political violence, including civil war, terrorism or social protests.

Prerequisites / notice
Exercises complete the lectures, where the literature will be further discussed. The participants write a short memo (max. 3 pages) about one of the required readings.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0007-00L</td>
<td>World Politics Since 1945: The History of International Relations</td>
<td>O</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>A. Wenger</td>
</tr>
</tbody>
</table>

Abstract
This lecture series provides students with an overview of the development of international relations since the end of World War II. The first part of the series deals with the development of and changes in Cold War security policy structures. The second part deals with the period after the transformation of 1989/91; the focus here is on current issues in international security policy.

Objective
By the end of the semester, participants should have a solid knowledge of the history and theoretical foundations of International Relations since the end of the Second World War.

Content
- cf. "Diploma Supplement"
- The lecture is being supported by a website on Moodle. If you have any questions, please contact Fabio Schmocker (fabio.schmocker@sipo.gess.ethz.ch)

Competencies
- Concepts and Theories: assessed
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Leadership and Responsibility: fostered
- Sensitivity to Diversity: fostered
- Negotiation: assessed

Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: fostered

Business Administration I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0065-00L</td>
<td>Business Administration I</td>
<td>O</td>
<td>4 credits</td>
<td>3V</td>
<td>P. Barmettler</td>
</tr>
</tbody>
</table>

Abstract
The course BA I provides an understanding of the principles of General Business Management. It comprises an introduction to the basic business principles within a business acumen with a clear focus on value creation.

The theory conveyed is illustrated with exercises, case studies and examples from business practice.
Objective

Objectives
- Understanding and application of instruments and methods of general management.
- Driving customer equity.
- Reflection of common business practices.

Content


I ENTREPRENEURIAL THINKING AND ACTION
1. Customer orientation and value creation
2. Business and Environment
3. Legal forms of business under Swiss corporate law

II BUSINESS PROCESSES
4. Marketing I
5. Marketing II

III SUPPORTING PROCESSES
6. Human Resource Management I
7. Human Resource Management II

IV MANAGEMENT PROCESSES
8. Organisation
9. Value-based management
10. Mission, Business Norms and Business Culture
11. Strategic Management

Literature


853-0063-00L Military History I O 4 credits 2V+3U M. Olsansky, T. Cubito, A. Wettstein

Abstract
The lecture outlines the development of the armed forces (assets regarding manpower, technology and armament), the concepts of warfare and the actual warfare in the 19th and 20th century.

Objective
- Distinguish between military history as a subject and historiography as a way of describing events;
- Analyse the modern developments regarding armed forces and warfare in the context of socio-economic changes;
- Based on the approach regarding revolution in military affairs, describe the evolution of the armed forces and of warfare;
- Exemplify the issues regarding the evolution of the combat (First and Second World War, Vietnam War and Algerian War).

Content
The lecture first examines the bases of the science of (military) history. It focuses on how military history developed from war history, on specific similarities and differences between military history and general historiography, the different ways of dealing with history in Switzerland, Germany, France and in the Anglo-Saxon cultural area (different approaches) as well as on institutions which deal with military history such as universities, military academies, national and international commissions and associations etc.

The lecture is structured along the lines of the concept of “Military Revolution” and starts with the formation of modern, European armed forces after the Oranian Army reform in the 17th century.

Based on the “Military Revolution” approach, the lecture examines the structural changes regarding the armed forces and the development of warfare from the 18th to the 20th century. Special emphasis will be put on how the battlefield was revolutionized due to the Napoleonic wars, the industrialization in the 19th century, the First World War, the mechanization and totalization during the Second World War and the period of the Cold War.

Literature

Competencies
Subject-specific Competencies Concepts and Theories fostered
Method-specific Competencies Analytical Competencies fostered
Social Competencies Sensitivity to Diversity fostered
Personal Competencies Critical Thinking fostered
Self-direction and Self-management fostered

853-0082-00L Strategic Studies I O 3 credits 2V M. Berni, M. Wyss

Abstract
The lecture Strategic Studies deals with the use of political and military power from an interdisciplinary and global perspective.

Objective
Participants know how the understanding of strategy has changed over time.
They understand the interplay between the basic components of strategy.
They know the main strategic concepts and models and are able to discuss them critically.
By examining selected historical and contemporary examples, they are aware of the inherent tension between the formulation (declaration) and application (implementation) of strategies. They are able to critically analyse original texts and contemporary publications in the field of strategic studies.
They are able to use case studies to explain how technological change affects strategic thinking.

Content
The two-semester course covers key issues in strategic studies.
The first semester focuses on key concepts and foundations, which are applied and critically discussed in the second semester.
Both political and military theorists, practitioners and case studies will be discussed. The course also emphasizes the role of non-European thinkers and theories. The focus will then be on the impact and practical implementation.
For each of the strategies discussed, the original context and the state of technological development will be highlighted.

Lecture notes
Prior to the lectures, the respective slides are provided as well as a primary sources and literature, as preparatory readings (via Moodle).
Prerequisites / notice

The lecture is held in German.

Passive knowledge of English and French are required.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Method-specific Competencies
- Analytical Competencies: assessed
- Media and Digital Technologies
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Sensitivity to Diversity: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed

Abstract

Switzerland in the context of European integration

The course (lecture and tutorial) deals with the theory, development and central policy areas of European integration as well as the structures and processes of the EU as a political system. The course systematically links this basic knowledge with an analysis of the bilateral relationship between Switzerland and the EU.

Objective

The idea that Switzerland's relationship with the EU is at a 'crossroads' is a cliché that has been used repeatedly in recent decades. But could it be true this time? Since the breakdown of the negotiations on a framework agreement and the recently launched attempt for a third package of bilateral treaties, there is more uncertainty than ever in the Swiss-EU relationship. Switzerland is once again faced with the decision between greater proximity or isolation.

The seminar places the bilateral relationship between Switzerland and the EU in the broader context of European integration. It helps to understand the EU as a highly developed instrument of transnational problem solving and as a special political system. It provides basic knowledge about the history, institutions, procedures and policy areas of the EU and offers an introduction to important approaches in integration theory and political science analyses of European integration. The seminar systematically links this basic knowledge of the political system of the EU with an examination of the logic, development and perspective of the bilateral relationship between the EU and Switzerland.

Content

Course plan
1. A brief history of European integration
2. The European Union as a political system
3. The European Union as a community of law
4. The European Union as a system of differentiated integration
5. Theories of integration: Why integration?
6. Ten years of polycrisis: What next for the EU?
7. A brief history of the relationship between Switzerland and the EU
8. Trade
9. Free movement of persons
10. Justice and home affairs, foreign affairs, migration
11. Research, cohesion, energy
12. Domestic political discourse and public opinion in Switzerland
13. The future of Switzerland-EU relations

Literature

Literatur wird über Moodle bereitgestellt.

Prerequisites / notice

Die Leistungskontrolle findet durch eine Seminarpräsentation und einen schriftlichen Schlusstest statt.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed

Method-specific Competencies
- Analytical Competencies: assessed

Social Competencies
- Communication: assessed

Personal Competencies
- Critical Thinking: assessed

Abstract

In terms of structure and content, the event follows the lecturer's book "Militärökonomie" (Military Economics), which is available in two language versions:

- German language: ISBN 978-3-658-06146-3

Objective

- Recognizing parallels and contrasts between business and military thinking;
- Recognize and analyze planned economic systems;
- Understand the link between institutions, human action and economic results.
The semester program of the course is divided into 14 modules of 90 minutes each, which combine lecture (teaching of analytical techniques) and exercise (application by means of concrete case studies).

The contents correspond to sections 1 to 2.2.5 of the above book. The following will be discussed:

1. fundamental military economic problems including historical introduction to the topic
2. the institutional foundations of a military organisation
3. the modern military as a planned economy system
4. actors and stakeholders in the system

Lecture notes
Lecture slides are given to the participants before the first lecture. In addition, the above mentioned book will be handed over to the participants. Participants of the lecture who are not professional officer candidates are requested to obtain the book from the library or bookstore.

Literature

Prerequisites / notice
none.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility assessed
Self-presentation and Social Influence fostered
Sensitivity to Diversity assessed
Negotiation fostered

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Languages

First Foreign Language

Number Title Type ECTS Hours Lecturers
853-0416-00L English, Part III O 3 credits 4G S. Schweizer

Abstract
The knowledge and skills acquired in the second semester serve as a basis for further improvements in the areas of speaking, listening, reading and writing, which will enable students to enroll for the Cambridge exams. The goal is to reach Council of Europe (CEFR) level C1 or C2 depending on the linguistic proficiency of the students.

Objective
This three-semester English course should enable the participants to successfully use the English language in an international military setting.

Content
Read, analyse and write military and civilian documents
Listening comprehension using current radio or TV reports
Practise speaking with group discussions and short presentations
Systematic revision and extension of key grammar points
Systematic acquisition of general and military vocabulary

5. Semester

Remaining Core Courses of the Bachelor's Programme

Number Title Type ECTS Hours Lecturers
853-0049-00L Introduction to Constitutional Law in Security Policy O 3 credits 2V R. Müller

Abstract
The lecture deals with questions of competence and the security policy instruments in the federal state, conveys the basic principles of police law and deals with the management of extraordinary situations. Special topics are the army, civil protection, the intelligence service, cooperation (at home and abroad), the legal status of army members and private security providers.

Objective
The students can
- explain the basic concepts of security law;
- outline the basic constitutional order for Swiss security policy, identify the competences of the Confederation and assess the advantages and disadvantages of this basic order;
- explain and evaluate special legal forms of action;
- distinguish the tasks of security policy actors and assess forms of cooperation;
- derive legal limitations for operations of the armed forces from the Federal Constitution;
- identify the basic principles and individual special aspects of military-civilian cooperation;
- identify the police powers of the armed forces and determine the permissibility of using forms of coercion;
- describe the legal status of members of the armed forces and explain the special responsibility of officers;
- establish the relationship between the actions of state actors and the guarantee of fundamental rights;
- assess current challenges in security law.
The objective of this two-semester seminar-style course is to write an advanced-level research paper in the field of Strategic Studies. In the first part, terms of security and police law are introduced, the Swiss security constitution (Confederation and cantons) is explained and the significance of fundamental rights guarantees is shown.

In the second part, the security policy instruments of the Confederation and the cantons are assessed critically. A special focus is placed on the army. In addition to its constitutional anchoring and its tasks, the forms of deployment enshrined in the relevant regulations (e.g. military act) are examined from a legal perspective. Special attention is given to police powers of military forces.

The third part of the course deals in greater depth with the intelligence service, civil protection, the legal permitted tasks of private security providers and the legal status of military personnel.

Lecture notes
Reader:
https://moodle-app2.let.ethz.ch/course/view.php?id=11049

Literature
The basic source of the lectures is (purchase recommended):
- Gianfranco Albertini/Thomas Armbruster/Beat Spörri, Militärisches Einsatzecht, Zürich 2016 (ISBN 978-3-7255-7080-5; around CHF 89.90)

Other texts are prepared in a reader.

Competencies
Subject-specific Competencies
Concepts and Theories
assessed

Method-specific Competencies
Analytical Competencies
assessed

Social Competencies
Leadership and Responsibility
assessed

Personal Competencies
Critical Thinking
assessed

853-0038-00L Swiss Foreign Policy

Abstract
This course analyzes the foundations and challenges of Swiss foreign policy. After reviewing the history of foreign policy conceptions since the early 20th century, we will discuss the determining factors of Swiss foreign policy and examine, together with guest speakers from the foreign ministry, current international developments and respective foreign policy challenges.

Objective
Students should acquire a sound understanding of Swiss foreign policy and the relevant academic and political debates associated with it.

Content
Nach einer Einführung in die Außenpolitikanalyse behandelt die Lehrveranstaltung zunächst die historischen Grundlagen und die konzeptionelle Entwicklung der schweizerischen Außenpolitik. Dabei stehen die unterschiedlichen Reaktionen der Schweiz auf die internationalen Neuordnungen nach 1918, 1945 und 1989 und die seitherige Ausgestaltung der Schweizer Außenpolitik im Zentrum.


Einbezug von Gastreferaten von Mitarbeitenden des Eidgenössischen Departements für auswärtige Angelegenheiten (EDA).

The course will be supported by an e-learning environment.

Lecture notes
Students will receive a handout of slides accompanying the lectures.

The course will be supported by an e-learning environment.

853-0321-00L Advanced Course II (Seminar)

Abstract
The objective of this two-semester seminar-style course is to write an advanced-level research paper in the field of Strategic Studies. In the second semester, students write their seminar paper and present it in plenary.

Objective
Students write their seminar paper based on the research design they developed during Advanced Course I (Seminar). Students should consider the seminar paper as preparation for their BA thesis.

Content
Advanced Course II builds upon Advanced Course I. Within the broader framework of the overall seminar topic (The Strategic Relevance of Surprise, Deception, and Intelligence) and based on the approved research design as developed during Advanced Course I, participants write their seminar papers in consultation with their lecturers (30 pages max).

Lecture notes
none

Literature
Basic literature is available on Moodle (Advanced Course I). The search for additional literature is a fundamental part of the research process. Students may consult their lecturers if they have any questions.

Prerequisites / notice
Accepted research design (Advanced Course I) is required.

Competencies
Subject-specific Competencies
Concepts and Theories
assessed

Method-specific Competencies
Analytical Competencies
assessed

Social Competencies
Communication
assessed

Personal Competencies
Adaptability and Flexibility
assessed

853-0061-00L Introduction to Cybersecurity Politics

Abstract
The lecture is an introduction to global cybersecurity politics. The focus is on the strategic use of cyberspace by state and non-state actors (threats) and different answers to these new challenges (countermeasures).

Objective
Participants learn to assess the advantages and disadvantages of cyberspace as a domain for strategic military operations. They understand the technical basics of cyber operations and know how technology and politics are interlinked in this area. They understand the security challenges for and the motivations of states to be active in cyberspace offensively and defensively and they are familiar with the consequences for international politics.
We start with an overview of cybersecurity issue from 1980 to today and look at events and actors responsible for turning cybersecurity matters into a security political issue with top priority. After familiarizing ourselves with the technical basics, we look at different forms of cyberviolence and trends in cyber conflicts (technique in social and political practice). Then, we turn to countermeasures: we compare national cybersecurity strategies, examine international norms building, and scrutinize concepts such as cyber-power and cyber-deterrence (technique in social and political regulartory contexts).

Lecture notes
A script with background information and comments on the literature will be made available at the beginning of the semester.

Literature
Literature for each session will be available on Moodle.

Prerequisites / notice
The lecture is being supported by a website on Moodle.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Sensitivity to Diversity: fostered
Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed
- Self-direction and Self-management: fostered

Social Psychology of Groups

Abstract
Basic social psychological topics are elaborated, presented, and discussed in the most application-oriented way.

Objective
You are able to recognize and explain various social psychological aspects and factors and to evaluate them in your everyday decisions in terms of planning, content and operations. This means you will be able to assess when various social psychological aspects may play a role in your everyday work. And you are able to assess what this may subsequently mean for your work or leadership processes.

Content

1) Führungspychologie: Kurzer Einblick in neuere Führungstheorien.
2) Destructive Führung: Was sollten wir nicht machen?
3) Soziale Kognition: Warum und auf Basis welcher wenigen Informationen wir sehr schnell Urteile über Personen treffen.
4) Soziale Wahrnehmung/Attribution: Wie erklären wir uns, dass sich jemand im Alltag in gewisser Art und Weise verhält?
5) Diversity & Frauen & Führung: Woran kann es liegen, dass weibliche Führungskräfte besondere Herausforderungen bei der Ausübung von Führung haben?
6) Sozialer Einfluss: Welche Normen erleben Sie beim Militär? Und wie leiten diese Erwartungen unser Verhalten im Berufsalltag?
7) Grupenpsychologie: Was heisst "Gruppe"? Wie entwickeln sich (militärische) Gruppen, z.B. in der RS? Welche Prozesse können zwischen Gruppen geschehen?
9) Überzeugungsstrategien
Literature


Prerequisites / notice

Languages

Second Foreign Language

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0402-00L</td>
<td>German, Part II</td>
<td>W</td>
<td>3 credits</td>
<td>4G</td>
<td>S. Schweizer</td>
</tr>
</tbody>
</table>

Abstract

Based on the knowledge and skills acquired during the first semester, speaking and discussion skills related to military situations are examined and put into practice. Attention is focused on issues such as instruction, qualification and career interviews.

Objective

This two-semester German course should enable the French and Italian speaking participants to fulfill their function as professional officers also in the German language.

Content

Read, analyse and write military and civilian documents
Listening comprehension using current radio or TV reports
Practise speaking with group discussions and short presentations
Systematic revision and extension of key grammar points
Systematic acquisition of general and military vocabulary

| 853-0404-00L | French, Part II | W | 3 credits | 4G | S. Schweizer |

Abstract

Based on the knowledge and skills acquired during the first semester, speaking and discussion skills related to military situations are examined and put into practice. Attention is focused on issues such as instruction, qualification and career interviews.

Objective

This two-semester French course should enable the German speaking participants to fulfill their function as professional officers also in the French language.

Content

Read, analyse and write military and civilian documents
Listening comprehension using current radio or TV reports
Practise speaking with group discussions and short presentations
Systematic revision and extension of key grammar points
Systematic acquisition of general and military vocabulary

Bachelor's Colloquium and Bachelor's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0315-00L</td>
<td>BA Colloquium</td>
<td>O</td>
<td>2 credits</td>
<td>2K</td>
<td>F. Schimmelfennig</td>
</tr>
</tbody>
</table>

Abstract

The BA Colloquium prepares students for their BA thesis with regard to content, administration, and methodology. During the colloquium, students choose a topic and a supervisor for their thesis. The skills students have acquired during the course of their studies are also enhanced and optimized.

Objective

The students are being prepared administratively and methodologically to write their BA-thesis after completing the course.

Content

The BA Colloquium prepares students for their BA thesis with regard to content, administration, and methodology. During the colloquium, each student has to choose a topic for his/her BA-thesis. The students also choose their supervisors, whereas the goal is an even distribution of the supervisors. Finally, the methodological competences which were acquired during the first four semesters will be complemented.
### Electives

#### Recommended Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0054-00L</td>
<td>Bachelor's Thesis</td>
<td></td>
<td>10 credits</td>
<td>8D</td>
<td>Lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>The Bachelor Thesis completes the Bachelor program and consists of a scientific project carried out independently under the tuition of an ETH or MILAK lecturer in Public Policy.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The elaboration of the Bachelor Thesis should further students' capacities to work independently, structured and scientifically.</td>
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</tbody>
</table>

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### Additional Elective Courses

*These Electives may be chosen from the start of the Bachelor Study Programme.*

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1033-00L</td>
<td>History of Sports</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>M. Gisler</td>
</tr>
<tr>
<td>Abstract</td>
<td>Comprehension for development and changes of sports from the ancient world to the presence. Description of sports in services of national idea, from education and health promotion from the middle of the 18th century till this day.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Understanding for the development and adaptation of sports from the ancient world to present times.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Ein Skript für die aktuelle Veranstaltung wird abgegeben.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>376-1107-00L</td>
<td>Sport Pedagogy</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>C. Herrmann</td>
</tr>
<tr>
<td>Abstract</td>
<td>The teacher-student interaction presents a complex psychosocial event, demonstrating the need for a psychological extension of the classical social science / sports pedagogical perspective. Therefore, this lecture will be focused on &quot;pedagogical-psychological aspects of competence development in the context of a multi-perspective physical education&quot;.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Development of pedagogical-psychological competences for the optimisation of future teaching activities.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Content | - Subject area of educational psychology  
- Motivating students in physical education  
- Building self-efficacy and strengthen the self-concept  
- Promoting positive emotions and a positive attitude to anxiety  
- Encouraging self-directed learning  
- Leading classes and promoting cooperation  
- Communicating with students efficiently  
- Reflecting your own expectations critically  
- Handling gender issues sensitively  
- Promoting inclusion / Strengthening social and moral development  
- Dealing with difficult students  
- Evaluating achievements of students |      |      |      |                            |
| Lecture notes | Teaching materials for the individual lectures are provided to the students via moodle. |      |      |      |                            |

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**Data:** 15.06.2024 12:39  
**Autumn Semester 2024**  
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This lecture is intended as an introduction to sport psychology and imparts knowledge on selected areas of the subject.

Students are given insight into different work areas of sport psychology. In order to understand what «sport psychology» is, it is necessary to explain the essence and tasks of sport psychology and what it relates to, and to work out an underlying basis for key topics, such as cognition and emotions. Students' expertise is furthered by presenting and providing more in-depth treatment of additional topics of sport psychology. Selected intervention forms are intended to provide insight into applied sport psychology and ensure that mental processes and their impact in sport can be recognised. Case studies and practical exercises (e.g. objective training) are intended to prompt students to reflect to a greater extent on the forms in which sport psychology can be applied in their practice of sports and to integrate these in their teaching.

Main Topics
- Introduction to sport psychology
- Cognitions in sports: mental rehearsal and mental training
- Emotions and stress
- Motivation: goal-setting in sports
- Career and career transition in elite sport
- Coach-Athlete-Interaction
- Psychological aspects of sport-injury rehabilitation
- Group dynamics in sport

Selected materials for the lecture are available on the Moodle platform. Lecture notes are instructional materials for each course will be made available to students. All lecture materials will be available to students on Moodle.

This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined.

Particularly suitable for students of D-ITET, D-USYS.

The course is open to all ETH students and visiting students from other universities. Participation does not require previous coursework in the social sciences or environmental policy.

The objectives in this course are to (1) gain an overview of important questions pertaining to international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions in this policy area and how to address them in a conceptually and methodologically meaningful and insightful way; (3) gain an overview of important global and regional environmental problems and how they are or could be solved.

Determined by students' expertise is furthered by presenting and providing more in-depth treatment of additional topics of sport psychology.

Credits and Exam
After passing a written test at the end of the course (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test). Visiting students (e.g., from the University of Zurich, exchange students) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory. No separate registration for the exam is required, registration for the course as such covers everything. The exam will take place on campus, either in the F3 lecture hall or in a computer room. That is, you must be present in person at ETH Zurich on the exam date/time.
Abstract
The students shall obtain a basic knowledge about the legal environment of entrepreneurs. They shall be able to recognize and evaluate legal issues connected to an entrepreneurial activity and suggest possible solutions.

Objective
The students shall obtain the following competence:
- They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise.
- They shall be able to contribute to the legal management of the company and to discuss legal issues.
- They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company.

Lecture notes
A comprehensive script will be made available online on the moodle platform.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Analytical Competencies: assessed
- Problem-solving: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed

851-0735-10L
Startups and Law
W 2 credits 2V P. Peyrot
Particularly suitable for students of D-ITET, D-MAVT.

Abstract
The course gives a detailed introduction on various aspects of professional project management out of theory and practice. Established concepts and methods for project organization, planning, execution and evaluation are introduced and major challenges discussed. The course includes an introduction to specialized project management software as well as agile project management concepts.

Objective
Projects are not only the base of work in modern enterprises, but also the primary type of cooperation with customers. Students of ETH will often work in or manage projects in the course of their career. Good project management knowledge is not only a guarantee for individual, but also for company-wide success.

The goal of this course is to give a detailed introduction into project management. The students should learn to plan and execute a project.

Content
Project planning (aims, appointments, capacities, efforts and costs), project organization, scheduling and risk analysis, project execution, supervision and control, project evaluation, termination and documentation, conflict management, multinational project management, IT support as well as agile project management methods such as SCRUM.

Lecture notes
No.

The lecture slides and other additional material will be available for download from Moodle a week before each class.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: fostered
- Project Management: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Project Management: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: assessed

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: assessed

101-0515-00L
Project Management
W 2 credits 2G C. G. C. Marx

Abstract
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.
Objective
On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

851-0861-01L  
Arabic I A1.1  
W  3 credits  3G  University lecturers

Abstract
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees:

Registration dates:

Objective
On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

851-0541-00L  
Truth and Historical Injustice: The Production of Knowledge about Past Mass Atrocities  
W  3 credits  2V  S. M. Scheuzger

Abstract
The course deals with the scientific production of knowledge about past mass atrocities. It looks at the interplay of different disciplines, methods and technological means that have been involved in this production over time. Further, it poses the question of what truth can mean in this context.

Objective
The students a) know the main features of the discussion about the truth in the reconstruction of past events; b) have an understanding of the interplay, but also the coexistence of different scientific methods and technological means in the multidisciplinary production of knowledge about past mass crimes; c) have knowledge of important processes of dealing with past mass crimes from the second half of the 20th century onwards.

Content
When discussing the truthfulness of the academic study of the past, politically and ideologically motivated mass crimes are often cited as historical events in order to substantiate the necessity of a claim to truth. In doing so, moral arguments can be made or historical truth can be asserted as a basic prerequisite for living together in a democratic society under constitutional conditions.

The production of knowledge about past atrocities has always been an endeavour in which various scientific disciplines have been involved. The multidisciplinary character of the production of knowledge about mass crimes has become even more accentuated since the second half of the 20th century, not least due to the emergence of new technological possibilities.

The course offers a brief introduction to the discussion about the meaning of truth about past events. It looks at how different scientific approaches - from the humanities to the natural sciences - have been involved in coming to terms with mass crimes and how they have been related to each other. It deals with the question of what role certain techniques and technologies have played in the production of knowledge about past atrocities and how this has changed over time. These techniques and technologies range from the evaluation of documents and the taking of testimonies to specialised database programs, genetic analysis or imaging techniques, to digital technologies for the procurement of information on social media and the internet or for the modelling of past events.

In addressing these questions, the course looks at processes of dealing with the past from the middle of the 20th century to the 21st century in Europe, Latin America and Africa.

Competencies
Subject-specific Competencies
Concepts and Theories  assessed
Techniques and Technologies  assessed

Method-specific Competencies
Analytical Competencies  fostered

Personal Competencies
Critical Thinking  fostered

Public Policy Bachelor - Key for Type
O  Compulsory  E-  Recommended, not eligible for credits
W+  Eligible for credits and recommended  Z  Courses outside the curriculum
W  Eligible for credits  Dr  Suitable for doctorate

Key for Hours
V  lecture  P  practical/laboratory course
G  lecture with exercise  A  independent project
U  exercise  D  diploma thesis
S  seminar  R  revision course / private study
K  colloquium  

ECTS  European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
In regression, the dependency of a random response variable on other variables is examined. We consider the theory of linear regression.


Prerequisites / notice
This is the course unit with former course title "Regression".

401-4623-00L Time Series Analysis

Abstract
The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

Objective
The goal of the course is to have a good overview of the different types of time series and the approaches used in their statistical analysis.

Content
This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exhibited by time series is the dependence between successive observations.

The key topics which will be covered as:
- Stationarity
- Autocorrelation
- Trend estimation
- Elimination of seasonality
- Spectral analysis, spectral densities
- Forecasting
- ARMA, ARIMA, Introduction into GARCH models

Literature
The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis

Prerequisites / notice
Basic knowledge in probability and statistics

401-3622-00L Statistical Modelling

Abstract
In regression, the dependency of a random response variable on other variables is examined. We consider the theory of linear regression with one or more covariates, high-dimensional linear models, nonlinear models and generalized linear models, robust methods, model choice and nonparametric models. Several numerical examples will illustrate the theory.

Objective
Introduction into theory and practice of a broad and popular area of statistics, from a modern viewpoint.

Content

Prerequisites / notice
This is the course unit with former course title "Regression".

401-0625-01L Applied Analysis of Variance and Experimental Design

Abstract
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Objective
Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Content
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Literature

Prerequisites / notice
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Competencies
- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
- Personal Competencies
  - Critical Thinking

Mathematical Statistics

The two core courses Fundamentals of Mathematical Statistics (401-3621-00L) and Likelihood Inference (401-8623-00L) are similar in content. Therefore only one of them can be recognised towards the Master's degree in the core course area «Mathematical Statistics».

401-3621-00L Fundamentals of Mathematical Statistics

Abstract
In this course we study the basics of theoretical statistics. The course includes methods for designing estimators, confidence intervals and tests, and various ways to evaluate the accuracy of estimators, confidence intervals and tests. We consider optimality criteria such as admissibility and minimaxity, as well as Bayesian criteria. We will also present the asymptotic point of view.

Objective
The aim of this course is to gain insight into the main statistical ideas and concepts. The course considers classical low-dimensional models, with pointers towards today's highly complex models.

Lecturers
- L. Meier
- M. Kalisch
- F. Balabdaoui
- G. Oehlert
- L. Meier
- M. Kalisch
- F. Balabdaoui
- G. Oehlert
### Subject Specific Electives

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<thead>
<tr>
<th>Number</th>
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<td>401-3601-00L</td>
<td>Probability Theory</td>
<td>W</td>
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<td>401-3461-00L Functional Analysis I</td>
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<td>401-3531-00L Differential Geometry I</td>
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<td>401-3601-00L Probability Theory</td>
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<td>can be recognised for the Master's degree in Mathematics or Applied Mathematics. In this case, you cannot change the category assignment by yourself in myStudies but must take contact with the Study Administration Office (<a href="http://www.math.ethz.ch/studiensekretariat">www.math.ethz.ch/studiensekretariat</a>) after having received the credits. Moreover, 401-3601-00L Probability Theory can only be recognised for the Master Programme in Mathematics if neither 401-3642-00L Brownian Motion and Stochastic Calculus nor 401-3602-00L Applied Stochastic Processes has been recognised for the Bachelor Programme.</td>
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<td>The material covered in this course has a significant overlap with the material that has been covered in 401-3620-22L Student Seminar in Statistics: Causality F52023.</td>
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<td>Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).</td>
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<td>H. Bauer, Probability Theory, de Gruyter 1996</td>
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<td>J. Jacod and P. Protter, Probability essentials, Springer 2004</td>
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<td>A. Klenke, Wahrscheinlichkeitstheorie, Springer 2006</td>
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<td>D. Williams, Probability with martingales, Cambridge University Press 1991</td>
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<td>- Measure Theory</td>
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<td></td>
<td>- Basic notions in probability theory (probability space, conditional probability, Borel Cantelli, Dynkin Lemma, random variables, expectation, variance, law of large numbers).</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
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| 401-3627-00L | High-Dimensional Statistics | W | 4 credits | 2V | not available |
|             | Does not take place this semester. |
|             | “High-Dimensional Statistics” deals with modern methods and theory for statistical inference when the number of unknown parameters is of much larger order than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed. |
| Objective   | Knowledge of methods and basic theory for high-dimensional statistical inference |
| Content     | Lasso and Group Lasso for high-dimensional linear and generalized linear models; Additive models and many smooth univariate functions; Non-convex loss functions and 1-regularization; Stability selection, multiple testing and construction of p-values; Undirected graphical modeling |
| Prerequisites / notice | Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics). |

| 401-4632-15L | Causality | W | 5 credits | 3G | J. Peters |
|             | In statistics, we are used to search for the best predictors of some random variable. In many situations, however, we are interested in predicting a system's behavior under manipulations. For such an analysis, we require knowledge about the underlying causal structure of the system. In this course, we study concepts and theory behind causal inference. |
| Objective   | After this course, you should be able to |
|             | - understand the language and concepts of causal inference |
|             | - know the assumptions under which one can infer causal relations from observational and/or interventional data |
|             | - describe and apply different methods for causal structure learning |
|             | - given data and a causal structure, derive causal effects and predictions of interventional experiments |
| Content     | The material covered in this course has a significant overlap with the material that has been covered in 401-3620-22L Student Seminar in Statistics: Causality F52023. |
| Literature  | Parts of this course will be based on the book “Elements of Causal Inference” (MIT Press, open access). More details will follow. |
| Prerequisites / notice | Prerequisites: basic knowledge of probability theory and regression |
| Competencies | Subject-specific Competencies | Concepts and Theories | assessed |
|            | Techniques and Technologies | assessed |

| 401-3612-00L | Stochastic Simulation | W | 5 credits | 2V+1U | F. Sigrist |
|             | Does not take place this semester. |
### 401-6433-00L Data Analytics in Organisations and Business

**Abstract**
This course covers organizations and businesses' end-to-end data analytics process and deepens each process stage. It shows why a stage is needed and what actions are taken in each stage. It gives steps successfully applied in practice and loopholes when issues arise. Case studies from various industries will be presented for each stage.

**Objective**
This course aims to give the students an understanding of the whole data analytics life cycle in the business world. It shows the expectations of companies and how it is measured. It enables the student to manage successfully all the non-methodological aspects of a data analytics project which are the primary source of failure in end-to-end executions. The student will become familiar with the "business language, and cultural aspects of organizations. It also gives an overview of the data analytics tool, platform, and methods ecosystem for successfully technical data analyses.

**Content**
1. Introduction
2. Framing the business problem
3. Framing the analytics problem
4. Data
5. Identification of problem-solving approaches and appropriate tools
6. How to set up and validate models
7. The deployment of a model
8. Model lifecycle
9. Operating models and roles
10. Some words about soft skills needed by statistical and mathematical professionals

**Lecture notes**
The lecture's presentation slides will be provided.

**Prerequisites / notice**
Familiarity with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

### 401-6217-00L Using R for Data Analysis and Graphics (Part II)

**Abstract**
The course builds on part I and covers the following additional topics:
- Elements of the R language: control structures (if, else, loops), lists, overview of R objects, attributes of R objects;
- More on R functions;
- Applying functions to elements of vectors, matrices and lists;
- Object oriented programming with R: classes and methods;
- Tayloring R: options
- Extending basic R: packages

**Objective**
The students will be able to use the software R efficiently for data analysis, graphics and simple programming.

**Content**
The course focuses on practical work at the computer. We will make use of the graphical user interface RStudio: www.rstudio.org

**Lecture notes**
The course resources will be provided via the Moodle web learning platform. As from FS 2019, subscribing via Mystudies should "automatically" make you a student participant of the Moodle course of this lecture, which is at

https://moodle-app2.let.ethz.ch/course/view.php?id=20848
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making fostered
- Media and Digital Technologies assessed
- Problem-solving assessed

Social Competencies
- Communication fostered

Personal Competencies
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking fostered
- Self-direction and Self-management fostered

401-0627-00L Smoothing and Nonparametric Regression with Examples

Abstract
Starting with an overview of selected results from parametric inference, kernel smoothing will be introduced along with some asymptotic theory, optimal bandwidth selection, data driven algorithms and some special topics. Selected numerical examples will be used for motivation. The presented methods will also be applicable elsewhere.

Objective
The students will learn about methods of kernel smoothing and application of concepts to data. The aim will be to build sufficient interest in the topic and intuition as well as the ability to implement the methods to various different datasets.

Content
Rough Outline:
- Parametric estimation methods: selection of important results
  - Method of Least squares: regression & diagnostics
- Nonparametric curve estimation
  - Density estimation, Kernel regression, Local polynomials, Bandwidth selection, various theoretical results related to consistency
  - Selection of special topics (as time permits, we will discuss some of the following): rapid change points, mode estimation, partial linear models, probability and quantile curve estimation, etc.
- Applications: potential areas of applications will be discussed such as, change assessment, trend and surface estimation and others.

Lecture notes
Summaries or outlines of some of the lecture material may be communicated to registered students by Email at irregular intervals.

Literature
- Statistical Inference, by S.D. Silvey, Chapman & Hall.
- Density Estimation, by B.W. Silverman, Chapman and Hall.
- Nonparametric Simple Regression, by J. Fox, Sage Publications.

Prerequisites / notice
Prerequisites: A background in Linear Algebra, Calculus, Probability & Statistical Inference including Estimation and Testing.

447-6289-00L Bayesian Statistics

Abstract
Introduction to the Bayesian approach to statistics: decision theory, prior distributions, hierarchical Bayes models, empirical Bayes, Bayesian tests and model selection, empirical Bayes, Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods.

401-3628-14L Bayesian Statistics

Abstract
Does not take place this semester.
Objective

Students understand the conceptual ideas behind Bayesian statistics and are familiar with common techniques used in Bayesian data analysis.

Content

Topics that we will discuss are:

- Difference between the frequentist and Bayesian approach (decision theory, principles), priors (conjugate priors, noninformative priors, Jeffrey's prior), tests and model selection (Bayes factors, hyper-g priors for regression), hierarchical models and empirical Bayes methods, computational methods (Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods)

Lecture notes

A script will be available in English.

Literature


Additional references will be given in the course.

Prerequisites / notice

Familiarity with basic concepts of frequentist statistics and with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

Competencies

- Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

- Method-specific Competencies
- Analytical Competencies assessed
- Problem-solving assessed

- Social Competencies
- Self-presentation and Social Influence assessed

- Personal Competencies
- Creative Thinking assessed
- Critical Thinking assessed

Prerequisites / notice

- Familiarity with basic concepts of frequentist statistics and with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

Competencies

- Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

- Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed

- Social Competencies
- Communication assessed
- Cooperation and Teamwork fostered
- Sensitivity to Diversity fostered

- Personal Competencies
- Adaptability and Flexibility fostered
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

Prerequisites / notice

- Familiarity with basic concepts of frequentist statistics and with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

Competencies

- Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies fostered

- Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed

- Social Competencies
- Communication assessed
- Cooperation and Teamwork fostered
- Sensitivity to Diversity fostered

- Personal Competencies
- Adaptability and Flexibility fostered
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

401-4944-20L

Mathematics of Data Science

Objective

Introduction to various mathematical aspects of Data Science.

Abstract

Mostly self-contained, but fast-paced, introductory masters level course on various theoretical aspects of algorithms that aim to extract information from data.

Literature


Prerequisites / notice

- Familiarity with basic concepts of frequentist statistics and with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

Competencies

- Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies fostered

- Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed

- Social Competencies
- Communication assessed
- Cooperation and Teamwork fostered
- Sensitivity to Diversity fostered

- Personal Competencies
- Adaptability and Flexibility fostered
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

Data: 15.06.2024 12:39   Autumn Semester 2024   Page 2346 of 2653
Creative Thinking assessed fostered Concepts and Theories assessed fostered https://people.math.ethz.ch/~abandeira/BandeiraSingerStrohmer-MDS-draft.pdf (see Subject-specific Competencies fostered Communication fostered Analytical Competencies assessed fostered Decision-making assessed Media and Digital Technologies fostered Problem-solving assessed Project Management fostered Social Competencies Communication fostered Cooperation and Teamwork fostered Sensitivity to Diversity fostered Personal Competencies fostered Creative Thinking fostered Critical Thinking fostered Integrity and Work Ethics fostered Self-awareness and Self-reflection fostered Self-direction and Self-management fostered

We encourage students who are interested in mathematical data science to take both this course and 227-0434-10L Mathematics of Information taught by Prof. H. Bölcskei. The two courses are designed to be complementary.

A. Bandeira and H. Bölcskei

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Social Competencies Communication fostered Cooperation and Teamwork fostered Sensitivity to Diversity fostered

Personal Competencies fostered Creative Thinking fostered Critical Thinking fostered Integrity and Work Ethics fostered Self-awareness and Self-reflection fostered Self-direction and Self-management fostered

401-4656-21L AI in the Sciences and Engineering W 6 credits 2V+2U S. Mishra

Aimed at students in a Master's Programme in Mathematics, Engineering and Physics.

Abstract AI is having a profound impact on science by accelerating discoveries across physics, chemistry, biology, and engineering. This course aims to present a highly topical selection of AI applications across these fields. Emphasis will be placed on using AI, particularly deep learning, to understand systems modelled by PDEs, and key scientific machine learning concepts and themes will be discussed.

Objective Learning objectives:
- Aware of advanced applications of AI in the sciences and engineering
- Familiar with the design, implementation, and theory of these algorithms
- Understand the pros/cons of using AI and deep learning for science
- Understand key scientific machine learning concepts and themes

Content A selection of the following topics will be presented in the lectures:
1. Key scientific tasks common to many scientific domains, such as simulation, inverse problems, equation discovery, design, and control problems, and issues with traditional methods for solving them
2. Physics-informed neural networks for solving forward, inverse and equation discovery problems related to PDEs
3. Neural operators, including Fourier neural operators and DeepONets, for learning efficient surrogate models, and their theoretical foundations
4. Differentiable scientific algorithms, neural differential equations, and the benefits of hybrid workflows
5. AI for symbolic regression and equation discovery
6. Applications of graph neural networks in science
7. Guest lectures on AI for chemistry and biology
8. Large language models and other Foundation models for scientific discovery

Applications using these techniques will be illustrated across fluid dynamics, wave physics, medical physics, molecular design, and computational biology. Several examples where AI algorithms outperform traditional scientific workflows will be shown.

Lecture notes Lecture slides, recordings, and tutorials will be available on Moodle.

Literature Prerequisites / notice
- All the material in the course is based on research articles written in last 1-3 years. The relevant references will be provided.
- An understanding of basic ML concepts including supervised learning, overfitting/underfitting, optimisation, and neural networks is required; you should understand the main concepts in the ETH 252-0220-00L Introduction to Machine Learning course (but note, completing this course is not a formal requirement)
- Familiar with PDEs and numerical methods for solving them
- Basic competence in Python and some practical familiarity with deep learning frameworks (e.g. PyTorch, TensorFlow, or Keras)

Competencies

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<td>Techniques and Technologies</td>
<td>Problem-solving</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>Project Management</td>
</tr>
<tr>
<td></td>
<td>Fostered</td>
<td>Assessed</td>
</tr>
</tbody>
</table>

Social Competencies Communication fostered Cooperation and Teamwork fostered

Personal Competencies fostered Adaptable and Flexible fostered

401-3931-00L Responsible Machine Learning with Insurance Applications W 4 credits 2G M. Mayer, C. Lorentzen-Geiser
This lecture covers important aspects of applying supervised machine learning models in a responsible way, based on sound statistical theory. The focus is on model interpretability, calibration (bias) assessment, and proper model comparison. The methods are illustrated with actuarial datasets.

Objective

The student is familiar with the main tools of model interpretability, calibration assessment, and model comparison and knows how to apply supervised machine learning in a responsible way.

Content

- Overview of supervised machine learning (statistical learning theory, GLMs, tree based methods, and neural nets; cross-validation)
- Model interpretability methods (partial dependence plots, measures of variable importance, and SHAP)
- Bias/calibration assessment with identification functions
- Model comparison with consistent scoring functions
- Working with dependent observations and further topics

Prerequisites / notice

This course will be held in English and counts towards the diploma of “Aktuar SAV”. For the latter, see details under www.actuaries.ch.

Competencies

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies

252-0535-00L Advanced Machine Learning W 10 credits 3V+2U+4A C. Cottrini Jimenez

Abstract

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistical knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
- What is data?
- Bayesian Learning

Computational learning theory

Supervised learning:
- Ensembles: Bagging and Boosting
- Max Margin methods
- Neural networks

Unsupervised learning:
- Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

252-3005-00L Natural Language Processing W 7 credits 3V+3U+1A R. Cotterell

Abstract

This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Objective

The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

Content

This course presents an introduction to general topics and techniques used both in research and in commercial natural language systems. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Literature

Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

227-0423-00L Neural Network Theory W 4 credits 2V+1U H. Bölcskei

Abstract

The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation theorems, capacity of separating surfaces, generalization, fundamental limits of deep neural network learning, VC dimension.

Objective

After attending this lecture, participating in the exercise sessions, and working on the homework problem sets, students will have acquired a working knowledge of the mathematical foundations of neural networks.

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2348 of 2653
1. Universal approximation with single- and multi-layer networks
2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory
3. Fundamental limits of deep neural network learning
4. Geometry of decision surfaces
5. Separating capacity of nonlinear decision surfaces
6. Vapnik-Chervonenkis (VC) dimension
7. VC dimension of neural networks
8. Generalization error in neural network learning

Lecture notes
Detailed lecture notes are available on the course web page
https://www.mins.ee.ethz.ch/teaching/nnt/

Prerequisites / notice
This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

263-3210-00L Deep Learning W 8 credits 3V+2U+2A T. Hofmann

Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://ml2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/ss19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18

263-5210-00L Probabilistic Artificial Intelligence W 8 credits 3V+2U+2A A. Krause

Abstract
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice
Solid basic knowledge in statistics, algorithms and programming.

The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Method-specific Competencies
- Communication
- Cooperation and Teamwork
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

Social Competencies

Personal Competencies

263-5300-00L Guarantees for Machine Learning W 7 credits 3V+1U+2A F. Yang

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2349 of 2653
Reliable and Trustworthy Artificial Intelligence

Abstract
Creating reliable, secure, robust, and fair machine learning models is a core challenge in artificial intelligence and one of fundamental importance. The goal of the course is to teach both the mathematical foundations of this new and emerging area as well as to introduce students to the latest and most exciting research in the space.

Objective
Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of engineering and research problems. To facilitate deeper understanding, the course includes a group coding project where students will build a system based on the learned material.

Content
The course is split into 4 parts:

Robustness of Machine Learning

- Adversarial attacks and defenses on deep learning models.
- Certified training of deep neural networks (combining symbolic and continuous methods).

Privacy of Machine Learning

- Threat models (e.g., stealing data, poisoning, membership inference, etc.).
- Attacking federated machine learning (across vision, natural language and tabular data).
- Differential privacy for defending machine learning.
- AI Regulations and checking model compliance.

Fairness of Machine Learning

- Introduction to fairness (motivation, definitions).
- Enforcing individual fairness (for both vision and tabular data).
- Enforcing group fairness (e.g., demographic parity, equalized odds).

Robustness, Privacy and Fairness of Foundation Models

- We discuss all previous topics, as well as programmability, in the context of latest foundation models (e.g., LLMs).


Students have usually taken a subset of Fundamentals of Mathematical Statistics, Probabilistic AI, Neural Network Theory, Optimization for Data Science, Advanced ML, Statistical Learning Theory, Probability Theory (D-MATH)

Prerequisites / notice
Students should have a very strong mathematical background (real analysis, probability theory, linear algebra) and solid knowledge of core concepts in machine learning taught in courses such as "Introduction to Machine Learning", "Regression" / "Statistical Modelling". In addition to these prerequisites, this class requires a high degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2350 of 2653
Introduction to GNN concepts: 1) problem-solving on graphs (node-, edge-, graph-level objectives), structural priors (inductive biases) of G. Rätsch assessed

Subject-specific Competencies
- 2V+2U+1A

Lectures will include: microarray preprocessing; normalization; exploratory data analysis techniques such as clustering, PCA and multidimensional scaling; controlling error rates of statistical tests (FPR versus FDR versus FWER); Irima (linear models for microarray analysis); mapping algorithms (for RNA/ChIP-seq); RNA-seq quantification; statistical analyses for differential count data; isoform switching; epigenomics data including DNA methylation; gene set analyses; classification

Prerequisites / notice
263-3210-00 Deep Learning or 263-0008-00 Computational Intelligence Lab;
252-0220-00 Introduction to Machine Learning; Statistics/Probability; Programming in Python; Unix Command Line.

263-5351-00L Machine Learning for Genomics W 6 credits 2V+2U+1A V. Boeva

Abstract
The course reviews solutions provided by machine learning to the most challenging questions in human genomics.

Objective
- Over the last few years, the parallel development of machine learning methods and molecular profiling technologies for human cells, such as sequencing, created an extremely powerful tool to get insights into the cellular mechanisms in healthy and diseased contexts. In this course, we will discuss the state-of-the-art machine learning methodology solving or attempting to solve common problems in human genomics. At the end of the course, you will be familiar with (1) classical and advanced machine learning architectures used in genomics, (2) bioinformatics analysis of human genomic and transcriptomic data, and (3) data types used in this field.

Content
- Short introduction to major concepts of molecular biology: DNA, genes, genome, central dogma, transcription factors, epigenetic code, DNA methylation, signaling pathways
- Prediction of transcription factor binding sites, open chromatin, histone marks, promoters, nucleosome positioning (convolutional neural networks, position weight matrices)
- Prediction of variant effects and gene expression (hidden Markov models, topic models)
- Deconvolution of mixed signal (NMF, ICA)
- DNA, RNA and protein folding (RNN, LSTM, transformers)
- Data imputation for single-cell RNA-seq data, clustering and annotation (diffusion and methods on graphs)
- Batch correction (autoencoders, optimal transport)
- Survival analysis (Cox proportional hazard model, regularization penalties, multi-omics, multi-tasking)

Prerequisites / notice
- Introduction to Machine Learning, Statistics/Probability, Programming in Python, Unix Command Line

401-6282-00L Statistical Analysis of High-Throughput Genomic and Transcriptomic Data (University of Zurich) W 5 credits 3G H. Rehраuеr

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: STA426

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

Abstract
A range of topics will be covered, including basic molecular biology, genomics technologies and in particular, a wide range of statistical and computational methods that have been used in the analysis of DNA microarray and high throughput sequencing experiments.

Objective
- Understand the fundamental "scientific process" in the field of Statistical Bioinformatics
- Be equipped with the skills/tools to preprocess genomic data (Unix, Bioconductor, mapping, etc.) and ensure reproducible research (Sweave)
- Have a general knowledge of the types of data and biological applications encountered with microarray and sequencing data
- Have the general knowledge of the range of statistical methods that get used with microarray and sequencing data
- Gain the ability to apply statistical methods/knowledge/software to a collaborative biological project
- Write a coherent summary of a bioinformatics problem and its solution in statistical terms

Content
Lectures will include: microarray preprocessing; normalization; exploratory data analysis techniques such as clustering, PCA and multidimensional scaling; controlling error rates of statistical tests (FPR versus FDR versus FWER); Irima (linear models for microarray analysis); mapping algorithms (for RNA/ChIP-seq); RNA-seq quantification; statistical analyses for differential count data; isoform switching; epigenomics data including DNA methylation; gene set analyses; classification

Lecture notes
- Lecture notes, published manuscripts

Prerequisites / notice
- Prerequisites: Basic knowledge of the programming language R, sufficient knowledge in statistics

Former course title: Statistical Methods for the Analysis of Microarray and Short-Read Sequencing Data
Clinical Biostatistics (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: STA404

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline_s.html

Abstract
Discussion of the different statistical methods that are used in clinical research.

Content
Discussion of the different statistical methods that are used in clinical research. Among other subjects the following will be introduced: sample size calculation, randomization and blinding, analysis of clinical trials (parallel groups design, analysis of covariance, crossover design, equivalence studies), intention-to-treat analysis, multiple testing, group sequential methods, adaptive designs, diagnostic studies, and agreement studies.

Literature

Prerequisites / notice
Basic knowledge of the programming language R, sufficient knowledge in calculus, linear algebra, probability, statistics

Seminar or Semester Paper

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<tr>
<td>401-3620-74L</td>
<td>Student Seminar in Statistics: ...</td>
<td>W</td>
<td>4 credits</td>
<td>2S</td>
<td>Y. Chen</td>
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<tr>
<td>401-3630-04L</td>
<td>Semester Paper ■</td>
<td>W</td>
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<td>6A</td>
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<tr>
<td>401-3630-06L</td>
<td>Semester Paper ■</td>
<td>W</td>
<td>6 credits</td>
<td>9A</td>
<td>Supervisors</td>
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<tr>
<td>252-5051-00L</td>
<td>Advanced Topics in Machine Learning ■</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>R. Cotterell, M. El-Assady, N. He, F. Yang</td>
</tr>
</tbody>
</table>

Free Electives

Several further courses offered at the University of Zurich belong to the curriculum of the Master's Programme in Statistics. With the consent by the Advisor (http://stat.ethz.ch/~kalisch/) such a course is eligible as a free elective.

Science in Perspective

Two credits are needed from the "Science in Perspective" programme with language courses excluded if three credits from language courses have already been recognised for the Bachelor's degree.

see https://www.uzh.ch/dame/ethz/common/docs/weisungsammlung/files-en/science-in-perspective.pdf (Eight credits must be acquired in this category: normally six during the Bachelor's degree programme, and two during the Master's degree programme. A maximum of three credits from language courses from the range of the Language Center of the University of Zurich and ETH Zurich may be recognised. In addition, only advanced
courses (level B2 upwards) in the European languages English, French, Italian and Spanish are recognised. German language courses are recognised from level C2 upwards.

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-MATH

# Master's Thesis

<table>
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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>401-2000-00L</td>
<td>Scientific Works in Mathematics</td>
<td>O</td>
<td>0 credits</td>
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<td>D. Possamaï</td>
</tr>
</tbody>
</table>

Abstract

Introduction to scientific writing for students with focus on publication standards and ethical issues, especially in the case of citations (references to works of others.)

Objective

Learn the basic standards of scientific works in mathematics.

- Types of mathematical works
- Publication standards in pure and applied mathematics
- Data handling
- Ethical issues
- Citation guidelines

Prerequisites / notice


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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-2000-01L</td>
<td>Lunch Sessions – Thesis Basics for Mathematics Students</td>
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<td>0 credits</td>
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</table>

Abstract

Optional MathBib training course

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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>401-4990-02L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>57D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Abstract

The master's thesis concludes the study programme. Thesis work should prove the students' ability to independent, structured and scientific working.

Objective

Thesis work should prove the students' ability to independent, structured and scientific working.

Content

Five-month project to solve a research question. The content can be more theoretical (e.g. proving a new result) or applied (developing new methods or making a very sophisticated application and adapting existing methods).

Prerequisites / notice

Supervisors are chosen on a first-come-first-served basis. Collaborations with industry are possible.

# Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tr>
<td>406-0173-AAL</td>
<td>Linear Algebra I and II</td>
<td>E-</td>
<td>6 credits</td>
<td>13R</td>
<td>N. Hungerbühler</td>
</tr>
</tbody>
</table>

Abstract

Linear algebra is an indispensable tool of engineering mathematics. The course is an introduction to basic methods and fundamental concepts of linear algebra and its application to engineering sciences.

Objective

After completion of this course, students are able to recognize linear structures and to apply adequate tools from linear algebra in order to solve corresponding problems from theory and applications. In addition, students have a basic knowledge of the software package Matlab.

Content


Reading:

Gilbert Strang "Introduction to linear algebra", Wellesley-Cambridge Press: Chapters 1-6, 7.1-7.3, 8.1, 8.2, 8.6


<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<th>Instructor</th>
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<tbody>
<tr>
<td>406-0243-AAL</td>
<td>Analysis I and II</td>
<td>14</td>
<td>M. Akveld</td>
<td></td>
</tr>
<tr>
<td>406-0603-AAL</td>
<td>Stochastics (Probability and Statistics)</td>
<td>4</td>
<td>9R</td>
<td>M. Kalisch</td>
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<tr>
<td>406-2604-AAL</td>
<td>Probability and Statistics</td>
<td>8</td>
<td>17R</td>
<td>F. Balabdaoui</td>
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</tbody>
</table>

**Literature**

### 406-0243-AAL
**Analysis I and II**

*Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.*

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**
Mathematical tools for the engineer

**Objective**
Mathematics as a tool to solve engineering problems. Basic mathematical knowledge for engineers. Mathematical formulation of technical and scientific problems.

**Content**
- Complex numbers.
- Calculus for functions of one variable with applications.
- Simple Mathematical models in engineering.

### 406-0603-AAL
**Stochastics (Probability and Statistics)**

*Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.*

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**
Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

**Objective**
The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

**Content**
- From "Statistics for research" (online)
  - Ch 1: The Role of Statistics
  - Ch 2: Populations, Samples, and Probability Distributions
  - Ch 3: Binomial Distributions
  - Ch 6: Sampling Distribution of Averages
  - Ch 7: Normal Distributions
  - Ch 8: Student's t Distribution
  - Ch 9: Distributions of Two Variables
- From "Introductory Statistics with R (online)"
  - Ch 1: Basics
  - Ch 2: The R Environment
  - Ch 3: Probability and distributions
  - Ch 4: Descriptive statistics and tables
  - Ch 5: One- and two-sample tests
  - Ch 6: Regression and correlation

**Literature**
- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
  - From within the ETH, this book is freely available online under: http://onlinelibrary.wiley.com/book/10.1002/0471477435
  - From within the ETH, this book is freely available online under: http://www.springerlink.com/content/m17578/

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Media and Digital Technologies
  - Problem-solving
- Personal Competencies
  - Self-direction and Self-management

**406-2604-AAL**
**Probability and Statistics**

*Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.*

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.
Abstract
- Probability spaces
- Discrete models, Random walk
- Conditional probabilities, independence
- Continuous models
- Limit theorems
- Methods of moments
- Maximum likelihood estimation
- Hypothesis testing
- Confidence intervals
- Introductory Bayesian statistics
- Linear regression model

Objective
The first part of the course gives an overview of the main concepts needed to understand probability theory (sample spaces, discrete models, random walk, continuous models and limit theorems such as the Laws of Large Numbers and the Central limit theorem). It will be based on the German script "Wahrscheinlichkeitsrechnung und Statistik".

The second part covers some fundamental results of mathematical statistics including estimation methods, hypothesis testing as well as the linear regression model. For this part, we will use the script "Statistics for Mathematics". Both scripts are available at https://www.stat.math.ethz.ch/~fadouab/.

Content
Probability:
Chapters 1-5 (Probabilities and events, Discrete and continuous random variables, Generating functions) and Sections 7.1-7.5 (Convergence of random variables) from the book "Probability and Random Processes". Most of this material is also covered in Chap. 1-5 of "Mathematical Statistics and Data Analysis", on a slightly easier level.

Statistics:
Sections 8.1 - 8.5 (Estimation of parameters), 9.1 - 9.4 (Testing Hypotheses), 11.1 - 11.3 (Comparing two samples) from "Mathematical Statistics and Data Analysis".

Lecture notes
(*) Wahrscheinlichkeitsrechnung und Statistik

(*) Statistics for Mathematics

Both scripts can be found at https://www.stat.math.ethz.ch/~fadouab/

Literature
A. Irle, Wahrscheinlichkeitstheorie und Statistik, Teubner (2001)

Statistics Master - Key for Type

Dr Suitable for doctorate | W Eligible for credits
O Compulsory | E- Recommended, not eligible for credits
W+ Eligible for credits and recommended | Z Courses outside the curriculum

Key for Hours

V lecture | P practical/laboratory course
G lecture with exercise | A independent project
U exercise | D diploma thesis
S seminar | R revision course / private study
K colloquium

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### First Year Compulsory Courses

#### First Year Examination Block A

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<tbody>
<tr>
<td>401-0141-00L</td>
<td>Linear Algebra</td>
<td>O</td>
<td>5 credits</td>
<td>4V+1U</td>
<td>M. Akka Ginosar, R. Prohaska</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to Linear Algebra

**Objective**
Basic knowledge of linear algebra as a tool for solving engineering problems. Understanding of abstract mathematical formulation of technical and scientific problems. Together with Analysis we develop the basic mathematical knowledge for an engineer.

**Content**
Introduction and linear systems of equations, matrices, quadratic matrices, determinants and traces, general vector spaces, linear mappings, bases, change of basis, diagonalization, eigenvalues and eigenvectors, orthogonal transformations, scalar-product, inner product spaces.

**Lecture notes**
The lecturer will provide course notes.

**Literature**
- K. Nipp, D. Stoffer, Lineare Algebra, VdF Hochschulverlag ETH
- G. Strang, Lineare Algebra, Springer

**Competencies**
- Subject-specific Competencies: Concepts and Theories, assessed
- Method-specific Competencies: Analytical Competencies, assessed
- Personal Competencies: Critical Thinking, fostered

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0845-00L</td>
<td>Computer Science I</td>
<td>O</td>
<td>5 credits</td>
<td>2V+2U</td>
<td>M. Lüthi, A. Streich</td>
</tr>
</tbody>
</table>

**Abstract**
The course covers the basic concepts of computer programming.

**Objective**
Basic understanding of programming concepts. Students will be able to write and read simple programs and to modify existing programs. In the course "Computer Science I", the competency of programming is taught, applied and examined. Furthermore modeling is taught and applied.

**Content**
variables, types, control structures, functions, scoping, recursion, object-oriented programming. The programming language is Python.

**Lecture notes**
The slides and lecture notes will be made available for download on the course website.

**Literature**
- Learn to Code by Solving Problems
- A Python Programming Primer
- Daniel Zingaro
- Python Crash Course
- A Hands-On, Project-Based Introduction to Programming
- Eric Matthes
- Python for Data Analysis
- Data wrangling with pandas, NumPy & Jupyter, 3rd Edition
- Wes McKinney

**Competencies**
- Subject-specific Competencies: Concepts and Theories, assessed
- Method-specific Competencies: Analytical Competencies, assessed
- Personal Competencies: Critical Thinking, assessed

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

**Abstract**
This introductory lecture in ecology covers basic ecological concepts and the most important levels of complexity in ecological research. Ecological concepts are exemplified by using aquatic and terrestrial systems; corresponding methodological approaches are demonstrated. Threats to biodiversity and the appropriate management are discussed. A further aim of the lecture is that students achieve an understanding of biodiversity, why it is threatened and how it can be managed.

**Objective**
The objective of this lecture is to teach basic ecological concepts and the different levels of complexity in ecological research. The students should learn ecological concepts at these different levels in the context of concrete examples from terrestrial and aquatic ecology. Corresponding methods for studying the systems will be presented.

**Content**
- Biodiversity: variation, threats and conservation
- Influence of environmental factors on organisms; adaptation to environmental conditions
- Population dynamics: causes, description, prediction and regulation
- Interactions between species (competition, coexistence, predation, parasitism, food webs)
- Ecological communities: structure, stability, succession
- Ecosystems: compartments, material and energy flows

**Lecture notes**
Documents, lecture slides, exercises and relevant literature are available in Moodle. The documents for the next lecture will be available on Friday morning at the latest.

**Literature**
### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: fostered

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Sensitivity to Diversity: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### 151-0223-10L Engineering Mechanics

**Abstract**
Introduction to engineering mechanics: kinematics, statics and dynamics of rigid bodies and systems of rigid bodies.

**Objective**
Students can solve problems of elementary engineering mechanics.

**Content**
- Basic notions: position and velocity of particles, rigid bodies, planar motion, kinematics of rigid body, force, couple, power.
- Statics: static equivalence, force-couple system, center of forces, centroid, principle of virtual power, equilibrium, constraints, statics, friction.
- Dynamics: acceleration, inertial forces, d'Alembert's Principle, Newton's Second Law, principles of linear and angular momentum, equations of planar motion of rigid bodies.

**Lecture notes**
yes, in German

**Literature**

### First Year Examination Block B

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0241-00L</td>
<td>Analysis I</td>
<td>O</td>
<td>7</td>
<td>4V+2U</td>
<td>M. Akveld, G.-I. Ionita</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Mathematical tools for the engineer</td>
<td></td>
<td></td>
<td></td>
<td>Mathematical formulation of technical and scientific problems.</td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>Mathematics as a tool to solve engineering problems.</td>
<td></td>
<td></td>
<td></td>
<td>Basic mathematical knowledge for engineers.</td>
</tr>
<tr>
<td><strong>Content</strong></td>
<td>Complex numbers.</td>
<td></td>
<td></td>
<td></td>
<td>Calculus for functions of one variable with applications.</td>
</tr>
<tr>
<td></td>
<td>Simple Mathematical models in engineering.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Lecture notes</strong></td>
<td>Wird auf der Vorlesungshomepage zu Verfügung gestellt.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Urs Stammbach, &quot;Analysis III&quot; (erhältlich im ETH Store); <a href="https://people.math.ethz.ch/~stammb/analysisskript.html">https://people.math.ethz.ch/~stammb/analysisskript.html</a></td>
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</tbody>
</table>

| 529-2001-02L  | Chemistry I    | O    | 4    | 2V+2U | J. Cvengros, J. E. E. Buschmann, P. Funck, R. Verel |
| **Abstract**  | General Chemistry I: Chemical bond and molecular structure, chemical thermodynamics, chemical equilibrium. |       |      |       |                                           |
|               | In the course "Chemistry I", the competencies of process understanding, system understanding, modeling, concept development and data analysis & interpretation are taught, applied and examined. |       |      |       |                                           |
| **Objective** | Introduction to general and inorganic chemistry. Basics of the composition and the change of the material world. Introduction to the thermodynamically controlled physico-chemical processes. Macroscopic phenomena and their explanation through atomic and molecular properties. Using the theories to solve qualitatively and quantitatively chemical and ecologically relevant problems. |       |      |       |                                           |
| **Content**   | 1. Stoichiometry |       |      |       | Amount of substance and mass. Composition of chemical compounds. Reaction equation. Ideal gas law. |
|               | 4. Basics of chemical thermodynamics |       |      |       | System and surroundings. Description of state and change of state of chemical systems. |
| **Lecture notes** | Online-Skript mit durchgerechneten Beispielen. |       |      |       |                                           |
Literature
Weiterführende Literatur:
Catherine Housecroft, Edwin Constable, CHEMISTRY: AN INTRODUCTION TO ORGANIC, INORGANIC AND PHYSICAL CHEMISTRY, 3. Auflage, Prentice Hall, 2005.(englisch)

Competencies

Subject-specific Competencies
Concepts and Theories
- assessed
Techniques and Technologies
- assessed

Method-specific Competencies
Analytical Competencies
- assessed
Decision-making
- assessed
Media and Digital Technologies
- fostered
Problem-solving
- assessed
Project Management
- fostered

Social Competencies
Communication
- fostered
Cooperation and Teamwork
- fostered

Personal Competencies
Adaptability and Flexibility
- fostered
Creative Thinking
- assessed
Critical Thinking
- assessed
Integrity and Work Ethics
- fostered
Self-awareness and Self-reflection
- fostered
Self-direction and Self-management
- fostered

Additional First Year Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0004-00L</td>
<td>Introduction into Environmental Engineering</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>P. Molnar, R. Boes, P. Burlando, I. Hajnsek, S. Hellweg, M. Maurer, E. Morgenroth, R. Stocker, J. Wang</td>
</tr>
</tbody>
</table>

Abstract
In this course students are introduced to how environmental problems in the areas of water quantity and quality, waste production and recycling, air pollution control, are formulated and solved with engineering methods. The course makes a connection between the theoretical Bachelor foundation classes and practical topics of environmental engineering in six main thematic areas.

Objective
After completing this course, the student will be able to:
- formulate key global environmental problems
- develop a systems perspective and solutions to the problems (critical thinking)
- identify and solve simple numerical problems in the domain areas
- understand why/how we use data/models in environmental engineering
- develop own interest in the domain areas and see career opportunities

Content
Topics of study:
1. Water Science & Engineering – definition of the global water cycle and hydrological regimes, surface/subsurface flow equations (advection, diffusion), water resources management, climate change.
4. River and Hydraulic Engineering – utility hydraulic engineering (hydropower production), protective hydraulic engineering (flood protection), waters protection (river restoration, ecological measures at hydropower plants).
5. Air Quality – air quality parameters, main air pollutants, air quality in cities/indoor, emission control, the plume dispersion model.
6. Earth Observation – satellite observation of the Earth System from space, methods, environmental applications (glaciers, forest, land surface change)

Lecture notes
Course will take place in English and German (bilingual). The English textbook by Masters and Ela (see below) will be complemented by instructors materials to the individual thematic topics. Lecture presentations will be the main study material. There is no formal Script.

Literature
- lecture presentations and selected papers

Competencies

Subject-specific Competencies
Concepts and Theories
- assessed
Techniques and Technologies
- assessed

Method-specific Competencies
Analytical Competencies
- assessed
Decision-making
- assessed
Media and Digital Technologies
- fostered
Problem-solving
- fostered
Project Management
- fostered

Social Competencies
Communication
- fostered
Cooperation and Teamwork
- fostered
Customer Orientation
- fostered
Leadership and Responsibility
- fostered
Self-presentation and Social Influence
- fostered
Sensitivity to Diversity
- fostered

Personal Competencies
Creative Thinking
- fostered
Critical Thinking
- fostered
Self-awareness and Self-reflection
- fostered

Second and Third Year Compulsory Courses

Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0293-00L</td>
<td>Hydrology</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>P. Burlando</td>
</tr>
</tbody>
</table>
The course introduces the students to engineering hydrology. It covers first physical hydrology, that is the description and the measurement of hydrological processes (precipitation, interception, evapotranspiration, runoff, erosion, and snow), and it introduces then the basic mathematical models of the single processes and of the rainfall-runoff transformation, thereby including flood analysis.

Know the main features of engineering hydrology. Apply methods to estimate hydrological variables for dimensioning hydraulic structures and managing water resources.

The hydrological cycle: global water resources, water balance, space and time scales of hydrological processes.

Pretication: mechanisms of precipitation formation, precipitation measurements, variability of precipitation in space and time, precipitation regimes, point/basin precipitation, isohyet method, Thiessen polygons, storm rainfall, design hyetograph.

Interception: measurement and estimation.

Evaporation and evapotranspiration: processes, measurement and estimation, potential and actual evapotranspiration, energy balance method, empirical methods.

Infiltration: measurement, Horton’s equation, empirical and conceptual models, phi-index and percentage method, SCS-CN method.

Surface runoff and subsurface flow: Hortonian and Dunnian surface runoff, streamflow measurement, streamflow regimes, annual hydrograph, flood hydrograph analysis – baseflow separation, flow duration curve.

Basin characteristics: morphology, topographic and phreatic divide, hypsometric curve, slope, drainage density.

Rainfall-runoff models (R-R): rational, linear model of rainfall-runoff transformation, concept of the instantaneous unit hydrograph (IUH), linear reservoir, Nash model.

Flood estimation methods: flood frequency analysis, deterministic methods, probabilistic methods (e.g. statistical regionalisation, indirect R-R methods for flood estimation, rational method).

Erosion and sediment transport: watershed scale erosion, soil erosion by water, estimation of surface erosion, sediment transport.

Snow (and ice) hydrology: snow characteristic variables and measurements, estimation of snowmelt processes by the energy budget equation and conceptual melt models (temperature index method and degree-day method), snowmelt runoff.

The lecture notes as well as the lecture presentations and handouts may be downloaded from the website of the Chair of Hydrology and Water Resources Management.

The lecture notes as well as the lecture presentations and handouts may be downloaded from the website of the Chair of Hydrology and Water Resources Management.
### Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-4001-00L</td>
<td>Microbiology</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>M. Schuppler, M. La Fortezza, M. Pilhofer, S. Robinson</td>
</tr>
<tr>
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<td>Some parts of the lecture will be taught in English.</td>
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<tr>
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<td>Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.</td>
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<td>Objective</td>
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<td>Teaching of basic knowledge in microbiology.</td>
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<td></td>
<td></td>
<td>Content</td>
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<td>Lecture notes</td>
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<td>Wird von den jeweiligen Dozenten ausgegeben.</td>
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<td>Literature</td>
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<td></td>
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<td></td>
<td>Die Behandlung der Themen erfolgt auf der Basis des Lehrbuchs Brock, Biology of Microorganisms</td>
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<td>Competencies</td>
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<tr>
<td></td>
<td>Subject-specific Competencies</td>
<td></td>
<td></td>
<td></td>
<td>Concept and Theories assessed</td>
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<td></td>
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<td></td>
<td>Techniques and Technologies assessed</td>
</tr>
<tr>
<td>402-0023-01L</td>
<td>Physics</td>
<td>O</td>
<td>7</td>
<td>5V+2U</td>
<td>J. Faist</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>This course gives an overview of important concepts in classical dynamics, thermodynamics, electromagnetism, quantum physics, atomic physics, and special relativity. Emphasis is placed on demonstrating key phenomena using experiments, and in developing skills for quantitative problem solving.</td>
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<td>Objective</td>
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<td>The goal of this course is to make students able to explain and apply the basic principles and methodology of physics to problems of interest in modern science and engineering. An important component of this is learning how to solve new, complex problems by breaking them down into parts and applying simplifications. A secondary goal is to provide to students an overview of important subjects in both classical and modern physics.</td>
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<td>Content</td>
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<td></td>
<td></td>
<td>Electrodynamics, Thermodynamics, Quantum physics, Waves and Oscillations, special relativity</td>
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<td>Lecture notes</td>
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<td></td>
<td>Lecture notes and exercise sheets will be distributed via Moodle</td>
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<td>Literature</td>
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<td>Competencies</td>
</tr>
<tr>
<td></td>
<td>Subject-specific Competencies</td>
<td></td>
<td></td>
<td></td>
<td>Concept and Theories assessed</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
<td>Techniques and Technologies assessed</td>
</tr>
<tr>
<td>103-0233-10L</td>
<td>Fundamentals of GIS</td>
<td>O</td>
<td>6</td>
<td>5G</td>
<td>M. Raubal</td>
</tr>
<tr>
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<td></td>
<td>Fundamentals of geographic information systems: spatial data modeling; metrics &amp; topology; vector, raster and network data; thematic data; spatial statistics; system architectures; data quality; spatial queries and analysis; geovisualisation; spatial databases; labs with GIS software</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Knowing theoretical aspects of geographic information regarding data acquisition, representation, analysis and visualisation.</td>
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<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>Knowing the fundamentals of geoinformation technologies for the realization, application and operation of geographic information systems in engineering projects.</td>
</tr>
</tbody>
</table>

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**Data:** 15.06.2024 12:39  **Autumn Semester 2024**  **Page 2360 of 2653**
The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for Earth Observation.

Lecture notes
Vorlesungspräsentationen werden digital zur Verfügung gestellt.

Literature

Competencies

Content
- Einführung GIS & GIScience
- Konzeptionelles Modell & Datenschema
- Vektorgeometry & Topologie
- Rastergeometry und -algebra
- Netzwerke
- Thematische Daten
- Räumliche Statistik
- Systemarchitekturen & Interoperabilität
- Datenqualität, Unsicherheiten & Metadaten
- Räumliche Abfragen und Analysen
- Präsentation raumbezogener Daten
- Geodatenbanken

Examination Block 3

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0675-00L</td>
<td>Earth Observation</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>I. Hajnsek, P. Bernhard</td>
</tr>
</tbody>
</table>

Abstract
The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for bio/geo/environmental parameter estimation.

Objective
The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for bio/geo/environmental parameter estimation. Students should know at the end of the course:
1. Basics of measurement principle
2. Fundamentals of image acquisition
3. Basics of the sensor-specific geometries
4. Sensor-specific determination of environmental parameters

Content
Die Lehrveranstaltung gibt einen Einblick in die heutige Erdebeobachtung mit dem folgenden skizzierten Inhalt:
- Einführung in die Fernerkundung von Luft- und Weltraum gestützten Systemen
- Einführung in das Elektromagnetische Spektrum
- Einführung in optische Systeme (optisch und hyperspektral)
- Einführung in Mikrowellen-Technik (aktiv und passiv)
- Einführung in atmosphärische Systeme (meteo und chemisch)
- Einführung in die Techniken und Methoden zur Bestimmung von Umweltparametern
- Einführung in die Anwendungen zur Bestimmung von Umweltparametern in der Hydrologie, Glaziologie, Forst und Landwirtschaft, Geologie und Topographie

Lecture notes
Folien zu jeden Vorlesungsblock werden zur Verfügung gestellt.

Literature
Ausgewählte Literatur wird am Anfang der Vorlesung vorgestellt.

Examination Block 3

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0031-10L</td>
<td>Systems Engineering</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>B. T. Adey</td>
</tr>
</tbody>
</table>

Abstract
- Systems Engineering is a way of thinking that helps engineer sustainable systems, i.e., ones that meet the needs of stakeholders in the short, medium and long term.
- This course provides an overview of the main principles of Systems Engineering, and includes an introduction to the use of operations research methods in the determination of optimal systems.

Objective
The world’s growing population, changing demographics, and changing climate pose formidable challenges to humanity’s ability to live sustainably. Ensuring that humanity can live sustainably requires accommodating Earth’s growing and changing population through the provision and operation of a sustainable and resilient built environment. This requires ensuring excellent decision-making as to how the built environment is constructed and modified.

The objective of this course is to ensure the best possible decision making when engineering sustainable systems, i.e., ones that meet the needs of stakeholders in the short, medium and long term. In this course, you will learn the main principles of Systems Engineering that can help you from the first idea that a system may not meet expectations, to the quantitative and qualitative evaluation of possible system modifications. Additionally, the course includes an introduction to the use of operations research methods in the determination of optimal solutions in complex systems.

More specifically upon completion of the course, you will have gained insight into:
- how to structure the large amount of information that is often associated with attempting to modify complex systems
- how to set goals and define constraints in the engineering of complex systems
- how to generate possible solutions to complex problems in ways that limit exceedingly narrow thinking
- how to compare multiple possible solutions over time with differences in the temporal distribution of costs and benefits and uncertainty as to what might happen in the future
- how to assess values of benefits to stakeholders that are not in monetary units
- how to assess whether it is worthwhile obtaining more information in determining optimal solution
- how to take a step back from the numbers and qualitatively evaluate the possible solutions in light of the bigger picture
- the basics of operations research and how it can be used to determine optimal solutions to complex problems, including linear, integer and network programming, dealing with multiple objectives and conducting sensitivity analyses.
The lectures are structured as follows:

1. Introduction – An introduction to System Engineering, a way of thinking that helps to engineer sustainable systems, i.e. ones that meet the needs of stakeholders in the short, medium and long terms. A high-level overview of the main principles of System Engineering. The expectations of your efforts throughout the semester.
2. Situation analysis – How to structure the large amount of information that is often associated with attempting to modify complex systems.
3. Goals and constraints – How to set goals and constraints to identify the best solutions as clearly as possible.
4. Generation of possible solutions – How to generate possible solutions to problems, considering multiple stakeholders.
5. The principles of net-benefit maximization and a series of methods that range from qualitative and approximate to quantitative and exact, including pairwise comparison, elimination, weighting, and expected value.
6. The idea behind the supply and demand curves and revealed preference methods.
7. The concept of equivalence, including the time value of money, interest, life times and terminal values.
8. The relationship between net-benefit and the benefit-cost ratio. How incremental cost benefit analysis can be used to determine the maximum net benefit. Internal rates of return.
9. How to consider multiple possible futures and use simple rules to help pick optimal solutions and to determine the value of more information.
10. Once quantitative analysis is used it becomes possible to use operations research methods to analyse large numbers of possible solutions. Linear programming and the simplex method.
11. How sensitivity analysis is conducted using linear programming.
12. How to use operations research to solve problems that consist of discrete values, as well as how to exploit the structure of networks to find optimal solutions to network problems.
13. How to set up and solve problems when there are multiple objectives.

The course uses a combination of qualitative and quantitative approaches.

- The lecture materials consist of a script, the slides, example calculations in Excel, Moodle quizzes, and exercises.
- The lecture materials will be distributed via Moodle before each lecture.

**Literature**

Appropriate literature in addition to the lecture materials will be handed out when required via Moodle.

### Competencies

**Subject-specific Competencies**

- Concepts and Theories fostered
- Techniques and Technologies assessed

**Method-specific Competencies**

- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

**Social Competencies**

- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

**Personal Competencies**

- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

### Literature

- **851-0723-10L** Environmental Law
  - O 4 credits 3V M. Pfüger, A. Gossweiler, C. Jäger
  - Abstract: This class introduces students to the fundamentals of legal systems, focusing on environmental law. It covers the fundamentals of constitutional and administrative law, as opposed to private and criminal law. The class will focus on concepts, terminology and procedures of Swiss environmental law, supplemented through case studies.
  - Objective: Students learn fundamental structures of the legal system, understand core concepts and selected problems of public law, focusing on Swiss and European environmental law. These insights can be applied in further law courses, in particular in the course "Environmental law: Areas and Case Studies."
  - Lecture notes: Christoph Jäger/Andreas Bühler, Schweizerisches Umweltrecht, Bern 2016
  - Literature: Weitere Literaturangaben folgen in der Vorlesung

### Laboratory Course in Environmental Engineering

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>102-0527-10L</td>
<td>Environmental Laboratory I ■</td>
<td>O</td>
<td>4</td>
<td>4P</td>
<td>D. Braun, L. Bioley, M. Vogt, L. von Känel</td>
</tr>
</tbody>
</table>

- **Abstract**: A practical introduction to important measurement methods for environmental engineers. Results of the measurements are compared to models and deviations are quantified with statistical methods.
- **Objective**: The laboratory offers students an insight into various experimental methods relevant to environmental engineering. The students deal with problems of measurement technology and measurement uncertainty, learn to characterize systems and to compare and discuss the results of the measurements with simple models. The work is documented with scientific reports or presented in presentations.
Es werden Experimente zu den folgenden Themen durchgeführt:
- Verweilzeit in einer Rührkesselkaskade
- Hydrodynamische Versuche
- Photometrische Bestimmungen von Inhaltsstoffen
- Carbonatgleichgewicht
- Gasgleichgewichte

Die folgenden analytischen Methoden werden dabei eingesetzt:
- UV/VIS-Spektroskopie
- pH
- Druckmessungen

Lecture notes
Wird abgegeben

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
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<td>assessed</td>
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<td></td>
<td>Project Management</td>
<td>fostered</td>
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</table>

Social Competencies
Communication assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Subject-Specific Electives

River and Hydraulic Engineering

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
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<tr>
<td>101-1249-00L</td>
<td>Hydraulics of Engineering Structures</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>I. Albayrak, F. Evers</td>
</tr>
</tbody>
</table>

Abstract
Hydraulic fundamentals are applied to hydraulic structures for wastewater, flood protection and hydropower. Typical case studies from engineering practice are further described.

Objective
Understanding and quantification of fundamental hydraulic processes with particular focus on hydraulic structures for wastewater, flood protection and hydropower.

In the course "Hydraulics of Engineering Structures", the competencies of process understanding, system understanding and measurement methods are taught, applied and examined. The competencies modeling, concept development and data analysis & interpretation are taught and data analysis & interpretation is applied in addition.

Content
1. Introduction & Basic equations
2. Losses in flow & Maximum discharge
3. Uniform flow & Critical flow
4. Hydraulic jump & Stilling basin
5. Backwater curves
6. Weirs & End overfall
7. Side weir & Side channel
8. Bottom opening, Venturi & Culverts, Restrictors, Inverted siphons
9. Fall manholes & Vortex drop
10. Supercritical flow & Special manholes
11. Aerated flows & Low level outlets
12. Hydraulics of sediment bypass tunnels
13. Vegetated flows - Introduction & Application
14. Summary

Lecture notes
Text books

Literature

Theory of Structures (for Environmental Engineering)

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>101-0113-10L</td>
<td>Theory of Structures (for Environmental Engineering)</td>
<td>W</td>
<td>3</td>
<td>2.5G</td>
<td>B. Sudret</td>
</tr>
</tbody>
</table>

Abstract
Introduction to structural mechanics, statically determinate beams and frame structures, trusses. Stresses in statically determinate structures.

Objective
- Understanding the response of elastic beam and frame structures
- Ability to correctly apply the equilibrium conditions
- Understanding the basics of continuum mechanics
- Computation of stresses in elastic structures

In the course "Theory of Structures (for Environmental Engineering)", the competencies of process understanding, system understanding and modeling are taught and applied. The competence process understanding and system understanding are examined, too.

Content
- Equilibrium, reactions, static determinacy
- Internal forces (normal and shear forces, moments)
- Arches and cables
- Elastic trusses
- Influence lines
- Basics of continuum mechanics
- Stresses in elastic beams

Lecture notes
Bruno Sudret, "Einführung in die Baustatik", 2021
Available on Moodle with exercises.

Literature
B. Sudret, Baustatik - eine Einführung, 2022, Springer Vieweg.
Generelle Entwässerungsplanung (GEP) 

Vertiefung der Grundlagen für die Dimensionierung anspruchsvoller Bauwerke mithilfe der numerischen Simulation und Darstellung der Ergebnisse für Zielgruppen in der schweizerischen Wasserwirtschaft.


Die Studierenden kennen die Grundzüge der Schweizer Raumplanung, ihre wichtigsten Instrumente auf nationaler, kantonaler, regionaler und kommunaler Ebene und systematische Problemlösungsverfahren. Sie können das vermittelte theoretische Wissen direkt an konkreten, praxisorientierten Übungsaufgaben umsetzen.

Die Vorlesung deckt die Grundlagen der (Schweizerischen) Raumplanung und Landschaftsentwicklung ab:
- Was ist Raumplanung (Definitionen und Begriffe)
- Aktuelle Herausforderungen, Entwicklungen und Tendenzen der Raumplanung
- Grundprinzipien, historische Entwicklung und Gesetzgebungen der Schweizer Raumplanung
- Die Raumplanung als staatliche Aufgabe – Raumordnungspolitik auf Bundesebene
- Instrumente der Raumplanung auf nationaler, kantonaler, regionaler und kommunaler Ebene (u.a. Sachpläne und Konzepte, Richtplanung, Nutzungsplanung, Sondernutzungsplanung, Mehrwertausgleich)
- Problemlösungsverfahren in der Raumplanung – systemtechnisches Vorgehen
- Thematische Vertiefungen: Siedlungsentwicklung nach innen; Klimaangepasste Raumplanung; Grundeigentum und kooperative Planung; Raumbeobachtung


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### Environment and Water

#### 651-3561-00L  
**Cryosphere**  
**Abstract**  
The course introduces the different components of the cryosphere - snow, glaciers, ice sheets, sea ice and lake ice, and permafrost - and their respective roles in the climate system. For each subsystem, essential physical aspects are emphasized, and their dynamics are described quantitatively and using examples.

**Objective**  
Students are able to:
- qualitatively explain relevant processes, feedbacks and relationships between the different components of the cryosphere,
- quantify and interpret physical processes, which determine the state of the cryospheric components, with simple calculations.

In the course "Cryosphere", the competencies of process understanding, modeling, data analysis & interpretation and measurement methods are taught, applied and examined. System understanding is taught and examined.

**Content**  
The course provides an introduction into the various components of the cryosphere: snow, glaciers, ice sheets, sea ice and lake ice, permafrost, and their roles in the climate system. Essential physical aspects are emphasized for each subsystem: e.g. the material properties of ice, mass balance and dynamics of glaciers, or the energy balance of sea ice.

**Literature**  

Further literature will be indicated during the lecture.

### 701-0479-00L  
**Environmental Fluid Dynamics**

**Abstract**  
This course covers the basic physical concepts and mathematical equations used to describe environmental fluid systems on the rotating Earth. Fundamental concepts (e.g. vorticity dynamics and waves) are formally introduced, applied quantitatively and illustrated using examples. Exercises help to deepen knowledge of the material.

**Objective**  
Students are able to:
- to name the basics, concepts and methods of environmental fluid dynamics,
- to understand and discuss the components of the basic physical equations
- to mathematically solve basic equations for simple problems of environmental fluid dynamics.

The competencies of process understanding and system understanding are taught, applied and examined.

**Content**  
Basic physical terminology and mathematical laws:
- Continuum hypothesis, forces, constitutive laws, state equations and basic principles of thermodynamics, kinematics, laws of mass and momentum on rotating earth.
- Concepts and illustrative flow systems: vorticity dynamics, boundary layers, instability, turbulence - with respect to environmental fluid systems.

Scale analysis: dimensionless variables and dynamical similarity, simplification of the fluid system, e.g. shallow water assumption, geostrophic flow.

Waves in environmental fluid systems.

**Literature**  
Will be presented in class.
See also: web-site.
### Climate and Air

#### 701-0023-00L Atmosphere
- **Type**: W
- **ECTS**: 3
- **Hours**: 2V
- **Lecturers**: E. Fischer, U. Lohmann

**Abstract**

Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

**Objective**

- to explain the physical structure and chemical composition of the atmosphere
- to quantitatively describe and understand the fundamental physical and chemical process in the atmosphere
- to explain the interactions and feedbacks between atmosphere - ocean - land surface, troposphere - stratosphere and weather - climate.

**Content**

Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds.

**Lecture notes**

Written information will be supplied.

**Literature**


### 701-0475-00L Atmospheric Physics
- **Type**: W
- **ECTS**: 3
- **Hours**: 2G
- **Lecturers**: U. Lohmann

**Abstract**

This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation, especially prediction of showers and severe convective storms, and optical phenomena.

**Objective**

- to explain the mechanisms of convective storm formation using knowledge of thermodynamics and cloud microphysics.
- to interpret precipitation radar images
- to evaluate the significance of clouds and aerosol particles for artificial weather modification.

In the course "Atmospheric Physics", the competencies of process understanding, system understanding and data analysis & interpretation are taught, applied and examined. Measurement methods are taught as well.
The course starts with introducing selected concepts of thermodynamics for atmospheric processes; the students learn the concept of the thermodynamic equilibrium and derive the Clausius-Clayperon equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Students also learn to use thermodynamic charts (tephigrams) and to identify cloud base, cloud top, available convective energy in radiosonde ascents. Atmospheric mixing processes are introduced as a basis for fog formation. The concept of an air parcel is used to understand convection.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

With these basics, the different forms of precipitation (convective vs. stratiform) are discussed and how they can be identified in radar images. Students will also learn under which conditions severe convective storms (especially supercells with tornados) can form.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

Lecture notes

Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=20400

Literature


An electronic version of this book can be obtained via the ETH library.

pdf-files of the revised book will be provided on moodle on a chapter-by-chapter basis.

We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments.

There is an additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.

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There is a additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Problem-solving

Social Competencies

- Communication

Personal Competencies

- Critical Thinking
- Self-direction and Self-management

102-0535-00L Noise Abatement

Abstract


Objective

The students will understand the basics of noise abatement: acoustics, impact of noise, measurement techniques and legislation. The students will be able to analyze different noise prob-lems and they will be able to solve simple problems of noise abatement.

In the course "Noise Abatement", the competencies of process understanding, modeling, data analysis & interpretation and measurement methods are taught, applied and examined. System understanding is taught and examined.

Content

- Physikalische Grundlagen: Schalldruck, Wellen, Quellenarten.
- Lärmwirkungen: Gehör, Gesundheitliche Wirkungen von Lärm, Störung/Belästigung, Belastungssmasse.

Lecture notes

Lärmarten und Prognoseverfahren: Messen/Berechnen, Strassenlärm, Eisenbahnlärm, Schiesslärm, Industrielärm.

Lecture notes

- Skript "Lärmbekämpfung" als PDF ab Beginn der Vorlesung verfügbar.

Prerequisites / notice

1 - 2 Excursionen

Climate and Soil

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
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<tr>
<td>101-0339-00L</td>
<td>Environmental Geotechnics – Polluted Sites and Waste Disposal</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Plötze</td>
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Abstract

The practice of landfilling, remediation of polluted sites, and the disposal of radioactive waste are based on the same concepts of environmental protection. Understanding the contaminants behaviour and how to reduce their release to the environment is the key to remediating polluted sites and designing multi-barrier systems.

Objective

- Describe the technologies available to minimise environmental contamination
- Describe the principles of dealing with polluted sites and propose and evaluate appropriate remediation techniques
- Explain the concepts underlying radioactive waste management practices.

Content

This lecture course consists of lectures with exercises and case studies.

- An overview of the principles of environmental protection in waste management and how this is applied in legislation.
- An overview of the chemistry underlying the release and transport of contaminants from the landfilled/contaminated material/radioactive waste repository focusing on processes controlling mobility of heavy metals and organic compounds
- Introduction to contaminant transport in porous adsorbing media
- Design and function of engineered barriers. Clay as a barrier.
- Polluted site remediation: Site investigation, assessment, and remediation technologies
- Concepts and safety in radioactive waste management
- Role of the geological and engineered barriers and radionuclide transport in geological media.

Prerequisites / notice

1 - 2 Excursionen
701-0501-00L Pedosphere

Abstract
Introduction to the formation and properties of soils as a function of parent rock, landscape position, climate, and soil organisms. Complex relationships between soil forming processes, physical and chemical soil properties, soil biota, and ecological soil properties are explained and illustrated by numerous examples.

Objective
Understanding of soils as integral parts of ecosystems, development and distribution of soils as a function of environmental factors, and processes leading to soil degradation.

Content
Definition of the pedosphere, soil functions, rocks as parent materials, minerals and weathering, soil organisms, soil organic matter, soil formation, principles of soil classification, global soil regions, physical soil properties and functions, chemical soil properties and functions, soil fertility, land use and soil degradation.

Lecture notes
Polybook

Literature

Prerequisites / notice
Prerequisites: Basic knowledge in chemistry, biology and geology.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Project Management fostered
Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Negotiation fostered
Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Negotiation fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

701-0533-00L Soil and Water Chemistry

Abstract
This course covers chemical and biogeochemical processes in soils and water and their influence on the behavior and cycling of nutrients and pollutants in terrestrial and aquatic systems. Approaches for quantitative modeling of the processes are introduced and applied in selected examples.

Objective
1. Understanding of important chemical properties and processes of soils and water and their influence on the behavior (e.g., chemical speciation, bioavailability, mobility) of nutrients and pollutants.
2. Quantitative applications of chemical equilibria to processes in natural systems.

Content
Chemical equilibria in aqueous solutions, gas equilibria, precipitation and dissolution of mineral phases, silicate weathering, weathering kinetics, formation of secondary minerals (clay minerals, oxides, sulfides), redox processes in natural systems, pH buffering and acidification, salinity and salinization, environmental behavior of selected essential and toxic trace elements.

Lecture notes
Lecture slides on Moodle

Literature
– Chapters 1, 3, 4, 6, 7 and 11 in Sigg/Stumm – Aquatische Chemie, 6. Auflage, vdf, 2016.

Prerequisites / notice
The lecture courses Pedosphere and Hydrosphere are highly recommended.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed
Social Competencies
Communication fostered
Personal Competencies
Critical Thinking fostered

701-1633-00L Energy Conversion

Abstract
This course provides the students with an introduction to thermodynamics and energy conversion. Students shall gain basic understanding of energy and energy interactions as well as their link to energy conversion technologies.
Thermodynamics is key to understanding and use of energy conversion processes in Nature and technology. Main objective of this course is to give a compact introduction into basics of Thermodynamics: Thermodynamic states and thermodynamic processes; Work and Heat; First and Second Laws of Thermodynamics. Students shall learn how to use energy balance equation in the analysis of power cycles and shall be able to evaluate efficiency of internal combustion engines, gas turbines and steam power plants. The course shall extensively use thermodynamic charts to building up students’ intuition about opportunities and restrictions to increase useful work output of energy conversion. Thermodynamic functions such as entropy, enthalpy and free enthalpy shall be used to understand chemical and phase equilibrium. The course also gives introduction to refrigeration cycles, combustion and refrigeration. The course compactly covers the standard course of thermodynamics for engineers, with additional topics of a general physics interest (nonideal gas equation of state and Joule-Thomson effect) also included.

In the course "Energy Conversion", the competencies of process understanding and system understanding are applied and examined and the competencies process understanding and modeling are taught.

Content

1. Thermodynamic systems, states and state variables
2. Properties of substances: Water, air and ideal gas
3. Energy conservation in closed and open systems: work, internal energy, heat and enthalpy
4. Second law of thermodynamics and entropy
5. Energy analysis of steam power cycles
6. Energy analysis of gas power cycles
7. Refrigeration and heat pump cycles
8. Nonideal gas equation of state and Joule-Thomson effect
9. Maximal work and exergy
10. Mixtures
11. Chemical reactions and combustion systems; chemical and phase equilibrium

Lecture notes

Lecture slides and supplementary documentation will be available online.

Literature


Prerequisites / notice

This course is intended for students outside of D-MAVT.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Students are assumed to have an adequate background in calculus, physics, and engineering mechanics.

Abstract

This course introduces the fundamentals of energy system modeling for the analysis and the optimization of the system design and operations.

Objective

At the end of this course, students will be able to:
- define and quantify the key performance indicators of sustainable energy systems;
- select and apply appropriate models for conversion, storage and transport of energy;
- develop mathematical models for the analysis, design and operations of multi-energy systems and solve them with appropriate mathematical tools;
- select and apply methodologies for the uncertainty analysis on energy systems models;
- apply the acquired knowledge to tackle the challenges of the energy transition.

In the course "Introduction to Modeling and Optimization of Sustainable Energy Systems", the competencies of process understanding, system understanding, modeling, concept development, data analysis & interpretation and measurement methods are taught, applied and examined. Programming is applied.

Content

The global energy transition; Key performance indicators of sustainable energy systems; Optimization models; Heat integration and heat exchanger networks; Life-cycle assessment; Models for conversion, storage and transport technologies; Multi-energy systems; Design, operations and analysis of energy systems; Uncertainties in energy system modeling.

Lecture notes

Lecture slides and supplementary documentation will be available online. Reference to appropriate book chapters and scientific papers will be provided.

Excursions of Subject-specific electives

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>102-0000-10L</td>
<td>Excursions for Environmental Engineers I</td>
<td>W</td>
<td>1 credit</td>
<td></td>
<td>J. Wang, further lecturers</td>
</tr>
</tbody>
</table>

Abstract

Half-day to one-day excursions as a supplement to the environmental engineering lectures.
Objective
As a supplement to the environmental engineering-specific lectures, the professorships offer half-day to one-day excursions in various subject areas. During the excursions, the students deepen the specialist knowledge acquired in the lectures and self-study and establish a link to practice and research.
These excursions are open to all Bachelor's students of Environmental Engineering, depending on availability, and can be assessed with credit points as part of the subject-specific electives. The excursions are voluntary and should preferably be attended from the 4th semester onwards.

102-0000-20L Excursions for Environmental Engineers II
No registration through myStudies. The registration for excursions and field courses goes through http://exkursionen.umelting.ethz.ch/ only.

Abstract
Half-day to one-day excursions as a supplement to the environmental engineering lectures.

Objective
As a supplement to the environmental engineering-specific lectures, the professorships offer half-day to one-day excursions in various subject areas. During the excursions, the students deepen the specialist knowledge acquired in the lectures and self-study and establish a link to practice and research.
These excursions are open to all Bachelor's students of Environmental Engineering, depending on availability, and can be assessed with credit points as part of the subject-specific electives. The excursions are voluntary and should preferably be attended from the 4th semester onwards.

Additional Compulsory Courses

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<tr>
<th>Number</th>
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</table>

Abstract
The course is organized in the form of seminars held by the students. Topics selected from the core disciplines of the curriculum (water resources, urban water engineering, material fluxes, waste technology, air pollution, earth observation) are discussed in the class on the basis of scientific papers that are illustrated and critically reviewed by the students.

Objective
Learn about recent research results in environmental engineering and analyse practical applications in environmental engineering.

Competencies
Subject-specific Competencies: Concepts and Theories - fostered
Method-specific Competencies: Media and Digital Technologies - fostered
Social Competencies: Communication - fostered, Cooperation and Teamwork - fostered, Customer Orientation - fostered, Self-presentation and Social Influence - fostered
Personal Competencies: Creative Thinking - fostered, Critical Thinking - fostered, Self-awareness and Self-reflection - fostered

Electives
The entire course programs of ETH Zurich and the University of Zurich are open to the students to individual selection.

Electives ETH Zurich
Course Catalogue of ETH Zurich

Science in Perspective
Recommended Science in Perspective (Type B) for D-BAUG

Language Courses
see Science in Perspective: Language Courses ETH/UZH

Bachelor’s Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>102-0006-00L</td>
<td>Bachelor’s Thesis</td>
<td>O</td>
<td>10 credits</td>
<td>21D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Abstract
The Bachelor Programme concludes with the Bachelor Thesis. This project is supervised by a professor. Writing up the Bachelor Thesis encourages students to show independence and to produce structured work.

Objective
The contents base upon the fundamentals of the Bachelor Programme. Students can choose from different subjects and tasks. The thesis consists of both a written report and an oral presentation.

Environmental Engineering Bachelor - Key for Type

| Z | Courses outside the curriculum | W+ | Eligible for credits and recommended |
| Dr | Suitable for doctorate | W | Eligible for credits |
| O | Compulsory | E- | Recommended, not eligible for credits |

Data: 15.06.2024 12:39
Autumn Semester 2024
Page 2370 of 2653
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<th>Key for Hours</th>
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</table>

ECTS: European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
# Environmental Engineering Master

## Majors

### Major Urban Water Management

#### Ecological System Design

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0307-01L</td>
<td>Advanced Environmental, Social and Economic Assessments</td>
<td>O</td>
<td>5 credits</td>
<td>4G</td>
<td>A. E. Braunschweig, S. Pfister, A. Kim</td>
</tr>
</tbody>
</table>

**Abstract**
This course deepens students' knowledge of environmental, economic, and social assessment methodologies and their various applications.

**Objective**
This course has the aim of deepening students' knowledge of the environmental, economic and social assessment methodologies and their various applications.

In particular, students completing the course should have the:
- ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors
- knowledge about the current state of the scientific discussion and new research developments
- ability to properly plan, conduct and interpret environmental assessment studies

**Content**
In the course element "Implementation of Environmental and other Sustainability Goals", students will learn to:
- describe key sustainability problems of the current economic system and measuring units.
- describe the management system of an organisation and how to develop a sustainability orientation
- discuss approaches to measure environmental performance of an organisation, including 'organisational LCA' (Ecobalance)
- explain the pros and cons of single score environmental assessment methods
- demonstrate life cycle costing
- interpret stakeholder relations of an organisation
- (if time allows) describe sustainable supply chain management and stakeholder management

**Lecture notes**
Part I (Advanced Environmental Assessments)
- Inventory database developments, transparency, data quality, data completeness, and data exchange formats, uncertainties
- Software tools (MFA, LCA)
- Allocation (multiooutput processes and recycling)
- Hybrid LCA methods.
- Consequential and marginal analysis
- Impact assessment of waterborne chemical emissions, sum parameters, mixture toxicity
- Spatial differentiation in Life Cycle Assessment
- Workplace and indoor exposure in Risk and Life Cycle Assessment
- Subjectivity in environmental assessments
- Multicriteria Decision Analysis
- Case Studies

**Literature**
Part II (Implementation of Environmental and other Sustainability Goals):
- Sustainability problems of the current economic system and its measuring units;
- The structure of a management system, and elements to integrate environmental management (ISO 14001) and social management (SA8000 as well as ISO 26000), especially into strategy development, planning, controlling and communication;
- Sustainability Opportunities and Innovation
- The concept of 'Continuous Improvement'
- Life Cycle Costing, Life Cycle Management
- environmental performance measurement of an organisation, including 'organisational LCA' (Ecobalance), based on practical examples of companies and new concepts
- single score env. assessment methods (Swiss ecopoints)
- stakeholder management and sustainability oriented communication
- an intro into sustainability issues of supply chain management

Students will get small exercises related to course issues.

**Prerequisites / notice**
This course should only be elected by students of environmental engineering with a with a Module in Ecological Systems Design. All other students should take the individual courses in Advanced Environmental Assessment and/or Implementation of Environmental and other Sustainability Goals (with or without exercise and lab).

Basic knowledge of environmental assessment tools is a prerequisite for this class. Students who have not yet had classwork in this topic are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. (2016). Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5,2)).

## Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Personal Competencies</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Creative Thinking</td>
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<tr>
<td></td>
<td>Techniques and Technologies</td>
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<td>Critical Thinking</td>
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</table>

## Process Engineering in Urban Water Management
In this course, students learn modern urban drainage engineering approaches, critical thinking, decision making in a complex environment.

### Systems Analysis in Urban Water Management

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>102-0227-00L</td>
<td>Systems Analysis and Mathematical Modeling in Urban Water Management</td>
<td>O</td>
<td>6 credits</td>
<td>4G</td>
<td>E. Morgenroth, M. Maurer</td>
</tr>
</tbody>
</table>

**Abstract**

Systematic introduction of material balances, transport processes (kinetics, stoichiometry and conservation), ideal reactors, residence time distribution, heterogeneous systems, dynamic response of reactors, parameter identification, local sensitivity, error propagation, and Monte Carlo simulations. Introduction to real-time control (PID controllers). Extensive numerical simulations with coding.

**Objective**

The goal of this course is to provide the students with an understanding of how urban water system can be described with mathematical models, and give them the to plan experiments, to evaluate error propagation and to test simple process control strategies in the field of process engineering in urban water management.

**Content**

The course will provide a broad introduction into the fundamentals of modeling water treatment systems. The topics are:

- Introduction into modeling and simulation
- The material balance equations, transport processes, transformation processes (kinetics, stoichiometry, conservation)
- Ideal reactors
- Hydraulic residence time distribution and modeling of real reactors
- Dynamic behavior of reactor systems
- Systems analytical tools: Sensitivity, parameter identification, error propagation, Monte Carlo simulation
- Introduction to process control (PID controller, fuzzy control)

**Lecture notes**

Copies of handouts will be available digitally.

**Literature**

There will be a required textbook that students need to purchase:


**Prerequisites / notice**

Students should have a general understanding of urban water management as many examples are taken from processes relevant to related systems. This course is offered in parallel to the course Process Engineering Ia. It is beneficial but not necessary to follow both courses simultaneously.

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Media and Digital Technologies
  - Problem-solving
- Personal Competencies
  - Critical Thinking
  - Self-direction and Self-management

**Process Engineering Ia**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>102-0217-00L</td>
<td>Process Engineering Ia</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>E. Morgenroth</td>
</tr>
</tbody>
</table>

**Abstract**

Biological processes used in wastewater treatment, organic waste management, biological resource recovery. Focus on fundamental principles of biological processes and process design based on kinetic and stoichiometric principles. Processes include anaerobic digestion for biogas production and aerobic wastewater treatment.

**Objective**

Students should be able to evaluate and design biological processes.

**Content**

Stoichiometry
- Microbial transformation processes
- Introduction to design and modeling of activated sludge processes
- Anaerobic processes, industrial applications, sludge stabilization

**Literature**

There will be a textbook that students need to purchase (see http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html for further information).

**Prerequisites / notice**

For detailed information on prerequisites the student should consult the lecture program and important information (syllabus) of Process Engineering Ia that can be accessed via http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html

**Competencies**

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Problem-solving
- Social Competencies
  - Communication
  - Customer Orientation
- Personal Competencies
  - Critical Thinking

### Water Infrastructure Planning and Stormwater Management

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>102-0250-00L</td>
<td>Urban Drainage Planning and Modelling</td>
<td>O</td>
<td>6 credits</td>
<td>4G</td>
<td>M. Maurer, U. Karaus, J. P. Leitão Correia, M. Stähle</td>
</tr>
</tbody>
</table>

**Abstract**

In this course, students learn modern urban drainage engineering approaches, critical thinking, decision making in a complex environment as well as dealing with insufficient data and ill-defined problems.

**Objective**

By the end of the course, you should be able to do the following:

- Apply different methods and methodologies to assess the impact of urban drainage on water pollution and flooding potential.
- Distinguish between hydrological and hydrodynamic models and their correct application.
- Identify the difference between emission and immission oriented approaches for identifying drainage measures.
- Identify relevant measures, quantity their effects and assess their relative ranking/priority.
- Consider uncertainties and handle incomplete data and information.
- Make decisions and recommendations in a complex application case.
- Teamwork. State principles of effective team performance and the functions of different team roles; work effectively in problem-solving teams.
- Communication. Communicate and document your findings in concise group presentations and a written report.
In urban drainage, the complexity of the decision-making, the available methodologies and the data availability have increased significantly.

In current environmental engineering practice, the focus has shifted from tables and nomograms to sophisticated simulation tools.

The topics cover:
- Integrated urban water management
- Hydrological and hydrodynamic modelling
- Water quality based assessment
- Freshwater ecology
- Hydraulic capacity assessment
- Sewer network operation
- Decision analysis

Prerequisites / notice
Prerequisites: 102-0214-00 Siedlungswasserwirtschaft and 102-0215-00 Siedlungswasserwirtschaft II or comparable educational background.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

Major Environmental Technologies

Air Quality Control

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<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>102-0377-00L</td>
<td>Air Pollution Modeling and Chemistry</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Henne, S. Reimann Bhend, J. Tang</td>
</tr>
</tbody>
</table>

Abstract
Air pollutants cause negative effects on humans, wildlife and buildings. To control and reduce the impact of air pollutants, their transfer from sources to receptors needs to be known. This transfer includes transport within the atmospheric boundary layer, chemical transformation reactions and phase-transfer processes from gases to particles.

Objective
The students understand the fundamental principles of atmospheric transport, dispersion and chemistry of pollutants on the local to regional scale and their transfer gas to particle phases (secondary aerosols). This includes the knowledge of important atmospheric reactions, sources and sinks. The obtained understanding enables the students to apply computational tools to predict the transport and transformation of chemicals at the local to regional scale.

Content
- Structure of the Atmosphere
- Thermodynamics of the atmosphere
- Atmospheric stability
- Atmospheric boundary layer and turbulence
- Dispersion in the atmospheric boundary layer
- Numerical models of atmospheric dispersion
- Gas phase reaction kinetics
- Tropospheric chemistry and ozone formation
- Chemistry box models
- Volatile organic pollutants (VOCs) and semi-volatile organic pollutants (SVOCs)
- Aerosol modelling
- Air pollution source apportionment
- Inverse modelling of emissions

Lecture notes
Continued updates of:
- Slides and handouts
- Home assignments and sample solutions
- R package and code for some of the home assignments
- MATLAB codes
- Key journal articles as discussed during lecture

Literature
Atmospheric chemistry

Atmospheric dynamics and boundary layer

Atmospheric modelling

Environmental organic chemistry and mass transfer

Mackay D., Multimedia environmental models: the fugacity approach; Boca Raton, Fla.: Lewis Publishers; 2001; 2nd ed

Atmospheric dynamics and boundary layer


Introduction to R
Process Engineering in Urban Water Management

No courses in autumn semester (HS), only in spring semester (FS).

System Analysis in Urban Water Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tbody>
<tr>
<td>102-0227-00L</td>
<td>Systems Analysis and Mathematical Modeling in Urban Water Management</td>
<td>O</td>
<td>6</td>
<td>4G</td>
<td>E. Morgenroth, M. Maurer</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>Systematic introduction of material balances, transport processes (kinetics, stoichiometry and conservation), ideal reactors, residence time distribution, heterogeneous systems, dynamic response of reactors, parameter identification, local sensitivity, error propagation, and Monte Carlo simulations. Introduction to real-time control (PID controllers). Extensive numerical simulations with coding.</td>
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<td>The goal of this course is to provide students with an understanding of how urban water system can be described with mathematical models, and give them the tools to plan experiments, to evaluate error propagation and to test simple process control strategies in the field of process engineering in urban water management.</td>
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<td><strong>Content</strong></td>
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<td></td>
<td>The course will provide a broad introduction into the fundamentals of modeling water treatment systems. The topics are: - Introduction into modeling and simulation - The material balance equations, transport processes, transformation processes (kinetics, stoichiometry, conservation) - Ideal reactors - Hydraulic residence time distribution and modeling of real reactors - Dynamic behavior of reactor systems - Systems analytical tools: Sensitivity, parameter identification, error propagation, Monte Carlo simulation - Introduction to process control (PID controller, fuzzy control)</td>
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<td></td>
<td><strong>Lecture notes</strong></td>
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<td></td>
<td>Copies of handouts will be available digitally.</td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<tr>
<td></td>
<td>There will be a required textbook that students need to purchase: Willi Gujer (2008): Systems Analysis for Water Technology. Springer-Verlag, Berlin Heidelberg</td>
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<tbody>
<tr>
<td>102-0217-00L</td>
<td>Process Engineering Ia</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>E. Morgenroth</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>Biological processes used in wastewater treatment, organic waste management, biological resource recovery. Focus on fundamental principles of biological processes and process design based on kinetic and stoichiometric principles. Processes include anaerobic digestion for biogas production and aerobic wastewater treatment.</td>
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<td>Students should be able to evaluate and design biological processes.</td>
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<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>Stoichiometry, Microbial transformation processes, Introduction to design and modeling of activated sludge processes, Anaerobic processes, industrial applications, sludge stabilization</td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<tr>
<td></td>
<td>There will be a textbook that students need to purchase: (see <a href="http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html">http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html</a> for further information).</td>
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<tr>
<td>102-0357-00L</td>
<td>Waste Recycling Technologies</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>M. Haupt, V. Burg</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Waste Recycling Technology (WRT) is a sub-discipline of Mechanical Process Engineering. WRT is employed in production plants processing contaminated soil, construction wastes, scrap metal, recovered paper and the like. While WRT is well established in Central Europe, it is only now just catching on in emerging markets as well.</td>
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<tr>
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<td><strong>Objective</strong></td>
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<td>At the core of this course is the separation of mixtures of solid bulk materials according to physical properties such as color, electrical conductivity, magnetism and so forth. After having taken this course, the students should have concepts not only of the unit operations employed in WRT but also of how these unit operations are integrated into the flow sheets of production plants.</td>
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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2375 of 2653
Environmental Geotechnics – Polluted Sites and Waste Recycling

Introduction
Waste Recycling: Scope and objectives
Waste recycling technologies in Switzerland

Fundamentals
Properties of particles: Liberation conditions, Particle size and shape, Porosity of bulk materials
Fluid dynamics of particles: Stationary particle beds, Fluidized beds, Free settling particles
Flow sheet basics: Balancing mass flows
Standard processes: batch vs. continuous
Assessment of separation success: Separation function; grade vs. recovery

Separation Processes
Separation according to size and shape (Classification): Screening, Flow separation
Separation according to material properties (Concentration): Manual Sorting, Gravity concentration; Magnetic separation, Eddy current separation, Electrostatic separation, Sensor technology, Froth flotation

Lecture notes
The script consists of the slides shown during the lectures. Background material will be provided on the script-server.

Literature
A list of recommended books will be provided.

Prerequisites / notice
The topic will be discussed not from the perspective of theory, but rather in the context of practical application. However, solid fundamentals in physics (in particular in mechanics) are strongly recommended.

102-0217-00L Process Engineering Ia

Abstract
Biological processes used in wastewater treatment, organic waste management, biological resource recovery. Focus on fundamental principles of biological processes and process design based on kinetic and stoichiometric principles. Processes include anaerobic digestion for biogas production and aerobic wastewater treatment.

Objective
Students should be able to evaluate and design biological processes.

Content
Stoichiometry
Microbial transformation processes
Introduction to design and modeling of activated sludge processes
Anaerobic processes, industrial applications, sludge stabilization

Lecture notes
For detailed information on prerequisites the student should consult the lecture program and important information (syllabus) of Process Engineering Ia that can be accessed via http://www.sww.iwu.ethz.ch/education/lectures/process-engineering-ia.html for further information.

101-0339-00L Environmental Geotechnics – Polluted Sites and Waste Disposal

Abstract
The practice of landfilling, remediation of polluted sites and the disposal of radioactive waste are based on the same concepts of environmental protection. Understanding the contaminants behaviour and how to reduce their release to the environment is the key to remediating polluted sites and designing multi-barrier systems.

Objective
On successful completion of this course students will be able to
- Assess the risk to the environment from landfills, contaminated sites and radioactive waste repositories in terms of the fate and transport of contaminants.
- Describe the technologies available to minimise environmental contamination
- Describe the principles of dealing with polluted sites and propose and evaluate appropriate remediation techniques
- Explain the concepts underlying radioactive waste management practices.

Content
This lecture course consists of lectures with exercises and case studies.
- An overview of the chemistry underlying the release and transport of contaminants from the landfilled/contaminated material/radioactive waste repository focusing on processes controlling mobility of heavy metals and organic compounds
- Introduction to contaminant transport in porous adsorbing media
- Design and function of engineered barriers. Clay as a barrier.
- Polluted site remediation: Site investigation, assessment, and remediation technologies
- Concepts and safety in radioactive waste management
- Role of the geological and engineered barriers and radionuclide transport in geological media.

Prerequisites / notice
excursion

Competencies

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Analytical Competencies
Decision-making
Problem-solving
Project Management

Method-specific Competencies
Techniques and Technologies
Analytical Competencies
Decision-making
Problem-solving

Social Competencies
Communication
Customer Orientation

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

E. Morgenroth

M. Plötze

Autumn Semester 2024
Advanced Environmental, Social and Economic Assessments

Abstract
This course deepens students' knowledge of environmental, economic, and social assessment methodologies and their various applications.

Objective
This course has the aim of deepening students' knowledge of the environmental, economic and social assessment methodologies and their various applications.

In particular, students completing the course should have the:
- ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors
- knowledge about the current state of the scientific discussion and new research developments
- ability to properly plan, conduct and interpret environmental assessment studies.

In the course element "Implementation of Environmental and other Sustainability Goals", students will learn to:
- describe key sustainability problems of the current economic system and measuring units.
- describe the management system of an organisation and how to develop a sustainability orientation.
- discuss approaches to measure environmental performance of an organisation, including 'organisational LCA' (Ecobalance).
- explain the pros and cons of single score environmental assessment methods.
- demonstrate life cycle costing.
- interpret stakeholder relations of an organisation.
- (if time allows) describe sustainable supply chain management and stakeholder management.

Content

Part I (Advanced Environmental Assessments):
- Inventory database developments, transparency, data quality, data completeness, and data exchange formats, uncertainties
- Software tools (MFA, LCA)
- Allocation (multioutput processes and recycling)
- Hybrid LCA methods.
- Consequential and marginal analysis
- Impact assessment of waterborne chemical emissions, sum parameters, mixture toxicity
- Spatial differentiation in Life Cycle Assessment
- Workplace and indoor exposure in Risk and Life Cycle Assessment
- Subjectivity in environmental assessments
- Multicriteria Decision Analysis
- Case Studies

Part II (Implementation of Environmental and other Sustainability Goals):
- Sustainability problems of the current economic system and its measuring units.
- The structure of a management system, and elements to integrate environmental management (ISO 14001) and social management (SA8000 as well as ISO 26000), especially into strategy development, planning, controlling and communication.
- Sustainability Opportunities and Innovation
- The concept of 'Continuous Improvement'
- Life Cycle Costing, Life Cycle Management
- environmental performance measurement of an organisation, including 'organisational LCA' (Ecobalance), based on practical examples of companies and new concepts.
- single score env. assessment methods (Swiss ecopoints)
- stakeholder management and sustainability oriented communication
- an intro into sustainability issues of supply chain management

Students will get small exercises related to course issues.

Lecture notes
Part I: Slides and background reading material will be available on lecture homepage
Part II: Documents will be available on ilias.

Literature
Will be made available.

Prerequisites / notice
This course should only be elected by students of environmental engineering with a module in Ecological Systems Design. All other students should take the individual courses in Advanced Environmental Assessment and/or Implementation of Environmental and other Sustainability goals (with or without exercise and lab).

Basic knowledge of environmental assessment tools is a prerequisite for this class. Students who have not yet had classwork in this topic are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. (2016). Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5,2)).

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Personal Competencies
- Creative Thinking
- Critical Thinking

Advanced Environmental Assessment (Computer Lab)

Abstract
Different tools and software used for environmental assessments, such as LCA are introduced. The students will have hands-on exercises in the computer rooms and will gain basic knowledge on how to apply the software and other resources in practice.

Objective
Become acquainted with various software programs for environmental assessment including Life Cycle Assessment, Environmental Risk Assessment, Probabilistic Modeling, Material Flow Analysis.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies

Personal Competencies
- Critical Thinking

Module is offered in Spring Semester.
E. Morgenroth assessed

Students should be able to evaluate and design biological processes.

At the core of this course is the separation of mixtures of solid bulk materials according to physical properties such as color, electrical conductivity, magnetism and so forth. After having taken this course, the students should have concept not only of the unit operations employed in WRT but also of how these unit operations are integrated into the flow sheets of production plants.

Introduction

Waste Recycling: Scope and objectives

Waste recycling technologies in Switzerland

Fundamentals

Properties of particles: Liberation conditions, Particle size and shape, Porosity of bulk materials

Fluid dynamics of particles: Stationary particle beds, Fluidized beds, Free settling particles

Process sheet basics: Balancing mass flows

Standard processes: batch vs. continuous

Assessment of separation success: Separation function; grade vs. recovery

Separation Processes

Separation according to size and shape (Classification): Screening, Flow separation

Separation according to material properties (Concentration): Manual Sorting, Gravity concentration; Magnetic separation, Eddy current separation, Electrostatic separation, Sensor technology, Froth flotation

Lecture notes

The script consists of the slides shown during the lectures. Background material will be provided on the script-server.

Literature

A list of recommended books will be provided.

Prerequisites / notice

The topic will be discussed not from the perspective of theory, but rather in the context of practical application. However, solid fundamentals in physics (in particular in mechanics) are strongly recommended.

102-0357-00L

Waste Recycling Technologies

Waste Recycling Technology (WRT) is a sub-discipline of Mechanical Process Engineering. WRT is employed in production plants processing contaminated soil, construction wastes, scrap metal, recovered paper and the like. While WRT is well established in Central Europe, it is only just now catching on in emerging markets as well.

Objective

At the core of this course is the separation of mixtures of solid bulk materials according to physical properties such as color, electrical conductivity, magnetism and so forth. After having taken this course, the students should have concept not only of the unit operations employed in WRT but also of how these unit operations are integrated into the flow sheets of production plants.

Content

Introduction

Waste Recycling: Scope and objectives

Waste recycling technologies in Switzerland

Fundamentals

Properties of particles: Liberation conditions, Particle size and shape, Porosity of bulk materials

Fluid dynamics of particles: Stationary particle beds, Fluidized beds, Free settling particles

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Lecture notes

The script consists of the slides shown during the lectures. Background material will be provided on the script-server.

Literature

A list of recommended books will be provided.

Prerequisites / notice

The topic will be discussed not from the perspective of theory, but rather in the context of practical application. However, solid fundamentals in physics (in particular in mechanics) are strongly recommended.

102-0217-00L

Process Engineering Ia

Biological processes used in wastewater treatment, organic waste management, biological resource recovery. Focus on fundamental principles of biological processes and process design based on kinetic and stoichiometric principles. Processes include anaerobic digestion for biogas production and aerobic wastewater treatment.

Objective

Students should be able to evaluate and design biological processes.

Content

Stoichiometry

Microbial transformation processes

Introduction to design and modeling of activated sludge processes

Anaerobic processes, industrial applications, sludge stabilization

Literature

There will be a textbook that students need to purchase (see http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html for further information).

Prerequisites / notice

For detailed information on prerequisites the student should consult the lecture program and important information (syllabus) of Process Engineering Ia that can be accessed via http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Decision-making

Problem-solving

Social Competencies

Communication

Customer Orientation

Personal Competencies

Critical Thinking

101-0339-00L

Environmental Geotechnics – Polluted Sites and Waste Disposal

The practice of landfilling, remediation of polluted sites and the disposal of radioactive waste are based on the same concepts of environmental protection. Understanding the contaminants behaviour and how to reduce their release to the environment is the key to remediating polluted sites and designing multi-barrier systems.

Objective

On successful completion of this course students will be able to

- Assess the risk to the environment from landfills, contaminated sites and radioactive waste repositories in terms of the fate and transport of contaminants.
- Describe the technologies available to minimise environmental contamination
- Describe the principles of dealing with polluted sites and propose and evaluate appropriate remediation techniques
- Explain the concepts underlying radioactive waste management practices.

Content

This lecture course consists of lectures with exercises and case studies.

- An overview of the principles of environmental protection in waste management and how this is applied in legislation.
- An overview of the chemistry underlying the release and transport of contaminants from the landfilled/contaminated material/ radioactive waste repository focusing on processes controlling mobility of heavy metals and organic compounds
- Introduction to contaminant transport in porous adsorbing media
- Design and function of engineered barriers. Clay as a barrier.
- Polluted site remediation: Site investigation, assessment, and remediation technologies
- Concepts and safety in radioactive waste management
- Role of the geological and engineered barriers and radionuclide transport in geological media.

Prerequisites / notice

excursion
### Water Resources Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>102-0468-10L</td>
<td>Watershed Modelling</td>
<td>O</td>
<td>6</td>
<td>4G</td>
<td>P. Molnar, A. Costa, S. Sinclair</td>
</tr>
</tbody>
</table>

**Abstract**
Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

**Objective**
The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies. A comprehensive exercise block builds on the lectures with a series of 4 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 50% by performance in the graded exercises and 50% by a semester-end oral examination (30 mins) on watershed modelling concepts.

**Content**
The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models students build their own simple bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focussed on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models at larger scales. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns.

**Prerequisites / notice**
Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences). Basic knowledge of Matlab (Python), ArcGIS (Q-GIS).

**Competencies**

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subjects-specific Competencies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Media and Digital Technologies</th>
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### Major Water Resources Management

#### Flow and Transport

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>101-0267-01L</td>
<td>Numerical Hydraulics</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>E. Secchi, D. Vanzo</td>
</tr>
</tbody>
</table>

**Abstract**
In the course Numerical Hydraulics the basics of numerical modelling of flows are presented.

**Objective**
The goal of the course is to develop the understanding of the students for numerical simulation of flows to an extent that they can later use commercial software in a responsible and critical way.

**Content**
The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their applicability is discussed. Using the example of non-steady state pipe flow numerical methods such as the method of characteristics and finite difference methods are introduced. The finite volume method as well as the method of characteristics are used for the solution of the shallow water equations. Special aspects such as wave propagation and turbulence modelling are also treated.

All methods discussed are applied practically in exercises. This is done using programs in MATLAB which partially are programmed by the students themselves. Further, some generally available softwares such as BASEMENT for non-steady shallow water flows are used.

**Lecture notes**
Slides from the lectures and programs used can be downloaded.

**Literature**
Given in lecture
At a time in which humans have significantly affected the natural environment and yet society increasingly values the many services of natural ecosystems, accounting for ecological processes in engineering design is a major contemporary challenge for environmental and civil engineers.

This is the fundamental topic in ecohydraulics, the discipline that focuses on the consequences of fluid flow and related physical processes on the organisms that inhabit aquatic environments. While still a young science, ecohydraulics already endows the engineer with an overall understanding and quantitative tools to predict how physical processes shape habitat quality and quantity, enabling the analysis of different management options for natural and man-made water bodies in terms of their ecosystem consequences.

This class will take a broad view of ecohydraulics and introduce students to key concepts in aquatic habitat modeling. Recognizing that an ecosystem is composed of diverse organisms with different seasonal habitat requirements across a range of scales, the class will focus on multiple representative groups of organisms, including fish, macroinvertebrates, plankton, and vegetation. The lectures will build on the students' knowledge of hydraulics, to give them both an appreciation for the dependence of organisms on their physical environment and a set of quantitative modeling approaches that they can take with them into engineering practice, in fields ranging from hydropower development and upgrade, to reservoir operation, river restoration, flood protection, water management and beyond. At the broadest scale, this class will contribute to the students' appreciation of the tight link between the natural and the built or impacted environment, and of the imperatives of considering both in the design process.

In the course, students learn about methods for the identification and measurement of landscape characteristics, as well as measures and policies for landscape planning. Landscape planning is put into the context of environmental systems (soil, water, air, climate, flora and fauna) and discussed with regard to socio-political questions of the future.

The aims of this course are:
1) To illustrate the concept of landscape planning, the economic relevance of landscape and nature in the context of the environmental systems (soil, water, air, climate, flora and fauna).
2) To show landscape planning as an integral information system for the coordination of different instruments by illustrating the aims, methods, instruments and their functions in landscape planning.
3) To show the importance of ecosystem services.
4) To learn basics about nature and landscape: Analysis and assessment of the complex interactions between landscape elements, effects of current and future land use (ecosystem goods and services, landscape functions).
5) To identify and measure the characteristics of landscape.
6) Learn how to use spatial data in landscape planning.

In this course, the following topics are discussed:
- Definition of the concept of landscape
- Relevance of landscape planning
- Landscape metrics
- Landscape change
- Methods, instruments and aims of landscape planning (policy)
- Socio-political questions of the future
- Environmental systems, ecological connectivity
- Ecosystem services
- Urban landscape services
- Practice of landscape planning
- Use of GIS in landscape planning

No script. The documentation, consisting of presentation slides are partly handed out and are provided for download on Moodle.

The contents of the course will be illustrated in the associated course 103-0347-01 U (Landscape Planning and Environmental Systems (GIS Exercises)) or in Project LAND within the Experimental and Computer Lab (for Environmental Engineers). A combination of courses is recommended.
The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on

**Method-specific Competencies**

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

**Social Competencies**

- Communication: assessed
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

**Personal Competencies**

- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

**Water Resources Management**

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Abstract

Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

Objective

- The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies. A comprehensive exercise block builds on the lectures with a series of 4 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 50% by performance in the graded exercises and 50% by a semester-end oral examination (30 mins) on watershed modelling concepts.

Content

- The first part (A) of the course is on watershed processes from sources on hillslopes to the river network. Students learn about how a fluvial system functions, how to identify sediment sources and sinks, how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change. Students are introduced to the basic concepts of fluvial system change, e.g. thresholds, equilibrium, criticality, to describe change. Students will learn about the importance of the concepts of connectivity and timescales of change. (2) The second part is to provide quantitative skills in making simple and more complex predictions of change and the data and models required. We will learn about typical landscape evolution models, and about hillslope erosion model concepts like RUSLE. We will learn how to identify sediment sources and sinks, and develop simple sediment budgets with the right data needed for this purpose. Finally we will learn about methods to describe the topology of river networks as conduits of sediment through the fluvial system.

- The course is evaluated 50% by performance in the graded exercises and 50% by a semester-end oral examination (30 mins) on watershed modelling concepts.

- There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

- Literature consists of collections from standard hydrological textbooks and research papers, collected by the instructors on the course moodle page.

- Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences). Basic knowledge of Matlab (Python), ArcGIS (Q-GIS),
Numerical Hydraulics

In the course Numerical Hydraulics the basics of numerical modelling of flows are presented. The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their applicability is discussed. Using the example of non-steady state pipe flow numerical methods such as the method of characteristics and finite difference methods are introduced. The finite volume method as well as the method of characteristics are used for the solution of the shallow water equations. Special aspects such as wave propagation and turbulence modelling are also treated.

All methods discussed are applied practically in exercises. This is done using programs in MATLAB which partially are programmed by the students themselves. Further, some generally available softwares such as BASEMENT for non-steady shallow water flows are used.

Hydraulic Engineering II

At a time in which humans have significantly affected the natural environment and yet society increasingly values the many services of natural ecosystems, accounting for ecological processes in engineering design is a major contemporary challenge for environmental and civil engineers.

This is the fundamental topic in ecohydraulics, the discipline that focuses on the consequences of fluid flow and related physical processes on the organisms that inhabit aquatic environments. While still a young science, ecohydraulics already endows the engineer with an overall understanding and quantitative tools to predict how physical processes shape habitat quality and quantity, enabling the analysis of different management options for natural and man-made water bodies in terms of their ecosystem consequences.

Given in lecture

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Problem-solving

Communication

Cooperation and Teamwork

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

Ecohydraulics and Habitat Modelling

At a time in which humans have significantly affected the natural environment and yet society increasingly values the many services of natural ecosystems, accounting for ecological processes in engineering design is a major contemporary challenge for environmental and civil engineers.

This is the fundamental topic in ecohydraulics, the discipline that focuses on the consequences of fluid flow and related physical processes on the organisms that inhabit aquatic environments. While still a young science, ecohydraulics already endows the engineer with an overall understanding and quantitative tools to predict how physical processes shape habitat quality and quantity, enabling the analysis of different management options for natural and man-made water bodies in terms of their ecosystem consequences.

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Hydraulic Engineering II

Information: Enrolment of Hydraulic Engineering II is not recommended without having attended Hydraulic Engineering (101-0206-00L) previously since Hydraulic Engineering II is strongly based on Hydraulic Engineering (101-0206-00L).

Hydraulic structures and their functions within hydraulic systems are treated in this lecture. The basic concepts of their layout and design with regard to economy and safety are provided. Knowledge of hydraulic structures and their functions within hydraulic systems. Skills for the layout and design of hydraulic structures with regard to economy and safety.
River Systems

Remark: partly in German.

Number | Title                | Type | ECTS | Hours | Lecturers       |
--------|----------------------|------|------|-------|-----------------|
101-0258-00L | River Engineering | O    | 3 credits | 2G   | V. Weitbrecht, I. Schalko, K. Sperger |

Abstract
The lecture addresses the fundamentals of river engineering to quantitatively describe the flow of water, transport of sediment and wood, and morphological changes such as erosion and deposition processes associated with river structures. In addition, design guidelines for river engineering structures are introduced.

Objective
At the end of the course, the students will be able to:
- recall and describe the fundamentals of transport processes in rivers,
- apply different calculation approaches and methods to tackle river engineering problems and tasks such as the discharge capacity of a river, scour estimation, or sediment budget of a river,
- design and dimension river engineering works needed to influence the processes in watercourses, and
- determine the interaction between flow (discharge), sediment transport, wood transport and the resulting channel evolution.

Content
- The first part of the lecture introduces the fundamentals of river engineering, such as methods to determine and calculate the river discharge, or sampling methods to characterize the bed material. In addition, the transport processes of sediment (bedload and suspended load) and wood in rivers will be examined, including the principles of incipient motion, and initiation of erosion or deposition processes.
- In the second part of the lecture, the methods will be explained to quantify the bed load budget and the morphological changes (erosion, deposition) in river systems. Specifically, natural channel formation processes, different bed forms and plan forms of rivers (straight, meandering, braided) are examined.
- The last part of the lecture focuses on the design of river engineering structures, including examples from an ongoing flood and river rehabilitation project at the Alpine Rhine in Austria and Switzerland.

Lecture notes and further documentation is specified in the lecture and in the manuscript.

Literature
1. Erosion and Sedimentation; Pierre Y. Julien
2. River Mechanics; Pierre Y. Julien

Recommended lectures:
- Hydrology (102-0293-AAL), Hydraulics I (101-0203-01L), and Hydraulic Engineering (101-0206-00L).

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Problem-solving assessed

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Self-direction and Self-management fostered

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Content

The course consists of four sections: (1) Introduction to fluvial forms and processes and geomorphic concepts of landscape change, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, self-organised criticality, etc. are presented. (2) Landscape evolution modelling as a tool for describing the shape of the land surface. Soil formation and sediment production at long timescales. (3) The processes of sediment production, upland sheet-rill-gully erosion, basin sediment yield, rainfall-triggered landsliding, sediment budgets, and the modelling of the individual processes involved. Here we combine model concepts with field observations and look at many examples. (4) Processes in the river, floodplain and riparian zone, including river network topology, channel geometry, aquatic habitat, role of riparian vegetation, including basics of fluvial system management. The main focus of the course is on the hydrology-sediment connections at the field and catchment scale.

Lecture notes

There is no script.

Literature

The course materials consist of a series of 13 lecture presentations and notes to each lecture. The lectures were developed from textbooks, professional papers, and ongoing research activities of the instructor. All material is on the course webpage.

Prerequisites / notice

Prerequisites: Basic Hydrology and Watershed Modelling (or contact instructor).

Water Resources Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>102-0468-10L</td>
<td>Watershed Modelling</td>
<td>O</td>
<td>6 credits</td>
<td>4G</td>
<td>P. Molnar, A. Costa, S. Sinclair</td>
</tr>
</tbody>
</table>

Abstract

Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

Objective

The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies. A comprehensive exercise block builds on the lectures with a series of 4 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 50% by performance in the graded exercises and 50% by a semester-end oral examination (30 mins) on watershed modelling concepts.

Content

The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models students build their own simple bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focussed on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models at larger scales. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns.

Lecture notes

There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

Literature

Literature consist of collections from standard hydrological textbooks and research papers, collected by the instructors on the course moodle page.

Project Work (for all Majors)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<td>102-0999-00L</td>
<td>Project Work</td>
<td>O</td>
<td>12 credits</td>
<td>26A</td>
<td>Supervisors</td>
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</table>

Abstract

Working during one semester on a task on a topic in the chosen major

Objective

Promote independent, structured and scientific work; learn to apply engineering methods; deepen the knowledge in the field of the treated task.

Content

The project work is supervised by a professor. Students can choose from different subjects and tasks.

Elective Modules

For all majors.

EM: Air Quality Control


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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>102-0377-00L</td>
<td>Air Pollution Modeling and Chemistry</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Henne, S. Reimann Bhend, J. Tang</td>
</tr>
</tbody>
</table>

Abstract

Air pollutants cause negative effects on humans, wildlife and buildings. To control and reduce the impact of air pollutants, their transfer from sources to receptors needs to be known. This transfer includes transport within the atmospheric boundary layer, chemical transformation reactions and phase-transfer processes from gases to particles.

Objective

The students understand the fundamental principles of atmospheric transport, dispersion and chemistry of pollutants on the local to regional scale and their transfer gas to particle phases (secondary aerosols). This includes the knowledge of important atmospheric reactions, sources and sinks. The obtained understanding enables the students to apply computational tools to predict the transport and transformation of chemicals at the local to regional scale.
Content
- Structure of the Atmosphere
- Thermodynamics of the atmosphere
- Atmospheric stability
- Atmospheric boundary layer and turbulence
- Dispersion in the atmospheric boundary layer
- Numerical models of atmospheric dispersion
- Gas phase reaction kinetics
- Tropospheric chemistry and ozone formation
- Chemistry box models
- Volatile organic pollutants (VOCs) and semi-volatile organic pollutants (SVOCs)
- Aerosol modelling
- Air pollution source apportionment
- Inverse modelling of emissions

Lecture notes
Continued updates of:
- Slides and handouts
- Home assignments and sample solutions
- R package and code for some of the home assignments
- MATLAB codes
- Key journal articles as discussed during lecture

Literature
Atmospheric chemistry

Environmental organic chemistry and mass transfer
Mackay D., Multimedia environmental models : the fugacity approach; Boca Raton, Fla. : Lewis Publishers; 2001; 2nd ed

Atmospheric dynamics and boundary layer

Atmospheric modelling

Introduction to R

Prerequisites / notice
strongly recommended: 102-0635-01L Luftreinhaltung (Air Pollution Control) or similar

EM: Ecological Systems Design
Elective Module for Majors “Environmental Technologies”, “River and Hydraulic Engineering” and “Water Resources Management”.

<table>
<thead>
<tr>
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<th>Lecturers</th>
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<tr>
<td>102-0307-01L</td>
<td>Advanced Environmental, Social and Economic Assessments</td>
<td>W</td>
<td>5 credits</td>
<td>4G</td>
<td>A. E. Braunschweig, S. Pfister, A. Kim</td>
</tr>
</tbody>
</table>

Abstract
This course deepens students’ knowledge of environmental, economic, and social assessment methodologies and their various applications.

Objective
This course has the aim of deepening students’ knowledge of the environmental, economic and social assessment methodologies and their various applications.

In particular, students completing the course should have the
- ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors
- knowledge about the current state of the scientific discussion and new research developments
- ability to properly plan, conduct and interpret environmental assessment studies

In the course element “Implementation of Environmental and other Sustainability Goals”, students will learn to
- describe key sustainability problems of the current economic system and measuring units.
- describe the management system of an organisation and how to develop a sustainability orientation
- discuss approaches to measure environmental performance of an organisation, including ‘organisational LCA’ (Ecobalance)
- explain the pros and cons of single score environmental assessment methods
- demonstrate life cycle costing
- interpret stakeholder relations of an organisation
- (if time allows) describe sustainable supply chain management and stakeholder management
In the course Numerical Hydraulics the basics of numerical modelling of flows are presented.

Part I: Slides and background reading material will be available on lecture homepage.

Part II: Documents will be available on Ilias.

Lecture notes

Part I: Slides and background reading material will be available on lecture homepage
Part II: Documents will be available on Ilias

Literature

Will be made available.

Prerequisites / notice

This course should only be elected by students of environmental engineering with a with a Module in Ecological Systems Design. All other students should take the individual courses in Advanced Environmental Assessment and/or Implementation of Environmental and other Sustainability goals (with or without exercise and lab).

Basic knowledge of environmental assessment tools is a prerequisite for this class. Students who have not yet had classwork in this topic are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. (2016). Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5.2)).

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Personal Competencies
- Critical Thinking

102-0317-03L Advanced Environmental Assessment (Computer Lab) W 1 credit 1U S. Pfister

I)

Abstract
Different tools and software used for environmental assessments, such as LCA are introduced. The students will have hands-on exercises in the computer rooms and will gain basic knowledge on how to apply the software and other resources in practice.

Objective
Become acquainted with various software programs for environmental assessment including Life Cycle Assessment, Environmental Risk Assessment, Probabilistic Modeling, Material Flow Analysis.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Personal Competencies
- Critical Thinking

102-0267-01L Numerical Hydraulics W 3 credits 2G E. Secchi, D. Vanzo

Abstract
In the course Numerical Hydraulics the basics of numerical modelling of flows are presented.

Objective
The goal of the course is to develop the understanding of the students for numerical simulation of flows to an extent that they can later use commercial software in a responsible and critical way.

Content
The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their applicability is discussed. Using the example of non-steady state pipe flow numerical methods such as the method of characteristics and finite difference methods are introduced. The finite volume method as well as the method of characteristics are used for the solution of the shallow water equations. Special aspects such as wave propagation and turbulence modelling are also treated.

All methods discussed are applied practically in exercises. This is done using programs in MATLAB which partially are programmed by the students themselves. Further, some generally available softwares such as BASEMENT for non-steady shallow water flows are used.

Lecture notes

Slides from the lectures and programs used can be downloaded.

Literature

Given in lecture

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Social Competencies
- Communication

Personal Competencies
- Critical Thinking
- Integrity and Work Ethics

102-0259-00L Ecohydraulics and Habitat Modelling W 3 credits 2G R. Stocker, K.-D. Jorde,
At a time in which humans have significantly affected the natural environment and yet society increasingly values the many services of natural ecosystems, accounting for ecological processes in engineering design is a major contemporary challenge for environmental and civil engineers.

This is the fundamental topic in ecohydraulics, the discipline that focuses on the consequences of fluid flow and related physical processes on the organisms that inhabit aquatic environments. While still a young science, ecohydraulics already endows the engineer with an overall understanding and quantitative tools to predict how physical processes shape habitat quality and quantity, enabling the analysis of different management options for natural and man-made water bodies in terms of their ecosystem consequences.

This class will take a broad view of ecohydraulics and introduce students to key concepts in aquatic habitat modeling. Recognizing that an ecosystem is composed of diverse organisms with different seasonal habitat requirements across a range of scales, the class will focus on multiple representative groups of organisms, including fish, macroinvertebrates, plankton, plants, and vegetation. The lectures will build on the students' knowledge of ecohydraulics, to give them both an appreciation for the dependence of organisms on their physical environment and a set of quantitative modeling approaches that they can take with them into engineering practice, in fields ranging from hydropower development and upgrade, to reservoir operation, river restoration, flood protection, water management and beyond. At the broadest scale, this class will contribute to the students' appreciation of the tight link between the natural and the built or impacted environment, and of the imperatives of considering both in the design process.

### EM: Groundwater

**Elective Module for Majors "Environmental Technologies", "River and Hydraulic Engineering" and "Urban Water Management"**

### EM: Hydraulic Engineering


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<tr>
<th>Number</th>
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<tr>
<td>101-0247-01L</td>
<td>Hydraulic Engineering II</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>R. Boes</td>
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</tbody>
</table>

**Abstract**

Hydraulic structures and their functions within hydraulic systems are treated in this lecture. The basic concepts of their layout and design with regard to economy and safety are provided.

**Objective**

Knowledge of hydraulic structures and their functions within hydraulic systems. Skills for the layout and design of hydraulic structures with regard to economy and safety.

**Content**

- Weirs: Weir stability, gates, inflatable dams, appurtenant structures, fish up- and downstream passages.
- Conduits: Design of headraces, pressure shafts, and penstocks. Structural details and construction.
- Hydropower plants: Powerhouse and turbine types, design, functionality, construction processes.
- Dams: Types, appurtenant structures (river diversion, spillways, bottom and low-level outlets), dam type selection criteria, layout and design of gravity dams, buttress dams, arch dams, rockfill dams with central core or concrete face, reservoir sedimentation and sediment management, dam surveillance.
- Artificial reservoirs: Purpose, layout, sealing, appurtenant structures, environmental aspects.
- Economical aspects of hydraulic infrastructure

**Competencies**

Subject-specific Competencies
- Concepts and Theories: assessed
- Analytical Competencies: fostered
- Decision-making: fostered
- Problem-solving: fostered

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered

**Lecture notes**

manuscript and further documentation

**Literature**

is specified in the lecture and in the manuscript

**Prerequisites / notice**

Information: Because Hydraulic Engineering II is strongly based on Hydraulic Engineering (Wasserbau, 101-0206-00L) it is strongly recommended to have taken this course (101-0206-00L) or a similar one previously.

**EM: Landscape**

**Elective Module for Majors "Environmental Technologies", "Resource Management", "River and Hydraulic Engineering" and "Urban Water Management"**

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturer</th>
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<tr>
<td>103-0347-00L</td>
<td>Landscape Planning and Environmental Systems</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>L. G. Martins da Silva, A. Siviglia</td>
</tr>
</tbody>
</table>

**Abstract**

In the course, students learn about methods for the identification and measurement of landscape characteristics, as well as measures and policies for landscape planning. Landscape planning is put into the context of environmental systems (soil, water, air, climate, flora and fauna) and discussed with regard to socio-political questions of the future.

**Objective**

The aims of this course are:
1. To illustrate the concept of landscape planning, the economic relevance of landscape and nature in the context of the environmental systems (soil, water, air, climate, flora and fauna).
2. To show landscape planning as an integral information system for the coordination of different instruments by illustrating the aims, methods, instruments and their functions in landscape planning.
3. To show the importance of ecosystem services.
4. To learn basics about nature and landscape: Analysis and assessment of the complex interactions between landscape elements, effects of current and future land use (ecosystem goods and services, landscape functions).
5. To identify and measure the characteristics of landscape.
6. Learn how to use spatial data in landscape planning.
Content

In this course, the following topics are discussed:

- Definition of the concept of landscape
- Relevance of landscape planning
- Landscape metrics
- Landscape change
- Methods, instruments and aims of landscape planning (policy)
- Socio-political questions of the future
- Environmental systems, ecological connectivity
- Ecosystem services
- Urban landscape services
- Practice of landscape planning
- Use of GIS in landscape planning

Lecture notes

No script. The documentation, consisting of presentation slides are partly handed out and are provided for download on Moodle.

Prerequisites / notice

The contents of the course will be illustrated in the associated course 103-0347-01 U (Landscape Planning and Environmental Systems (GIS Exercises)) or in Project LAND within the Experimental and Computer Lab (for Environmental Engineers). A combination of courses is recommended.

Competencies

<table>
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<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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<tr>
<td>Concepts and Theories</td>
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<td>assessed</td>
<td>Communication</td>
<td>fostered</td>
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<tr>
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<td>assessed</td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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<tr>
<td>Analytical Competencies</td>
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<td>Media and Digital Technologies</td>
<td>Customer Orientation</td>
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<td></td>
<td>assessed</td>
<td>Problem-solving</td>
<td>Leadership and Responsibility</td>
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<td>assessed</td>
<td>Project Management</td>
<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
<td>assessed</td>
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<td>Integrity and Work Ethics</td>
<td>fostered</td>
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<td>Self-awareness and Self-reflection</td>
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<td></td>
<td></td>
<td></td>
<td>Self-direction and Self-management</td>
<td>fostered</td>
</tr>
</tbody>
</table>

102-0287-00L River Basin Erosion

Abstract

The course presents a view of the catchment processes of sediment production and transport that shape the landscape. Focus is on sediment fluxes from sources on hillslopes to the river network. Students learn about how a fluvial system functions, how to identify sediment sources and sinks, how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change.

Objective

The course has two fundamental aims: (1) The first aim is to provide environmental engineers with the physical process basis needed to understand fluvial system change, using the right language and terminology to describe landforms. We will cover the main geomorphic concepts of landscape change, e.g. thresholds, equilibrium, criticality, to describe change. Students will learn about the importance of the concepts of connectivity and timescales of change. (2) The second aim is to provide quantitative skills in making simple and more complex predictions of change and the data and models required. We will learn about typical landscape evolution models, and about hillslope erosion model concepts like RUSLE. We will learn how to identify sediment sources and sinks, and develop simple sediment budgets with the right data needed for this purpose. Finally we will learn about methods to describe the topology of river networks as conduits of sediment through the fluvial system.

Content

The course consists of four sections: (1) Introduction to fluvial forms and processes and geomorphic concepts of landscape change, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, self-organised criticality, etc. are presented. (2) Landscape evolution modelling as a tool for describing the shape of the land surface. Soil formation and sediment production at long timescales. (3) The processes of sediment production, upland sheet-rill-gully erosion, basin sediment yield, rainfall-triggered landsliding, sediment budgets, and the modelling of the individual processes involved. Here we combine model concepts with field observations and look at many examples. (4) Processes in the river, floodplain and riparian zone, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, criticality, to describe change. Students will learn about the importance of the concepts of connectivity and timescales of change.

Lecture notes

There is no script. The course materials consist of a series of 13 lecture presentations and notes to each lecture. The lectures were developed from textbooks, professional papers, and ongoing research activities of the instructor. All material is on the course webpage.

Prerequisites / notice

Prerequisites: Basic Hydrology and Watershed Modelling (or contact instructor).

EM: Process Engineering in Urban Water Management

Elective Module for Majors "Resource Management", "River and Hydraulic Engineering" and "Water Resources Management".

No courses in autumn semester (HS), only in spring semester (FS).

EM: Remote Sensing and Earth Observation


Remark: Students also taking module "Remote Sensing and Earth Observation" as replacement of 102-0617-01L Methodologies for Image Processing of Remote Sensing Data in module "Landscape" have to chose one out following list:

-701-1241-00L Atmospheric Remote Sensing (HS, 3 KP)
-701-1232-00L Radiation and Climate Change (FS, 3 KP)
-701-1644-00L Mountain Forest Hydrology (HS, 5 KP).

<table>
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<tr>
<th>Number</th>
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<th>Type</th>
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<tr>
<td>102-0627-00L</td>
<td>Applied Radar Remote Sensing</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>O. Frey</td>
</tr>
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</table>

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2388 of 2653
The lecture addresses the fundamentals of river engineering to quantitatively describe the flow of water, transport of sediment and wood, and morphological changes such as erosion and deposition processes associated with river structures. In addition, design guidelines for river engineering structures are introduced.

At the end of the course, the students will be able to:
- recall and describe the fundamentals of transport processes in rivers,
- apply different calculation approaches and methods to tackle river engineering problems and tasks such as the discharge capacity of a river, scour estimation, or sediment budget of a river,
- design and dimension river engineering works needed to influence the processes in watercourses, and
- determine the interaction between flow (discharge), sediment transport, wood transport and the resulting channel evolution.

The lecture notes/handouts for each topic will be provided online.

Additional reading material:
- ISBN: 978-0-306-47633-4
  https://doi.org/10.1007/0-306-47633-9

Lecturers:
- I. Hajnsek
- At the end of the course the student has the understanding of SAR basics and principles,
- SAR polarimetry,
- SAR interferometry and
- environmental parameter estimation from multi-parametric SAR data

Content
- The course starts with the real-aperture radar case and a first introduction to the concept of radar interferometry with applications to topographic mapping and mapping of surface displacements.

Based on that, the 2-D imaging concept used in synthetic aperture radar imaging is treated.

Then, we expand further on radar and SAR interferometric (InSAR) concepts and processing steps for single interferograms and stacks of interferograms also using persistent scatterer interferometry (PSI) to measure deformation based on time series of interferometric SAR data.

Finally, the 3-D radar imaging case (SAR tomography) is put into context with PSI/InSAR time series as an extension of the more classical interferometric approaches thereby closing the circle around the strongly related concepts of SAR imaging and interferometry.

The course should provide an understanding of SAR techniques and the use of the imaging tools for bio/geophysical parameter estimation.

The rationale behind the structure of the course follows the idea that radar imaging and radar/SAR interferometry are closely related and that a basic understanding of the radar imaging concept is helpful to understand and interpret interferometric radar data for various applications.

The lecture notes/handouts for each topic will be provided online.

Additional reading material:
- ISBN: 978-0-306-47633-4

Prerequisites / notice
- It is highly recommended that the student has previously taken the following courses:
  - 102-0617-00L: Basics and Principles of Radar Remote Sensing
  - 102-0617-01L: Methodologies for Image Processing of Remote Sensing

102-0617-00L Basics and Principles of Radar Remote Sensing for W 3 credits 2G I. Hajnsek

Environmental Applications
- The course will provide the basics and principles of Radar Remote Sensing (specifically Synthetic Aperture Radar (SAR)) and its imaging techniques for the use of environmental parameter estimation.

Objective
- The course should provide an understanding of SAR techniques and the use of the imaging tools for bio/geophysical parameter estimation.
- At the end of the course the student has the understanding of SAR basics and principles,
- SAR polarimetry,
- SAR interferometry and
- environmental parameter estimation from multi-parametric SAR data

Content
- The course is giving an introduction into SAR techniques, the interpretation of SAR imaging responses and the use of SAR for different environmental applications. The outline of the course is the following:
  1. Introduction into SAR basics and principles
  2. Introduction into electromagnetic wave theory
  3. Introduction into scattering theory and decomposition techniques
  4. Introduction into SAR interferometry
  5. Introduction into polarimetric SAR interferometry
  6. Introduction into bio/geophysical parameter estimation (classification/segmentation, soil moisture estimation, earth quake and volcano monitoring, forest height inversion, wood biomass estimation etc.)

Lecture notes
- Handouts for each topic will be provided

Literature
- First readings for the course:

Complete literature listing will be provided during the course.


Note only for HS23: The previous replacement course Wildbach- und Hangverbau for River Basin Erosion will not be offered in HS23. Students taking LAND and RIVER must take one from the following list as a substitute for River Basin Erosion, which occurs in both modules:
- 101-0577-00 An Introduction to Sustainable Development in the Built Environment (HS)
- 701-1257-00 European Climate Change (HS)
- 101-0577-00 An Introduction to Sustainable Development in the Built Environment (HS)
- 101-1249-00 Hydraulics of Engineering Structures (HS)

Number Title Type ECTS Hours Lecturers
101-0258-00L River Engineering W 3 credits 2G V. Weitbrecht, I. Schalko, K. Sperger

Abstract
- The lecture addresses the fundamentals of river engineering to quantitatively describe the flow of water, transport of sediment and wood, and morphological changes such as erosion and deposition processes associated with river structures. In addition, design guidelines for river engineering structures are introduced.

Objective
- At the end of the course, the students will be able to:
  - recall and describe the fundamentals of transport processes in rivers,
  - apply different calculation approaches and methods to tackle river engineering problems and tasks such as the discharge capacity of a river, scour estimation, or sediment budget of a river,
  - design and dimension river engineering works needed to influence the processes in watercourses, and
  - determine the interaction between flow (discharge), sediment transport, wood transport and the resulting channel evolution.
Content

The first part of the lecture introduces the fundamentals of river engineering, such as methods to determine and calculate the river discharge, or sampling methods to characterize the bed material. In addition, the transport processes of sediment (bedload and suspended load) and wood in rivers will be examined, including the principles of incipient motion, and initiation of erosion or deposition processes.

In the second part of the lecture, the methods will be explained to quantify the bed load budget and the morphological changes (erosion, deposition) in river systems. Specifically, natural channel formation processes, different bed forms and plan forms of rivers (straight, meandering, braided) are examined.

The last part of the lecture focuses on the design of river engineering structures, including examples from an ongoing flood and river rehabilitation project at the Alpine Rhine in Austria and Switzerland.

Lecture notes

Lecture slides can be downloaded via Moodle.

Literature

1. Erosion and Sedimentation; Pierre Y. Julien
2. River Mechanics; Pierre Y. Julien

Prerequisites / notice

Recommended lectures:
Hydrology (102-0293-AAL), Hydraulics I (101-0203-01L), and Hydraulic Engineering (101-0206-00L).

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking assessed
Self-direction and Self-management fostered

Objective

The course consists of four sections: (1) Introduction to fluvial forms and processes and geomorphic concepts of landscape change, and Environmental Soil Physics/Vadose Zone Hydrology assessed

The course provides theoretical and practical foundations for understanding and characterizing physical soil properties and processes and

The course has two fundamental aims: (1) The first aim is to provide environmental engineers with the physical process basis needed to

W

3 hours

2 credits

P. Molnar

102-0287-00L

River Basin Erosion

2G

Short practical exercises (voluntary) will be offered throughout the semester to improve the application of the learned subjects.

Content

The course consists of four sections: (1) Introduction to fluvial forms and processes and geomorphic concepts of landscape change, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, self-organised criticality, etc. are presented. (2) Landscape evolution modelling as a tool for describing the shape of the land surface. Soil formation and sediment production at long timescales. (3) The processes of sediment production, upland sheet-rill-gully erosion, basin sediment yield, rainfall-triggered landsliding, sediment budgets, and the modelling of the individual processes involved. Here we combine model concepts with field observations and look at many examples. (4) Processes in the river, floodplain and riparian zone, including river network topology, channel geometry, aquatic habitat, role of riparian vegetation, including basics of fluvial system management. The main focus of the course is on the hydrology-sediment connections at the field and catchment scale.

Lecture notes

There is no script.

Literature

The course materials consist of a series of 13 lecture presentations and notes to each lecture. The lectures were developed from textbooks, professional papers, and ongoing research activities of the instructor. All material is on the course webpage.

Prerequisites / notice

Prerequisites: Basic Hydrology and Watershed Modelling (or contact instructor).

Number Title Type ECTS Hours Lecturers

EM: Soil


701-0535-00L

Environmental Soil Physics/Vadose Zone Hydrology W 3 credits 2+1U A. Carminati, P. U. Lehmann Grunder

Abstract

The course provides theoretical and practical foundations for understanding and characterizing physical soil properties and processes and their relevance for terrestrial ecosystems, plant growth, hydrological processes and atmospheric-land gas exchange, across all relevant scales.

Objective

Students are able to:
- Characterize the different soils based on their key textural and structural properties.
- Simulate and predict soil water retention and flow under varying environmental conditions and understand the key driving forces (capillarity, gravity, friction) and related water properties (surface tension and viscosity).
- Predict soil hydraulic properties for varying soil textural classes.
- Predict solute transport in soils for varying environmental conditions.
- Predict energy balance and temperature dynamics in soils.
- Predict conditions for plant water stress
- Estimate the impact of soil properties on the hydrological cycle and on plant growth.

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INTRODUCTION
Week 1 (September 18)
Presentation of the role of soil physics in environmental sciences and terrestrial ecosystems: soils in the water cycle; soils and vegetation; soils and solute transport. Survey on students’ interests and expectations. Presentation of course structure and learning objectives.

BASIC SOIL PROPERTIES
Week 2 (September 25) and Week 3 (October 02)
soil texture, particle size distribution, soil structure, soil surface area, porosity and bulk density
Pore scale consideration (water in a single pore), pore sizes and shapes; surface tension; Young-Laplace equation; capillary rise; contact angle
Friction and laminar flow; Hagen-Poiseuille’s law; Washburn equation; numerical lab (REPORT 1)

SOIL HYDRAULIC PROPERTIES
Week 4 (October 09) and Week 5 (October 16)
Soil water content and soil water potential - The energy state of soil water; total water potential and its components; volumetric and gravimetric water contents; field capacity and wilting point
Soil water characteristics and pore size distribution
Saturated water flow in soils - Laminar flow in tubes (Poiseuille’s Law); Darcy’s Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts; effective conductivity; unsaturated hydraulic conductivity; Buckingham law.

TOOLBOX – MEASUREMENTS AND MODELING
Week 6 (October 23) and Week 7 (October 30)
Measuring soil hydraulic properties, fitting and interpretation; Lab tour - demonstration of soil physical methods; lecture on HYPROP method; report on Hyprop data (REPORT 2)
Modelling unsaturated water flow based on Richards equation - Using Hydrus1D for simulation of unsaturated flow; simulating HYPROP measurements (REPORT 3)

SOIL IN THE WATER CYCLE
Week 8 (November 06) – Week 9 (November 13)
Water infiltration - steady state solutions for infiltration; approximate solutions to infiltration (Green-Ampt, Philip); infiltration rate and ponding; outlook to preferential flow
Water evaporation - Energy balance and land atmosphere interactions - potential and actual evaporation, evaporation stages;

SOIL PLANT INTERACTIONS
Week 10 (November 20) Week 11 (November 27)
Root water uptake and transpiration – Theory and mechanisms controlling root water uptake; hydraulic properties of rhizosphere; plant and stomatal conductance.
Modelling root water uptake and transpiration; analytical approaches and modeling using Hydrus (REPORT 4)

SOLUTE TRANSPORT
Week 12 (December 04) Week 13 (December 11)
Transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application
Transport of reactive substances, preferential flow, simulations with Hydrus

CLOSURE
Week 14 (December 18)
Summary, course synthesis, connections between the different topics, questions, exam preparation

Literature
Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hille

Competencies
Subject-specific Competencies

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<thead>
<tr>
<th>Concept/Technique</th>
<th>Assessed/Coached</th>
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<td>Techniques and Technologies</td>
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Method-specific Competencies

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<td>Problem-solving</td>
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<td>Project Management</td>
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Social Competencies

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<tr>
<td>Cooperation and Teamwork</td>
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<td>Leadership and Responsibility</td>
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Personal Competencies

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<tr>
<td>Critical Thinking</td>
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<tr>
<td>Integrity and Work Ethics</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
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<tr>
<td>Self-direction and Self-management</td>
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</table>

701-1343-00L Soil-Plant Water Relations W 3 credits 2V A. Carminati

Abstract
Water limitation is a primary constraint on plant growth and terrestrial fluxes worldwide. In this course, the principles of water flow in soil and plants are discussed, with particular attention on the effect of drought on root water uptake, transpiration and plant growth. Strategies of plants to tolerate drought are discussed in relation to both agricultural and ecological implications.

Objective
The students are able to: explain and compare systematically the drivers of water stress to plants; to solve the equations of water flow in soil and plants and to calculate plant water status for varying soil and climatic conditions and plant traits; to critically review and present one research question in soil-plant water relations; to openly debate on the current trends in soil and plant water research and climate change ecology.
Part 1 - Lectures
Week 1: Introduction.
Week 2: Soil water relations; Principles of soil water retention and soil water flow; Soil hydraulic properties.
Week 3: Root water uptake; soil hydraulic constraints on transpiration
Week 4: Rhizosphere processes and properties; root-soil contact; root hairs; mycorrhiza; rhizodeposition.
Week 5: Water flow in roots and xylem; root anatomy, architecture and plasticity; cavitation.
Week 6: Transpiration; Vapor Pressure Deficit; Photosynthesis; stomatal regulation.
Week 7: Soil-plant-atmospheric continuum; Below- and above-ground feedbacks; Soil and atmospheric drivers of transpiration losses.

Part 2 - Seminar
Week 8: Plant response to drought and consequences for agriculture and forests. Open questions and introduction to seminar topics.
Week 9: Class work - preparation of the presentations/Debate
Week 10: Class work - preparation of the presentations/Debate
Week 11: Seminar/Debate (presentations)
Week 12: Seminar/Debate (presentations)
Week 13: Seminar/Debate (presentations)
Week 14: Feedback, Summary, Conclusion

Literature
Lecture notes; selection of articles

Prerequisites / notice
Vadose Zone Hydrology/Environmental Soil Physics (recommended but not required)

Competencies
- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies, Media and Digital Technologies

Objective
The goal of this course is to provide the students with an understanding of how urban water system can be described with mathematical models, and give them the tools to plan experiments, to evaluate error propagation and to test simple process control strategies in the field of process engineering in urban water management.

Content
The course will provide a broad introduction into the fundamentals of modeling water treatment systems. The topics are:
- Introduction into modeling and simulation
- The material balance equations, transport processes, transformation processes
- Ideal reactors
- Hydraulic residence time distribution and modeling of real reactors
- Dynamic behavior of reactor systems
- Systems analytical tools: Sensitivity, parameter identification, error propagation, Monte Carlo simulation
- Introduction to process control (PID controller, fuzzy control)

Lecture notes
Copies of handouts will be available digitally.

Literature

Prerequisites / notice
Students should have a general understanding of urban water management as many examples are taken from processes relevant to related systems. This course is offered in parallel to the course Process Engineering Ia. It is beneficial but not necessary to follow both courses simultaneously.

Competencies
- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies, Media and Digital Technologies

Objective
Biological principles used in wastewater treatment, organic waste management, biological resource recovery. Focus on fundamental principles of biological processes and process design based on kinetic and stoichiometric principles. Processes include anaerobic digestion for biogas production and aerobic wastewater treatment.

Content
- Stoichiometry
- Microbial transformation processes
- Introduction to design and modeling of activated sludge processes
- Anaerobic processes, industrial applications, sludge stabilization

Literature
There will be a textbook that students need to purchase (see http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html for further information).

EM: System Analysis in Urban Water Management

Elective Module for Majors "Resource Management", "River and Hydraulic Engineering" and "Water Resources Management".

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tr>
<td>102-0227-00L</td>
<td>Systems Analysis and Mathematical Modeling in Urban Water Management</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>E. Morgenroth, M. Maurer</td>
</tr>
</tbody>
</table>

Abstract
Systematic introduction of material balances, transport processes (kinetics, stoichiometry and conservation), ideal reactors, residence time distribution, heterogeneous systems, dynamic response of reactors, parameter identification, local sensitivity, error propagation, and Monte Carlo simulations. Introduction to real-time control (PID controllers). Extensive numerical simulations with coding.

Objective
The goal of this course is to provide the students with an understanding of how urban water system can be described with mathematical models, and give them the tools to plan experiments, to evaluate error propagation and to test simple process control strategies in the field of process engineering in urban water management.

Content
The course will provide a broad introduction into the fundamentals of modeling water treatment systems. The topics are:
- Introduction into modeling and simulation
- The material balance equations, transport processes, transformation processes (kinetics, stoichiometry, conservation)
- Ideal reactors
- Hydraulic residence time distribution and modeling of real reactors
- Dynamic behavior of reactor systems
- Systems analytical tools: Sensitivity, parameter identification, error propagation, Monte Carlo simulation
- Introduction to process control (PID controller, fuzzy control)

Lecture notes
Copies of handouts will be available digitally.

Literature

Prerequisites / notice
Students should have a general understanding of urban water management as many examples are taken from processes relevant to related systems. This course is offered in parallel to the course Process Engineering Ia. It is beneficial but not necessary to follow both courses simultaneously.

Competencies
- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies, Media and Digital Technologies

Objective
Biological principles used in wastewater treatment, organic waste management, biological resource recovery. Focus on fundamental principles of biological processes and process design based on kinetic and stoichiometric principles. Processes include anaerobic digestion for biogas production and aerobic wastewater treatment.

Content
- Stoichiometry
- Microbial transformation processes
- Introduction to design and modeling of activated sludge processes
- Anaerobic processes, industrial applications, sludge stabilization

Literature
There will be a textbook that students need to purchase (see http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html for further information).
Introduction

Analytical Competencies

Critical Thinking assessed

Students should be able to evaluate and design biological processes.

Subject-specific Competencies

M. Plötze

Waste Recycling Technologies fostered

There will be a textbook that students need to purchase (see http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html for further information).

Biological processes used in wastewater treatment, organic waste management, biological resource recovery. Focus on fundamental principles of biological processes and process design based on kinetic and stoichiometric principles. Processes include anaerobic digestion for biogas production and aerobic wastewater treatment.

Communication assessed

2G assessed

Concepts and Theories assessed

Critical Thinking assessed

ECTS assessed

Process Engineering Ia

Prerequisites / notice For detailed information on prerequisites the student should consult the lecture program and important information (syllabus) of Process Engineering Ia that can be accessed via http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html

Objective Students should be able to evaluate and design biological processes.

Content Stoichiometry

Microbial transformation processes

Introduction to design and modeling of activated sludge processes

Anaerobic processes, industrial applications, sludge stabilization

Literature There will be a textbook that students need to purchase (see http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html for further information).

Prerequisites / notice For detailed information on prerequisites the student should consult the lecture program and important information (syllabus) of Process Engineering Ia that can be accessed via http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html

Competencies

Subject-specific Competencies Concepts and Theories assessed

Techniques and Technologies assessed

Method-specific Competencies Analytical Competencies assessed

Decision-making fostered

Problem-solving assessed

Social Competencies Communication assessed

Customer Orientation fostered

Personal Competencies Critical Thinking assessed

Number Title Type ECTS Hours Lecturers
102-0217-00L Process Engineering Ia W 3 credits 2G E. Morgenroth

Abstract Biological processes used in wastewater treatment, organic waste management, biological resource recovery. Focus on fundamental principles of biological processes and process design based on kinetic and stoichiometric principles. Processes include anaerobic digestion for biogas production and aerobic wastewater treatment.

Objective Students should be able to evaluate and design biological processes.

Content Stoichiometry

Microbial transformation processes

Introduction to design and modeling of activated sludge processes

Anaerobic processes, industrial applications, sludge stabilization

Literature There will be a textbook that students need to purchase (see http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html for further information).

Prerequisites / notice For detailed information on prerequisites the student should consult the lecture program and important information (syllabus) of Process Engineering Ia that can be accessed via http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html

Competencies

Subject-specific Competencies Concepts and Theories assessed

Techniques and Technologies assessed

Method-specific Competencies Analytical Competencies assessed

Decision-making fostered

Problem-solving assessed

Social Competencies Communication assessed

Customer Orientation fostered

Personal Competencies Critical Thinking assessed

102-0357-00L Waste Recycling Technologies 

Abstract Waste Recycling Technology (WRT) is a sub-discipline of Mechanical Process Engineering. WRT is employed in production plants processing contaminated soil, construction wastes, scrap metal, recovered paper and the like. While WRT is well established in Central Europe, it is only just now catching on in emerging markets as well.

Objective At the core of this course is the separation of mixtures of solid bulk materials according to physical properties such as color, electrical conductivity, magnetism and so forth. After having taken this course, the students should have concept not only of the unit operations employed in WRT but also of how these unit operations are integrated into the flow sheets of production plants.

Content Introduction

Waste Recycling: Scope and objectives

Waste recycling technologies in Switzerland

Fundamentals

Properties of particles; Liberation conditions, Particle size and shape, Porosity of bulk materials

Fluid dynamics of particles: Stationary particle beds, Fluidized beds, Free settling particles

Flow sheet basics: Balancing mass flows

Standard processes: batch vs. continuous

Assessment of separation success: Separation function; grade vs. recovery

Separation Processes

Separation according to size and shape (Classification): Screening, Flow separation

Separation according to material properties (Concentration): Manual Sorting, Gravity concentration; Magnetic separation, Eddy current separation. Electrostatic separation, Sensor technology, Floth flotation

Lecture notes The script consists of the slides shown during the lectures. Background material will be provided on the script-server.

Literature A list of recommended books will be provided.

Prerequisites / notice The topic will be discussed not from the perspective of theory, but rather in the context of practical application. However, solid fundamentals in physics (in particular in mechanics) are strongly recommended.

101-0339-00L Environmental Geotechnics – Polluted Sites and Waste Disposal

Abstract The practice of landfiling, remediation of polluted sites and the disposal of radioactive waste are based on the same concepts of environmental protection. Understanding the contaminants behaviour and how to reduce their release to the environment is the key to remediating polluted sites and designing multi-barrier systems.

Objective On successful completion of this course students will be able to

- Assess the risk to the environment from landfills, contaminated sites and radioactive waste repositories in terms of the fate and transport of contaminants.
- Describe the technologies available to minimise environmental contamination
- Describe the principles of dealing with polluted sites and propose and evaluate appropriate remediation techniques
- Explain the concepts underlying radioactive waste management practices.
This lecture course consists of lectures with exercises and case studies.
- An overview of the principles of environmental protection in waste management and how this is applied in legislation.
- An overview of the chemistry underlying the release and transport of contaminants from the landfilled/contaminated material/radioactive waste repository focusing on processes controlling mobility of heavy metals and organic compounds
- Introduction to contaminant transport in porous adsorbing media
- Design and function of engineered barriers. Clay as a barrier.
- Polluted site remediation: Site investigation, assessment, and remediation technologies
- Concepts and safety in radioactive waste management
- Role of the geological and engineered barriers and radionuclide transport in geological media.

Prerequisites / notice

EM: Water Infrastructure Planning and Stormwater Management


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<th>Number</th>
<th>Title</th>
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<td>102-0250-00L</td>
<td>Urban Drainage Planning and Modelling</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>M. Maurer, U. Karaus, J. P. Leitão Correia, M. Stähle</td>
</tr>
</tbody>
</table>

Abstract
In this course, students learn modern urban drainage engineering approaches, critical thinking, decision making in a complex environment as well as dealing with insufficient data and ill-defined problems.

Objective
By the end of the course, you should be able to do the following:
- Apply different methods and methodologies to assess the impact of urban drainage on water pollution and flooding potential.
- Distinguish between hydrological and hydrodynamic models and their correct application.
- Identify the difference between emission and immission oriented approaches for identifying drainage measures.
- Identify relevant measures, quantify their effects and assess their relative ranking/priority.
- Consider uncertainties and handle incomplete data and information.
- Make decisions and recommendations in a complex application case.
- Teamwork. State principles of effective team performance and the functions of different team roles; work effectively in problem-solving teams.
- Communication. Communicate and document your findings in concise group presentations and a written report.

Content
In urban drainage, the complexity of the decision-making, the available methodologies and the data availability have increased significantly. In current environmental engineering practice, the focus has shifted from tables and nomograms to sophisticated simulation tools. The topics cover:
- Integrated urban water management
- Hydrological and hydrodynamic modelling
- Water quality based assessment
- Freshwater ecology
- Hydraulic capacity assessment
- Sewer network operation
- Decision analysis

Prerequisites / notice
Prerequisites: 102-0214-00 Siedlungswasserwirtschaft and 102-0215-00 Siedlungswasserwirtschaft II or comparable educational background.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

EM: Water Resources Management

Elective Module for Majors “Environmental Technologies”, and “Urban Water Management”.

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Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

Objective
The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies. A comprehensive exercise block builds on the lectures with a series of 4 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 50% by performance in the graded exercises and 50% by a semester-end oral examination (30 mins) on watershed modelling concepts.

Content
The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models students build their own simple bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focussed on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models at larger scales. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns.

Lecture notes
There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

Literature
Literature consist of collections from standard hydrological textbooks and research papers, collected by the instructors on the course moodle page.

Prerequisites / notice
Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences). Basic knowledge of Matlab (Python), ArcGIS (Q-GIS).

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed

Method-specific Competencies

Social Competencies
Communication fostered
Cooperation and Teamwork assessed

Personal Competencies
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Specialized Computer Laboratory

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<tr>
<th>Number</th>
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<td>Experimental and Computer Laboratory I (Year Course)</td>
<td>O</td>
<td>0</td>
<td>6P</td>
<td>D. Braun, F. Evers, M. Floriancic, S. Frei, P. U. Lehmann Grunder, B. Lüthi, S. Pfister, F. Rüssch, D. F. Vetsch, L. von Känel, to be announced</td>
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</table>

Abstract
In the Experimental and Computer Laboratory students are introduced to research and good scientific practice. Experiments are conducted in different disciplines of environmental engineering. Data collected during experiments are compared to the corresponding numeric simulations. The results are documented in reports or presentations.

Objective
The student will learn the following skills: basic scientific work, planning and conducting scientific experiments, uncertainty estimations of measurements, applied numerical simulations, modern sensor technology, writing reports.

Content
The Experimental and Computer Laboratory is building on courses in the corresponding modules. Material from these courses is a prerequisite or co-requisite (as specified below) for participating in the Experimental and Computer Laboratory (MODULE: Project in the Experimental and Computer Laboratory):
- Waterinfra: Water Network Management
- UWM: SysUWM + ProcUWM: Operation of Lab-WWTP
- AIR: Air Quality Measurements
- WasteBio: Anaerobic Digestion
- WasteRec: Plastic Recycling
- ESD: Environmental Assessment
- GROUND: Groundwater Field Course Kappelen
- WRM: Modelling Optimal Water Allocation
- FLOW: 1D Open Channel Flow Modelling
- LAND: Landscape Planning and Environmental Systems
- RIVER: Discharge Measurements
- HydEngr: Hydraulic Experiments
- RemSens: Earth Observation and Landscape Planning
- SOIL: Soil and Environmental Measurements Lab

Lecture notes
Written material will be available.

Electives
The entire course programs of ETH Zurich and the University of Zurich are open to the students to individual selection.

**Course Catalogue of ETH Zurich**

**Master's Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>102-0010-01L</td>
<td>Master's Thesis</td>
<td>W</td>
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*Abstract*  
The Master Programme concludes with the Master Thesis, which has to be done in one of the chosen Majors and has to be completed within 28 weeks. The Master Thesis is supervised by a professor and shall attest the students ability to work independently and to produce scientifically structured work.

*Objective*  
To work independently and to produce a scientifically structured work.

*Content*  
The topics of the Master Thesis are published by the professors. The Topic can be set also in consultation between the student and the professor.

**Science in Perspective**

*see Science in Perspective: Language Courses ETH/UZH*

*see Science in Perspective: Type A: Enhancement of Reflection Capability*

**Recommended Science in Perspective (Type B) for D-BAUG**

**Course Units for Additional Admission Requirements**

*The courses below are only available for MSc students with additional admission requirements.*

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>101-0203-AAL</td>
<td>Hydraulics I</td>
<td>E</td>
<td>5 credits</td>
<td>11R</td>
<td>R. Stocker</td>
</tr>
</tbody>
</table>

*Abstract*  
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

*Objective*  
The course teaches the basics of hydromechanics, relevant for civil and environmental engineers.

*Content*  
Properties of water, hydrostatics, continuity, Euler equation of motion, Navier Stokes equation, similarity, Bernoulli principle, momentum equation for finite volumes, potential flows, ideal fluids-real fluids, boundary layer, pipe flow, open channel flow, flow in porous media, flow measurements, demonstration experiments in the lecture hall and in the laboratory

*Lecture notes*  
Script and collection of problems available

*Literature*  
Bollrich, Technische Hydromechanik 1, Verlag Bauwesen, Berlin

| 102-0214-AAL | Introduction to Urban Water Management | E    | 6 credits | 13R   | E. Morgenroth, M. Maurer  |

*Abstract*  
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

*Objective*  
Introduction to urban water management (water supply, urban drainage, wastewater treatment, sewage sludge treatment). Introduction to Urban Water Management is a self-study course.

*Content*  

*Lecture notes*  

*Literature*  
In this self-study course the students must work through and understand selected sections from the following book


Students must understand and be able to discuss the required reading in a 30 min oral exam. The required reading is explained in detail on the website of the professorships of urban water management. Additional information can be obtained during the office hours of the professors’ assistants.

The required reading and studying should correspond roughly the time invested in the course Siedlungswasserwirtschaft GZ. Students are welcome to ask the assistants (http://www.sww.ifu.ethz.ch/group/teaching-assistants.html) for help with questions they have regarding the reading.
Some students joining the MSc program in Environmental Engineering at ETH Zürich have to take additional courses from our BSc program. The decision of what courses to take is done at the time of admission at ETH.

The course on "Introduction to Urban Water Management" is offered at ETH Zürich only in German. Students who can speak and understand German must take the course (Siedlungswasserwirtschaft GZ) and get a passing grade. For students that do not have sufficient German language skills there is a self-study course and they have to take an oral exam.

This course is required for further in depth courses in urban water management.

**Prerequisite:** Hydraulics I and Hydrology

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</table>

**Ecological Systems Analysis**

*Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.*

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**

Methodological basics and application of various environmental assessment tools.

**Objective**

Students learn about environmental assessment tools, such as material flow analysis, risk assessment, and life cycle assessment. They can identify and apply the appropriate tool in a given situation. Also, they are able to critically assess existing studies.

**Content**

- Methodological basics of material flow analysis, risk assessment and life cycle assessment
- Application of these methods to case studies

**Lecture notes**

No script, but literature available on moodle

**Waste Management**

*Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.*

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**

Introduction into the problems of waste handling with the goal to get the ability of seeing and improving the influence of commodities and products with there packaging to the environment - as they are becoming waste. Knowing the different mechanical and chemical processes, which are applicable in the field of waste management.

**Objective**

In the course "Waste Management", the competencies of process understanding, system understanding, modeling, concept development, measurement methods and data analysis & interpretation are taught. The competencies process understanding and system understanding are applied and examined in addition. Concept development is also examined.

**Content**

This lecture gives a comprehensive overview of the different waste-types and waste handling possibilities:

- Waste composition as a mirror of the human evolution
- Waste definition (formation, amount, energy content, waste composition)
- Several recycling possibilities and processes
- Thermal waste treatment (electricity/district heat as products), including off-gas cleaning and incineration residue handling with regards to the final residue storage in a landfill and the problems which have to be solved there
- Special fields like biological waste handling (composting, fermentation), handling of special wastes and municipal sewage sludge treatment
- Economical aspects

**Lecture notes**

Martin F. Lemann, Christoph Leitzinger, Leo S. Morf: Waste Management Edition 2020, 433 pages
ISBN 978-3-9525297-0-6

**Literature**

Martin F. Lemann, Christoph Leitzinger, Leo S. Morf: Waste Management Edition 2020, 433 pages
ISBN 978-3-9525297-0-6

**Prerequisites / notice**

Basic of chemical processes has to be known
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<td>Self-presentation and Social Influence</td>
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102-0455-AAL Groundwater I

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
The course provides a quantitative introduction to groundwater flow and contaminant transport. Further, system understanding and concept development are taught and applied, which are previous steps to groundwater modeling. To add measurement methods are taught and data analysis & interpretation is applied during the course.

Objective
Understanding of the basic concepts on groundwater flow and contaminant transport processes. Formulation and solving of practical problems.

Content
- Properties of porous and fractured media
- Darcy’s law, flow equation, stream functions, interpretation of pumping tests, transport processes, transport equation, analytical solutions for transport, numerical methods: finite differences method, aquifers remediation, case studies.

Literature
- W. Kinzelbach, R. Rausch, Grundwassermodellierung, Gebrüder Bornträger, Stuttgart, 1995

102-0635-AAL Air Pollution Control

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
The lecture provides an introduction to the formation of air pollutants by technical processes, the emission of these chemicals into the atmosphere and the impact on air quality. Theoretical description and modeling of these processes, air quality measurement techniques and pollution control techniques are covered.

Objective
The students gain general knowledge of the factors resulting in air pollution and the techniques used for air pollution control. The students can identify major air pollution sources and understand the methods for measurement, data collection and analysis. The students can evaluate possible control methods and equipment, design a control system and estimate the efficiency and cost.

Content
- the physical and chemical processes leading to emission of pollutants
- air quality analysis
- the meteorological parameters influencing air pollution dispersion
- deterministic and stochastic models, describing the air pollution dispersion
- measurement concepts to observe ambient air pollution
- removal of gaseous pollutants by absorption and adsorption
- control of NOx and SOx
- fundamentals of particulate control
- design and application of wet scrubbers

Literature
- Text book

Prerequisites / notice
College lectures on basic physics, chemistry and mathematics.
Introduction to Water Resources Management

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
The course offers an introduction to the basics of water resources analysis and management covering the topics of water demand vs availability, water exploitation and reservoir design, aquatic physics, water quality and pollution, water conservation and remediation in rivers, lakes and aquifers, sustainable water use.

Objective
Introduction to the basics of sustainable water resources management based on relevant hydrological processes, management approaches and mathematical models.

Content

Literature
Information is provided in the handouts or on the Moodle course webpage.

Competencies
Subject-specific Competencies
- Concepts and Theories
  - assessed
- Techniques and Technologies
  - assessed

Method-specific Competencies
- Analytical Competencies
  - assessed
- Decision-making
  - assessed
- Media and Digital Technologies
  - fostered
- Problem-solving
  - assessed
- Project Management
  - fostered

Social Competencies
- Communication
  - assessed
- Cooperation and Teamwork
  - fostered
- Customer Orientation
  - fostered
- Leadership and Responsibility
  - fostered
- Self-presentation and Social Influence
  - fostered
- Sensitivity to Diversity
  - fostered
- Negotiation
  - fostered

Personal Competencies
- Adaptability and Flexibility
  - assessed
- Creative Thinking
  - assessed
- Critical Thinking
  - assessed
- Integrity and Work Ethics
  - assessed
- Self-awareness and Self-reflection
  - fostered
- Self-direction and Self-management
  - assessed

Computer Science II

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to programming in Java. Procedural foundations of programming and outlook to object oriented programming. Variables, types, assignments, control structures (branch, loop), data structures, algorithms, line graphics, graphical user interface. Writing small programs.

Objective
Application of programming knowledge by the students. Working with a professional programming environment (Eclipse).

Content
In the exercises students train programming skills (in the programming language JAVA). Students can solve the exercises on their own laptop or in the computer labs at ETH. The software used in this course runs on MS Windows, MacOS X and Linux.

Personal Competencies
- Creative Thinking
  - assessed
- Critical Thinking
  - assessed
Abstract
General Chemistry I and II: Chemical bond and molecular structure, chemical thermodynamics, chemical equilibrium, kinetics, acids and bases, electrochemistry

Objective
Introduction to general and inorganic chemistry. Basics of the composition and the change of the material world. Introduction to the thermodynamically controlled physico-chemical processes. Macroscopic phenomena and their explanation through atomic and molecular properties. Using the theories to solve qualitatively and quantitatively chemical and ecologically relevant problems.

Content
1. Stoichiometry
2. Atoms and Elements (Quantummechanical Model of the Atom)
3. Chemical Bonding
4. Thermodynamics
5. Chemical Kinetics
6. Chemical Equilibrium (Acids and Bases, Solubility Equilibria)
7. Electrochemistry

Lecture notes
Nivaldo J. Tro
Chemistry - A molecular Approach (Pearson), Chapter 1-18

Literature
Housecroft and Constable, CHEMISTRY
Oxtoby, Gillis, Nachtrieb, MODERN CHEMISTRY

Competencies

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529-2002-AAL Chemistry II
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Chemistry II: Redox reactions, chemistry of the elements, introduction to organic chemistry

Objective
Erweitern der allgemeinen Grundlagen und Erarbeiten einer Basis, um Prozesse in komplexeren Umweltsystemen (Wasser / Luft / Boden) in ihrem zeitlichen und quantitativen Ablauf verstehen und beurteilen zu können.

Content
1. Redoxreactions
2. Inorganic Chemistry
Rules for nomenclature of inorganic compounds. Systematic description of the groups of elements in the periodical system and the most important compounds of these elements. Formation of compounds as a consequence of the electronoc structure of the elements.
3. Introduction to organic chemistry
Description of the most important classes of compounds and of the functional groups. Principal reactivity of these functional groups.
Stereochemistry.
Rection mechanisms: SN1- and SN2-reactions, electrophilic aromatic substitutions, eliminations (E1 and E2), addition reactions (C=C and C=O double bonds). Chemistry of carbony and carboxyl groups.
Rules for nomenclature of inorganic compounds. Systematic description of the groups of elements in the periodical system and the most important compounds of these elements. Formation of compounds as a consequence of the electronoc structure of the elements.
3. Introduction to organic chemistry
Description of the most important classes of compounds and of the functional groups. Principal reactivity of these functional groups.
Stereochemistry.
Rection mechanisms: SN1- and SN2-reactions, electrophilic aromatic substitutions, eliminations (E1 and E2), addition reactions (C=C and C=O double bonds). Chemistry of carbony and carboxyl groups.

Lecture notes

Literature

Competencies

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752-0100-AAL Biochemistry
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2400 of 2653
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Basic knowledge of enzymology, in particular the structure, kinetics and chemistry of enzyme-catalysed reaction in vitro and in vivo.

Objective
Based on the biology and chemistry courses in the 1. and 2. semester more detailed biochemical knowledge about enzymology, membrane biochemistry, and central metabolism will be presented.

Content
Program
Introduction, basics, composition of cells, biochemical units, repetition of relevant organic chemistry
Structure and function of proteins
Lipids and biological membranes
Enzymes and enzyme kinetics
Catalytic strategies
Metabolism: Basic concepts and design. Repetition of basic thermodynamics
Glycolysis
The citric acid cycle
Oxidative phosphorylation

Lecture notes
by Laurence A. Moran (Author), Robert A Horton (Author), Gray Scrimgeour (Author), Marc Perry (Author)

Literature
by Laurence A. Moran (Author), Robert A Horton (Author), Gray Scrimgeour (Author), Marc Perry (Author)

Prerequisites / notice
Basic knowledge in biology and chemistry is a precondition.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered

752-4001-AAL Microbiology
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Self-study course in microbiology.

Objective
Teaching of basic knowledge in microbiology.

Content
This is a self-study course for students with microbiology as an admission requirement. The goal of the course is that students acquire basics in microbiology, including bacterial cell biology, genetics, growth and physiology, metabolism, phylogeny and microbial diversity, and applications of microbiology.

Literature
This self-study course is based on the book ‘Brock, Biology of Microorganisms’.

102-0293-AAL Hydrology
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Objective
Kenntnis der Grundzüge der Hydrologie. Kennenlernen von Methoden, zur Abschätzung hydrologischer Grössen, die zur Dimensionierung von Wasserbauwerken und für die Nutzung von Wasserressourcen relevant sind.

Content
Der hydrologische Kreislauf: globale Wasserressourcen, Wasserbilanz, räumliche und zeitliche Dimension der hydrologischen Prozesse.
Niederschlag: Niederschlagsmechanismen, Regenmessung, räumliche/zeitliche Verteilung des Regens, Niederschlagsregime, Punktniederschlag/Gebietsniederschlag, Isohyeten, Thiessenpolygon, Extremniederschlag, Dimensionierungsniederschlag.
Interzeption: Messung und Schätzung.
Evaporation und Evapotranspiration: Prozesse, Messung und Schätzung, potentielle und effektive Evapotranspiration, Energiebilanzmethode, empirische Methode.
Infiltration: Messung, Horton-Gleichung, empirische und konzeptionelle Methoden, F-index und Prozentuale Methode, SCS-CN Methode.
Schnee und Eis: Schneeeigenschaften und -messungen Schätzung des Schneeschmelzprozesses durch die Energiebilanzmethode, Abfluss aus Schneeschmelze, Temperatur-Index- und Grad-Tag-Verfahren.
Ein internes Skript ist zur Verfügung (kostenpflichtig, nur Herstellungskosten).

Die Kopie der Folien zur Vorlesung können auf den Webseiten der Professur für Hydrologie und Wasserwirtschaft herunterladen werden.


Vorbereitend zu Hydrologie I sind die Vorlesungen in Statistik. Der Inhalt, der um ein Teil der Übungen zu behandeln und um ein Teil der Vorlesungen zu verstehen notwendig ist, kann zusammengefasst werden, wie hintereinander es beschrieben wird:

Elementare Datenverarbeitung: Hydrologische Messungen und Daten, Datenreduzierung (grafische Darstellungen und numerische Kenngrössen).


**Stochastik (Wahrscheinlichkeit und Statistik)**

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enroll for this course unit.

Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language “R”.

**Lecture notes**

Lecture notes and exercise sheets will be distributed via Moodle.


- **Abstract**
- **Objective**
- **Content**

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enroll for this course unit.

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**Lecture notes**

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**Literature**

Content
From "Statistics for research" (online)
Ch 1: The Role of Statistics
Ch 2: Populations, Samples, and Probability Distributions
Ch 3: Binomial Distributions
Ch 6: Sampling Distribution of Averages
Ch 7: Normal Distributions
Ch 8: Student's t Distribution
Ch 9: Distributions of Two Variables

From "Introductory Statistics with R" (online)
Ch 1: Basics
Ch 2: The R Environment
Ch 3: Probability and distributions
Ch 4: Descriptive statistics and tables
Ch 5: One- and two-sample tests
Ch 6: Regression and correlation

Literature
- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
From within the ETH, this book is freely available online under:
From within the ETH, this book is freely available online under:
http://www.springerlink.com/content/m17578/

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies assessed
Problem-solving assessed
Personal Competencies
Self-direction and Self-management assessed

406-0141-AAL Linear Algebra E- 5 credits 11R M. Akka Ginosar, R. Prohaska
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to Linear Algebra

Objective
Basic knowledge of linear algebra as a tool for solving engineering problems.
Understanding of abstract mathematical formulation of technical and scientific problems.

Content
Introduction and linear systems of equations, matrices, quadratic matrices, determinants and traces, general vector spaces, linear mappings, bases, change of basis, diagonalization, eigenvalues and eigenvectors, orthogonal transformations, scalar-product, inner product spaces.

Literature

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed
Personal Competencies
Critical Thinking fostered

406-0242-AAL Analysis II E- 7 credits 15R M. Akveld
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Mathematical tools of an engineer

Objective
Mathematics as a tool to solve engineering problems, mathematical formulation of problems in science and engineering. Basic mathematical knowledge of an engineers.

Content

Literature
Textbooks in English:
- J. Stewart: Multivariable Calculus, Thomson Brooks/Cole
- V. I. Smirnov: A course of higher mathematics. Vol. II. Advanced calculus
- M. Akveld, R. Sperb, Analysis II, vdf
- L. Papula: Mathematik für Ingenieure 2, Vieweg Verlag

406-0243-AAL Analysis I and II E- 14 credits 30R M. Akveld
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Mathematical tools for the engineer

Objective
Mathematics as a tool to solve engineering problems. Basic mathematical knowledge for engineers.

Mathematical formulation of technical and scientific problems.
Content
Complex numbers.
Calculus for functions of one variable with applications.
Simple Mathematical models in engineering.


Literature
Textbooks in English:
Textbooks in German:
- M. Akveld, R. Sperb: Analysis I, vdf
- M. Akveld, R. Sperb: Analysis II, vdf
- L. Papula: Mathematik für Ingenieure und Naturwissenschaftler, Vieweg Verlag
- L. Papula: Mathematik für Ingenieure 2, Vieweg Verlag

Environmental Engineering Master - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
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<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
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<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Environmental Studies TC

Detailed information on the programme at: https://www.ethz.ch/en/studies/teacher-training.html

Educational Science

Bitte beachten Sie, dass sich die Lerneinheitsnummer ab dem HS24 ändern wird. Diese Änderung hat keinen Einfluss auf die bisher absolvierten Lerneinheiten und erbrachten Leistungen und wird für den jeweiligen Studienabschluss anerkannt.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>871-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern, M. Rau</td>
</tr>
<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in the programs &quot;Teaching Diploma&quot; or &quot;Teaching Certificate&quot;. It is about learning in childhood and adolescence.</td>
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<tr>
<td>Abstract</td>
<td>This course looks into scientific theories and also empirical studies on human learning and relates it to the school.</td>
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<tr>
<td>Objective</td>
<td>Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioral research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.</td>
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<tr>
<td>Content</td>
<td>Thematische Schwerpunkte: Lernen als Verhaltensänderung und als Informationsverarbeitung; Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen; Intelligenztheorien, Geschlechtsunterschiede beim Lernen.</td>
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<tr>
<td>Literature</td>
<td>The focus will be on the book &quot;Intelligenz: Grosse Unterschiede und ihre Folgen&quot; by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>This lecture is only apt for students who intend to enrol in the programs &quot;Lehrdiplom&quot; or &quot;Didaktisches Zertifikat&quot;. It is about learning in childhood and adolescence.</td>
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<tr>
<td>871-0242-06L</td>
<td>Cognitive Activating Instructions in MINT Subjects ▪ W</td>
<td>2 credits</td>
<td>2S</td>
<td>R. Schumacher</td>
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<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<tr>
<td>Abstract</td>
<td>This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.</td>
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<tr>
<td>Objective</td>
<td>- Get to know cognitively activating instructions in MINT subjects</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.</td>
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<tr>
<td>871-0242-07L</td>
<td>Human Intelligence ▪ W</td>
<td>1 credit</td>
<td>1S</td>
<td>E. Stern</td>
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<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<td>Abstract</td>
<td>The focus will be on the book &quot;Intelligenz: Grosse Unterschiede und ihre Folgen&quot; by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.</td>
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<tr>
<td>Objective</td>
<td>- Understanding of research methods used in the empirical human sciences</td>
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<tr>
<td>Prerequisites / notice</td>
<td>In this class, students will learn concepts and skills for coping with psychosocial demands of teaching</td>
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<tr>
<td>871-0240-22L</td>
<td>Coping with Psychosocial Demands of Teaching (EW4 W DZ) ▪</td>
<td>2 credits</td>
<td>3S</td>
<td>S. Maurer, P. Caprez, I. Sargenti</td>
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<tr>
<td></td>
<td>The successful participation in EW1 (&quot;Human Learning&quot;) and EW2 (&quot;Designing Learning Environments for School&quot;) is recommended, but not a mandatory prerequisite.</td>
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<tr>
<td>Abstract</td>
<td>In this class, students will learn concepts and skills for coping with psychosocial demands of teaching</td>
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<tr>
<td>Objective</td>
<td>(1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks).</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Students possess theoretical knowledge and practical competences to be able to cope with the psychosocial demands of teaching.</td>
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<tr>
<td>871-0228-00L</td>
<td>Formation of Knowledge in STEM Fields in Primary and Secondary School ▪</td>
<td>2 credits</td>
<td>1S</td>
<td>U. Markwalder</td>
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<tr>
<td></td>
<td>Adresses to students enrolled either in Teaching Diploma* (TD) or Teaching Certificate (TC) (excluding Teaching Diploma Sport).</td>
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<tr>
<td>Abstract</td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW1)&quot;.</td>
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</tbody>
</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2405 of 2653
participation in the course 871-0240-00L "Human Learning (EW 1)".

Abstract
Course promotes exchange between student teachers and elementary school teachers in STEM teaching with 3 parts: 1) block seminar (ca. 16 h), 2) collaboration with elementary school teacher in a class (ca. 34 h, with approx. 50% spent in the elementary or middle school class and ca. 50% for preparation), and 3) final report (ca. 10 h). Registration implies participation in all 3 parts.

Objective
Deepening the understanding of knowledge formation and learning processes of primary and secondary students from a cognitive and developmental psychology perspective for students. The assistant ship provides didactic experience and exposure to a different school level (more heterogeneous groups such as for example low-performing to very high-performing Children, language problems etc.).

Content
Students learn more about the potential and challenges of pupils. They get to know the early stages of knowledge as well as the development of pre-concepts of students in their subject area. The seminar with a phase of cooperation consists of three phases: In the block seminar, pre-concepts are discussed in their own subject as well as theoretical inputs from developmental and cognitive psychology. During the cooperation phase, a teaching task defined by the primary and secondary school teachers is actively undertaken in a class. Finally, a final report is written, which contains a description of the students' level of knowledge. This seminar is only suitable for students who can adapt flexibly to the needs of pupils from lower class levels.

Prerequisites / notice
https://www.minterlink.ch/student

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Analytical Competencies assessed

Method-specific Competencies
Communication assessed
Cooperation and Teamwork assessed
Leadership and Responsibility assessed
Sensitivity to Diversity assessed

Social Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Self-awareness and Self-reflection assessed

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Self-awareness and Self-reflection assessed

Subject Didactics and Professional Training
Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

Number Title Type ECTS Hours Lecturers
701-0822-00L Mentored Assignment W 2 credits 4A C. Colberg, F. Keller

Abstract
The mentored paper is designed to bring together the findings from the 701-0823-00L Environmental Education Didactics I Information and the 701-0825-10L Environmental Education Didactics II. By using various teaching techniques and methods a semester plan, which is based on various curricula will be elaborated for a given topic.

Objective
1. The students have planned a curriculum for a semester course.
2. Students reflect on formative and summative ways such a teaching unit to examine and implement parts of it.
3. The students have implemented parts of the semester curriculum.
4. The students deal with the question to what extend teaching techniques, teaching methods but also sequences of self-study must be involved in the planning.

Content
Semester Planning
The students plan on the basis of the given curricula a teaching sequence. The resulting learning process is divided in phases with respect to a reasonable rhythm selecting different teaching methods.

Contents
Self-study
The students deal with various forms of self-study (moderated self-study, learning journal, PBL, case studies, etc.) and their integration in the semester plan. In addition to the formulation and determination of elements for self-study, they consider how they can check their effectiveness.

Tests
The students use adequate various types of examinations. They consider formative and summative ways. For this purpose they formulate test questions and tasks to match the objectives in the curriculum and semester schedule. The use of appropriate literature is required

Literature Study
The mentored assessment requires a specific study of literature which must be cited accordingly.

Lecture notes
A manual gives the students a guideline how to proceed.

Literature
The use of appropriate literature is part of the grading.

Prerequisites / notice
Completion of FD1 and FD2
### 701-0823-00L Environmental Education Didactics I

**Enrolment to Master’s degree studies required. Recognition either for Master’s degree studies or for Teaching Certificate.**

**Abstract**

Environmental Education Didactics supplies the basic concepts for the application of the contents of the lecture Human Learning (EW 1) in environmental education.

On the basis of selected environmental topics didactical theories are used practice-oriented, whereas the appliance of different teaching methods is pointed out. In addition a didactical topic is exercised exemplary in an assignment.

**Objective**

- Application of the principles and topics of educational sciences on environmental contexts.

**Content**

- Berufsfelder, Denkansätze, unsere Orientierung, Möglichkeiten der Umweltlehre, Umsetzungen des Stoffes, Wirkungen auf Zuhörer/-innen, Konfliktmanagement;
- Anwendungen allg. Didaktik z. B. in den Bereichen: Globale Umweltzusammenhänge, Klima, Kreislaufe, Boden als Lebensgrundlage, Abfallwirtschaft, Ökobilanzerzung als Beurteilungsgrundlage, Schadstoffe in der Umwelt, Quellenarbeit, Umwelt und Wirtschaft, Medien und Umfeld, Zukunftsperspektiven

**Lecture notes**

Die Unterlagen zu den behandelten Themen werden über die Polybox abgegeben.

**Literature**

Gemäss Literaturliste, die jeweils in den Lehrveranstaltungen abgegeben wird.

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Subject-specific Competencies</th>
<th>Methodspecific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
</table>

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### 701-0827-00L Teaching Internship Including Examination Lessons

**Environmental Studies**

Prerequisite: successful participation in Mentored Assignment (701-0822-00L).

**Abstract**

Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.

**Objective**

- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils’ work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

**Content**

The students will be able to watch and evaluate the teaching of colleagues and experts. They get profit out of their teaching experiences not only when preparing but also when teaching. Doing so they will be supported by their mentors.

Two lessons of the course will be split off for the examination - procedure.
**Lecture notes**
Dokumente unter
https://www.ethz.ch/de/studium/didaktische-ausbildung/studienangebot-zulassung/didaktik-zertifikat/dokumente--didaktik-zertifikat-.html

- Raster zum Bericht über das Unterrichtspraktikum im DZ Umweltlehre an der ETH Zürich (PDF)
- Beurteilungsbogen Prüfungslektionen Umweltlehre
- Schriftliche Unterrichtsvorbereitung für Prüfungslektionen (PDF)

**Literature**
Wird von der Praktikumslehrperson bestimmt.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<tr>
<td>Techniques and Technologies</td>
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<table>
<thead>
<tr>
<th>Method-specific Competencies</th>
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<tr>
<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<tr>
<td>Problem-solving</td>
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<tr>
<td>Project Management</td>
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<table>
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<tr>
<th>Social Competencies</th>
<th>Communication</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Cooperation and Teamwork</td>
<td>customer Orientation</td>
<td>assessed</td>
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<td>Leadership and Responsibility</td>
<td>self-presentation and Social Influence</td>
<td>fostered</td>
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<tr>
<td>Sensitivity to Diversity</td>
<td>negotiation</td>
<td>fostered</td>
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<table>
<thead>
<tr>
<th>Personal Competencies</th>
<th>adaptability and Flexibility</th>
<th>assessed</th>
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<tr>
<td>creative thinking</td>
<td>critical thinking</td>
<td>assessed</td>
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<tr>
<td>Integrity and Work Ethics</td>
<td>self-awareness and Self-reflection</td>
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<tr>
<td>Self-direction and Self-management</td>
<td>negotiation</td>
<td>fostered</td>
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**Environmental Studies TC - Key for Type**

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<thead>
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<th>Key for Type</th>
<th>E-</th>
<th>W+</th>
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<td>Compulsory</td>
<td>Eligible for credits and recommended</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<td>Z</td>
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**Key for Hours**

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**ECTS**
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Environmental Sciences Bachelor

Basic Courses I

First Year Examinations

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0007-00L</td>
<td>Tackling Environmental Problems I</td>
<td>O</td>
<td>5</td>
<td>4G</td>
<td>M. Mader, C. E. Pohl, C. Rapo</td>
</tr>
<tr>
<td>Abstract</td>
<td>In the case study we analyse a different topic from the field of sustainable development each year and develop solutions to it. Students are able: - carry out research on a given topic and present the results in a structured report which (a) shows the state of knowledge and (b) the need for knowledge and action (UPL I). - to integrate knowledge of diverse perspectives in a qualitative systems model, to identify problems and to suggest possible solutions from a specific stakeholder’s perspective (UPL II). - name the different roles within a group, explain the role(s) they are suited for, self-organise in groups, identify problems of collaboration and constructively address the problems (UPL I and II).</td>
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<tr>
<td>Objective</td>
<td>In the first semester the students compile what is known about the case topic, its principles and challenges. Each group of students makes an inquiry to a given part of the overall problem. The inquiry includes a thematic as well as stakeholder analysis. The results are written in a report and presented at an internal conference. During synthesis week, which takes place during semester break, the results of the different part inquiries are integrated in a qualitative system model. The students identify specific problems and develop solutions. In the second semester, students work independently and in exchange with stakeholders on previously identified problems. They develop a sustainability project with concrete measures that they could implement voluntarily in the third semester. The course concludes with the presentation of the student projects on the public “Market of Measures”. Most of the time students work independently in groups. Tutors support the students in key steps. Introductions are given for: - The overall topic of the case study (by external experts), - Inquiry, scientific writing and managing references (by experts of ETH library), - Role behaviour and collaboration in groups, - Preparing reports, posters and presentations, - Qualitative system modelling (SystemQ), - Developing solutions (design thinking, Checkland’s soft systems methodology, sustainability assessment).</td>
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<tr>
<td>Literature</td>
<td>Tutors will compile the case study dossier on the basis of the student reports of the autumn semester. Methodological documentation will be made available on Moodle during the case study together with the relevant background literature.</td>
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<td>Lecture notes</td>
<td>Slides are provided by instructors and are accessible via moodle.</td>
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</table>

| 701-0027-00L   | Environmental Systems I             | O    | 2    | 2V    | N. Dubois, A. Hall, R. Knutti |
| Abstract       | The lecture provides a science-based exploration of environmental aspects from three research fields: earth, climate, and health sciences. The students are able to explain important properties of the three environmental systems, to discuss critical drivers, trends and conflicts of their use, and to compare potential solutions. |
| Objective      | The lecture discusses the role of the environmental systems based on selected environmental problems, among these the exploration of raw materials and fossil fuels, climate change and its impacts on man and environment, and the spread and control of infectious diseases in the human population and agricultural systems. |
| Content        | Methodological documentation will be made available on Moodle during the case study together with the relevant background literature. |
| Lecture notes  | Tutors will compile the case study dossier on the basis of the student reports of the autumn semester. Methodological documentation will be made available on Moodle during the case study together with the relevant background literature. |
| Competencies   | Subject-specific Competencies: Concepts and Theories assessed Method-specific Competencies: Analytical Competencies assessed Media and Digital Technologies fostered Problem-solving assessed Social Competencies: Communication fostered Personal Competencies: Adaptability and Flexibility fostered Creative Thinking assessed Critical Thinking fostered Integrity and Work Ethics fostered |
| Lecture notes  | Slides are provided by instructors and are accessible via moodle. |

| 701-0029-00L   | Environmental Systems II            | O    | 3    | 2V    | A. Patt, H. Bugmann, N. Gruber |
| Abstract       | The lecture provides a science-based exploration of three important environmental systems: Inland waters, forest, and of food systems. The students are able to explain important functions of the three environmental systems, to discuss critical drivers, trends and conflicts of their use and to compare potential solutions. |
| Objective      | The lecture discusses the role of the environmental systems based on selected environmental problems, among these the exploration of raw materials and fossil fuels, climate change and its impacts on man and environment, and the spread and control of infectious diseases in the human population and agricultural systems. |
| Content        | Aquatic ecosystems and their function, water use and its impact, water pollution and water treatment, water and health, water technologies, water & energy. Forests and agroforest systems, trends and drivers of land use changes, sustainable forest management.  The main functions, trends and challenges of agricultural and food systems are discussed based on the four dimensions of food security (availability, access, utilization of food and stability of the food systems). |
| Lecture notes  | Lecture notes or other documentation are provided by instructors and accessible via moodle. |
| Competencies   | Subject-specific Competencies: Concepts and Theories assessed Method-specific Competencies: Analytical Competencies assessed Media and Digital Technologies fostered Problem-solving assessed Social Competencies: Communication fostered Personal Competencies: Adaptability and Flexibility fostered Creative Thinking assessed Critical Thinking fostered Integrity and Work Ethics fostered |
| Lecture notes  | Slides are provided by instructors and are accessible via moodle. |

| Abstract       | This introductory lecture in ecology covers basic ecological concepts and the most important levels of complexity in ecological research. Ecological concepts are exemplified by using aquatic and terrestrial systems; corresponding methodological approaches are demonstrated. Threats to biodiversity and the appropriate management are discussed. |
| Objective      | The objective of this lecture is to teach basic ecological concepts and the different levels of complexity in ecological research. The students should learn ecological concepts at these different levels in the context of concrete examples from terrestrial and aquatic ecology. Corresponding methods for studying the systems will be presented. A further aim of the lecture is that students achieve an understanding of biodiversity, why it is threatened and how it can be managed. |

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2409 of 2653
- Biodiversity: variation, threats and conservation
- Influence of environmental factors on organisms; adaptation to environmental conditions
- Population dynamics: causes, description, prediction and regulation
- Interactions between species (competition, coexistence, predation, parasitism, food webs)
- Ecological communities: structure, stability, succession
- Ecosystems: compartments, material and energy flows

**Lecture notes**
Documents, lecture slides, exercises and relevant literature are available in Moodle. The documents for the next lecture will be available on Friday morning at the latest.

**Literature**

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

- **Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Problem-solving

- **Social Competencies**
  - Cooperation and Teamwork
  - Sensitivity to Diversity

- **Personal Competencies**
  - Adaptability and Flexibility
  - Critical Thinking
  - Self-awareness and Self-reflection

**401-0251-00L Mathematics I**

<table>
<thead>
<tr>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Authors</th>
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</thead>
<tbody>
<tr>
<td>Mathematics I</td>
<td>6</td>
<td>O</td>
<td>4V+2U</td>
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</table>

**Abstract**
This course covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems - notably through ordinary differential equations.

**Objective**
Mathematics is of ever increasing importance to the Natural Sciences and Engineering. The key is the so-called mathematical modelling cycle, i.e. the translation of problems from outside of mathematics into mathematics, the study of the mathematical problems (often with the help of high level mathematical software packages) and the interpretation of the results in the original environment.

The goal of Mathematics I and II is to provide the mathematical foundations relevant for this paradigm. Differential equations are by far the most important tool for modelling and are therefore a main focus of both of these courses.

**Content**
1. Single-Variable Calculus:
   - review of differentiation, linearisation, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.
2. Linear Algebra and Complex Numbers:
   - systems of linear equations, Gauss-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, complex roots, fundamental theorem of algebra.
3. Ordinary Differential Equations:
   - separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

**Literature**
- Bretscher, O.: Linear Algebra with Applications (Pearson Prentice Hall).

**Prerequisites / notice**
Prerequisites: familiarity with the basic notions from Calculus, in particular those of function and derivative.

**529-2001-02L Chemistry I**

<table>
<thead>
<tr>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Authors</th>
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<tbody>
<tr>
<td>Chemistry I</td>
<td>4</td>
<td>O</td>
<td>2V+2U</td>
</tr>
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</table>

**Abstract**
General Chemistry I: Chemical bond and molecular structure, chemical thermodynamics, chemical equilibrium.

In the course "Chemistry I", the competencies of process understanding, system understanding, modeling, concept development and data analysis & interpretation are taught, applied and examined.

**Objective**
Introduction to general and inorganic chemistry. Basics of the composition and the change of the material world. Introduction to the thermodynamically controlled physico-chemical processes. Macroscopic phenomena and their explanation through atomic and molecular properties. Using the theories to solve qualitatively and quantitatively chemical and ecologically relevant problems.

**Content**
1. Stoichiometry
   - Amount of substance and mass. Composition of chemical compounds. Reaction equation. Ideal gas law.
2. Atoms
4. Basics of chemical thermodynamics
   - System and surroundings. Description of state and change of state of chemical systems.
5. First law of thermodynamics
6. Second law of thermodynamics
   - Entropy. Change of entropy in chemical systems and universe. Reaction entropy.
7. Gibbs energy and chemical potential.
8. Chemical equilibrium
9. Acids and bases
10. Dissolution and precipitation.
    - Heterogeneous equilibrium. Dissolution and solubility product. Carbon dioxide-carbonic acid-carbonate equilibrium.

**Lecture notes**
Online-Skript mit durchgerechneten Beispielen.
Weiterführende Literatur:

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

551-0001-00L General Biology I

Abstract
Organismic biology to teach the basic principles of classical and molecular genetics, evolutionary biology and phylogeny.
First in a series of two lectures given over two semesters for students of agricultural and food sciences, as well as of environmental sciences.

Objective
The understanding of some basic principles of biology (inheritance, evolution and phylogeny) and an overview of the diversity of life.

Content
The first semester focuses on the organismal biology aspects of genetics, evolution and diversity of life in the Campbell chapters 12-34.

Week 1-7 by Alex Widmer, Chapters 12-25
12 Cell biology Mitosis
13 Genetics Sexual life cycles and meiosis
14 Genetics Mendelian genetics
15 Genetics Linkage and chromosomes
20 Genetics Evolution of genomes
21 Evolution How evolution works
22 Evolution Phylogenetic reconstructions
23 Evolution Microevolution
24 Evolution Species and speciation
25 Evolution Macroevolution

Week 8-14 by Oliver Martin, Chapters 26-34
26 Diversity of Life Introduction to viruses
27 Diversity of Life Prokaryotes
28 Diversity of Life Origin & evolution of eukaryotes
29 Diversity of Life Nonvascular&seedless vascular plants
30 Diversity of Life Seed plants
31 Diversity of Life Introduction to fungi
32 Diversity of Life Overview of animal diversity
33 Diversity of Life Introduction to invertebrates
34 Diversity of Life Origin & evolution of vertebrates

Lecture notes
no script

Literature

Prerequisites /

notice
The lecture is the first in a series of two lectures given over two semesters for students with biology as a basic subject.

Additional First Year Compulsory Courses

Number Title Type ECTS Hours Lecturers
252-0839-00L Informatics O 2 credits 2G M. Dahinden, L. E. Fässler

Abstract
Students learn to apply selected concepts and tools from computer science for working on interdisciplinary projects. The following topics are covered: modeling and simulations, managing data with lists, tables and relational databases, introduction to programming.

Objective
The students learn to:
- choose and apply appropriate tools from computer science,
- process and analyze real-world data from their subject of study,
- handle the complexity of real-world data,
- query databases and understand and evaluate the corresponding database model,
- encode a problem into a program, test the program, and correct errors,
- implement models from the natural sciences as a simulation.

Content
1. Modeling and simulations
2. Data management with lists and tables
3. Data management with a relational database
4. Introduction to programming with Python 1 (variables & data types)
5. Introduction to programming with Python 2 (control structures & logic)
6. Introduction to programming with Python 3 (sequential data structures)

Lecture notes
All materials for the lecture are available at www.evim.ethz.ch

Literature

Prerequisites /

notice
This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

This practical course provides an introduction to elementary laboratory techniques, and the experiments cover a wide range of analytic and synthetic tasks:

- Selected samples (e.g. soil and water) will be analysed with various methods, such as titrations, spectrophotometry or ion chromatography. The chemistry of aqueous solutions (acid-base equilibria and solvation or precipitation processes) is studied.
- The synthesis of simple inorganic complexes or organic molecules is practised.
- Special features of plant cells: Plastids, vacuole, cell wall. Anatomy and function of various plant tissues (epidermis, vascular tissue, wood, etc.). Anatomy and function of different plant organs (root, stem, leaf, flower, fruit, seed).
- Measuring object sizes with the microscope. Preparation of specimen for light microscopy. Plant tissue staining techniques.
- Awareness of the link between plant anatomy, systematics, physiology, ecology, and development.
- Special features of plant cells: Plastids, vacuole, cell wall. Anatomy and function of various plant tissues (epidermis, vascular tissue, wood, etc.). Anatomy and function of different plant organs (root, stem, leaf, flower, fruit, seed).
- Measuring object sizes with the microscope. Preparation of specimen for light microscopy. Plant tissue staining techniques.

Furthermore, the description and recording of laboratory processes is an essential part of this course.

Literature

- A thorough study of all script materials is requested before the course starts.

Lecture notes

- The instructions to the experiments will be published on Moodle.

Competencies

- Subject-specific Competencies: Concepts and Theories fostered
- Method-specific Competencies: Analytical Competencies fostered
- Social Competencies: Communication fostered
- Personal Competencies: Adaptability and Flexibility fostered

529-0030-00L Laboratory Course: Elementary Chemical Techniques

Abstract

This practical course provides an introduction to elementary laboratory techniques. The experiments cover a wide range of techniques, including analytical and synthetic techniques (e.g. investigation of soil and water samples or the preparation of simple compounds). Furthermore, the handling of gaseous substances is practised.

Objective

This course is intended to provide an overview of experimental chemical methods. The handling of chemicals and proper laboratory techniques represent the main learning targets. Furthermore, the description and recording of laboratory processes is an essential part of this course.

Content

The classification and analysis of natural and artificial compounds is a key subject of this course. It provides an introduction to elementary laboratory techniques, and the experiments cover a wide range of analytic and synthetic tasks:

- Selected samples (e.g. soil and water) will be analysed with various methods, such as titrations, spectrophotometry or ion chromatography. The chemistry of aqueous solutions (acid-base equilibria and solvation or precipitation processes) is studied.
- The synthesis of simple inorganic complexes or organic molecules is practised.
- Special features of plant cells: Plastids, vacuole, cell wall. Anatomy and function of various plant tissues (epidermis, vascular tissue, wood, etc.). Anatomy and function of different plant organs (root, stem, leaf, flower, fruit, seed).
- Measuring object sizes with the microscope. Preparation of specimen for light microscopy. Plant tissue staining techniques.
- Awareness of the link between plant anatomy, systematics, physiology, ecology, and development.

Furthermore, the description and recording of laboratory processes is an essential part of this course.

Literature

- A thorough study of all script materials is requested before the course starts.

Lecture notes

- The instructions to the experiments will be published on Moodle.

Competencies

- Subject-specific Competencies: Concepts and Theories fostered
- Method-specific Competencies: Analytical Competencies fostered
- Social Competencies: Communication fostered
- Personal Competencies: Adaptability and Flexibility fostered

751-0801-00L Fundamentals of Microscopy and Plant Biology

Abstract


Objective

- Capability of preparing biological specimen, microscopy and documentation. Understanding the correlation between plant structure and function at the level of organs, tissues and cells.
- Awareness of the link between plant anatomy, systematics, physiology, ecology, and development.

Content

- Special features of plant cells: Plastids, vacuole, cell wall. Anatomy of seed plants: From cells to organs. Anatomy and function of various plant tissues (epidermis, vascular tissue, wood, etc.). Anatomy and function of different plant organs (root, stem, leaf, flower, fruit, seed).
- Anatomical adaptations to different environments.

Furthermore, the description and recording of laboratory processes is an essential part of this course.

Literature

- For further reading (not obligatory):
  - Gerhard Wanner: Mikroskopisch-Botanisches Praktikum, Georg Thieme Verlag, Stuttgart.

Lecture notes

- Online in Moodle Course

Prerequisites / notice

- Groups of a maximum of 20 students.

Competencies

- Subject-specific Competencies: Concepts and Theories fostered
- Method-specific Competencies: Analytical Competencies fostered
- Social Competencies: Communication fostered
- Personal Competencies: Adaptability and Flexibility fostered

Basic Courses II

Examination Blocks

Examination Block 1

Number Title Type ECTS Hours Lecturers

402-0063-00L Physics II O 5 credits 3V+1U A. Vaterlaus

Abstract

Introduction to the way physicists think and work with the help of concept questions, demonstration experiments and problem solving. Wherever possible, applications from thermodynamics, electricity and magnetism are taught from the areas of the degree programmes.

Objective

Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve them.

Content

- Thermodynamics with first and second law, phase transformations, transport phenomena. Introduction to electricity and magnetism, as well as waves and modern physics.

Lecture notes

- A script will be distributed

Literature

- Friedhelm Kuypers
  - Physik für Ingenieure und Naturwissenschaftler
  - Band 2 Elektrizität, Optik, Wellen
  - Wiley-VCH, 2012
  - ISBN 3527411445, 9783527411443
  - (4. Auflage 2022)
Mathematics IV: Statistics

Objective
Teaching of basic knowledge in microbiology.

Content
- to explain the physical structure and chemical composition of the atmosphere
- to quantitatively describe and understand the fundamental physical and chemical process in the atmosphere
- to explain the interactions and feedbacks between atmosphere - ocean - land surface, troposphere - stratosphere and weather - climate.

In the course "Atmosphere", the competencies of process understanding, system understanding and data analysis & interpretation are taught, applied and examined.

Literature

Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Method-specific Competencies
  - Analytical Competencies: fostered
  - Decision-making: fostered
  - Problem-solving: assessed
- Personal Competencies
  - Communication: fostered
  - Self-direction and Self-management: fostered

LECTURERS
E. Fischer, U. Lohmann

ECTS
3

Lectures
2V

Prerequisites / notice

Voraussetzungen: Mathematik I, II

Examination Block 2

Mathematics III: Systems Analysis

Objective
The objective of the systems analysis course is to deepen and illustrate the mathematical concepts on the basis of a series of very concrete examples. Topics covered include: linear box models with one or several variables, non-linear box models with one or several variables, time-discrete models, and continuous models in time and space.

Content
- to explain the physical structure and chemical composition of the atmosphere
- to quantitatively describe and understand the fundamental physical and chemical process in the atmosphere
- to explain the interactions and feedbacks between atmosphere - ocean - land surface, troposphere - stratosphere and weather - climate.

In the course "Atmosphere", the competencies of process understanding, system understanding and data analysis & interpretation are taught, applied and examined.

Literature

Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Problem-solving: assessed
- Personal Competencies
  - Creative Thinking: fostered
  - Critical Thinking: fostered

LECTURERS
C. Brunner, R. Knutti, H. Wernli

ECTS
4

Lectures
2+1U

Prerequisites / notice

Voraussetzungen: Mathematik I, II
### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Sensitivity to Diversity: fostered

**Personal Competencies**
- Creative Thinking: fostered
- Critical Thinking: fostered
- Self-awareness and Self-reflection: fostered

### Pedosphere

**701-0501-00L**

**Title:** Pedosphere

**ECTS:** 3

**Hours:** 2V

**Lecturers:** R. Kretzschmar

**Abstract**

Introduction to the formation and properties of soils as a function of parent rock, landscape position, climate, and soil organisms. Complex relationships between soil forming processes, physical and chemical soil properties, soil biota, and ecological soil properties are explained and illustrated by numerous examples.

**Objective**

Understanding of soils as integral parts of ecosystems, development and distribution of soils as a function of environmental factors, and processes leading to soil degradation.

**Content**

Definition of the pedosphere, soil functions, rocks as parent materials, minerals and weathering, soil organisms, soil organic matter, soil formation, principles of soil classification, global soil regions, physical soil properties and functions, chemical soil properties and functions, soil fertility, land use and soil degradation.

**Lecture notes**

Polybook

**Literature**


**Prerequisites / notice**

Prerequisites: Basic knowledge in chemistry, biology and geology.

### Additional Compulsory Courses

**Number**

<table>
<thead>
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<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>701-0501-00L</td>
<td>Laboratory Course in Physics for Students of Environmental Sciences</td>
<td>O</td>
<td>2 credits</td>
<td>M. Münnich, A. Biland, A. Eggenberger, N. Gruber</td>
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</table>

**Abstract**

Learning with the basic principles of scientific experimentation. By performing experiments in different fields of experimental physics the students will learn the usage of measurement instruments as well as the correct analysis and the estimation of the accuracy of the measurement results.

**Objective**

Working in a laboratory forms an important part of modern scientific education. Using simple experimental setup the laboratory course will provide basic knowledge of:

- the setup of experiments,
- various measurement techniques,
- the use of various measurement instruments,
- the correct performance of experiments,
- the analysis of the accuracy of the measurements,
- and the interpretations of the measured quantities.

The course will also deepen the knowledge of experimental physics.

In addition to experiments selected from the physics lab for physicists, this lab course offers experiments specially developed for bachelor students in environmental sciences, which illustrate the mutual relationships between physical processes and chemical and biological phenomena.

**Content**

The students select 3 out of 18 offered experiments that they want to conduct. After conducting these experiments, the students document and analyze their measurements, estimate the accuracy of their results, and compare them with the values expected according to the laws of physics. Introductory lectures with exercises in Jupyter Notebooks as evaluation tools and in determining the accuracy of measurement results ("error calculation"), as well as a preliminary experiment for practicing experiment evaluation, complement the practical.

**Lecture notes**

Manuals for the experiments and Jupyter Notebook templates are provided online on the Moodle course pages.

**Competencies**

**Subject-specific Competencies**
- Concepts and Theories: fostered
- Techniques and Technologies: fostered

**Method-specific Competencies**
- Analytical Competencies: fostered
- Media and Digital Technologies: fostered
- Problem-solving: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-direction and Self-management: fostered

### Social Sciences and Humanities

**Compulsory**

**Number**

<table>
<thead>
<tr>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2414 of 2653
Analyzing Arguments in Science and Ethics

**Abstract**

Problems of the environment and sustainable development are complex from a scientific as well as from an ethical point of view. Addressing them requires the ability to deal with arguments. This course provides basic knowledge and methods for reconstructing, analysing and evaluating arguments. We exercise and improve these abilities by using examples from science, ethics and political debates.

**Objective**

Students acquire basic knowledge and methods for analyzing arguments. They are able to apply these methods to complex arguments concerning scientific and ethical questions about the environment and sustainable development, and to construct themselves arguments and apply them successfully. Moreover, they are able to evaluate the contribution of arguments to controversial debates with the help of rules. Students acquire thereby a crucial skill for Critical Thinking, which aims at responsible argumentation, communication and action.

**Content**

In the sciences as well as in public discussions or in our everyday life, we try to convince others or to achieve consent in matters of disagreement. We do this with the help of arguments. But what are the criteria for arguments to be convincing and for claims to be clear? And how do we expediently feed arguments into a debate? How can we identify and avoid fallacies in reasoning? How do we analyse and define concepts? This course provides basic knowledge of conceptual analysis and argumentation theory as well as methods for identifying, reconstructing and evaluating claims and arguments. Its focus is on systematically addressing the following two questions: What do you mean? How do you know? The first question aims at a better understanding of the claim in question, the second at assessing the reasons that support or undermine the claim. We exercise and improve the abilities to address these questions by using texts on scientific and ethical questions concerning the environment and sustainable development. The course provides thus crucial skills for Critical Thinking, which aims at responsible argumentation, communication and action.

**Lecture notes**

Handouts will be available.

**Literature**


**Prerequisites / notice**

This is a compulsory course in the social sciences and humanities in the second year of the BA Environmental sciences. For 2 ECTS-credits, all written tasks that are distributed during the course need to be solved.

Environmental Policy of Switzerland

**Abstract**

This course presents the basics of public policy analysis and the specific characteristics of Swiss environmental policy. Policy instruments, actors and processes are addressed from a political science perspective both theoretically as well as by means of current Swiss environmental policy examples.

**Objective**

Beyond acquiring basic knowledge about public policy analysis, this course teaches students how to analytically address current and concrete questions of environmental policy. Through exercises the students learn about political science concepts and frameworks as well as real-life political decision-making processes. The well-grounded examination of complex political conflict situations is an important precondition for the entry into the (environmental policy) workforce or a future research career.

**Content**

The processes of change, overuse or destruction of the natural environment through humans have historically placed high demands on social and political institutions. In the interplay between the environment, society and economy, the environmental policy field encompasses the sum of public measures that have the goal to eliminate, reduce or avoid environmental degradation. The course systematically presents the basics of environmental policy instruments, actors, programs and processes as well as their change over time. Invited practitioners will provide us with insight regarding the current developments in forest, water and spatial planning policies. A key aspect is the distinction between politics and political science and specifically environmental policy.

**Lecture notes**

The reader and additional lecture material and exercises will be posted on Moodle.

**Literature**

Reader and additional lecture material on moodle.

**Prerequisites / notice**

The detailed semester program (syllabus) is made available to the students at the beginning of the semester. During the lecture we will work with Moodle and edukapp. We ask that all students register themselves on these platforms before the lecture and to bring a laptop, tablet or smartphone to class, so that you can complete exercises using Moodle and edukapp.

**Competencies**

- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies
- Social Competencies: Sensitivity to Diversity
- Personal Competencies: Critical Thinking

**Economics**

Not for students belonging to D-MTEC!

**Abstract**

This course introduces basic economic concepts and theories. Beginning with microeconomics, the course starts with the topics of supply and demand, markets, and behavioral economics before moving on to the key macroeconomic concepts of national accounts, the labor market, trade, and monetary policy.

**Objective**

After successful completion of the course you will be able to:

- Describe the basic micro- and macroeconomic problems and theories.
- Introduce economic reasoning appropriately to a given topic.
- Evaluate economic measures.

**Content**

Households, firms, supply and demand: How are household preferences and consumption patterns formed? How does a household react to price changes? How are goods prices formed? At what prices are companies willing to offer goods? How do we make economic decisions?

Markets: What is "perfect competition" and how does a competitive market work? Are monopolies always a bad thing? How can the state influence the market?

Market failure: What happens when prices give wrong signals?

Labour market: How do supply and demand work in the labour market? What influences unemployment?

National accounts: How big is the Swiss economy?

Foreign trade: Why do countries trade with each other? What are the consequences for the domestic market?

Money and inflation: What exactly is money? How does money creation work and what happens when there is too much (or too little) money on the market?

Students will be asked to apply these concepts to issues in their own field of study and to current issues in society. This goal will be achieved through participation in exercises, class discussions and reading material from current media. By the end of the course, students should be able to apply economic analysis confidently and independently.
Environmental Law

851-0738-04L

Hours: 2V
ECTS: 2 credits
Lecturers: B. Schibli

Students who have attended and passed the course unit 851-0741-00L in the spring semester may not attend this course unit (851-0738-04L) again and can't credited it.

Abstract
Environmental law regulates the protection of human beings and their environment, such as animals, plants, habitats, soil, waters and air. It plays an increasing role in relation to public and private projects. The lecture gives an overall view of Swiss environmental law. Specific subjects will be dealt with in more detail based on case studies and group work.

Objective
- The students are able:
  - to apply environmental law in a specific case.
  - to explain in which cases the basic principles and the particular instruments of environmental law apply.
  - to identify the shortcomings of environmental law and the legislative needs in this regard.
  - to describe the tasks and competencies of environmental scientists compared to those of lawyers.

Electives

Social Sciences

701-0709-00L

Political Geography (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: 07SMGEO423

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

Abstract
This module explores the relationship between politics, space, power, and the environment. Political processes today take shape in a complex geographic context; at the same time, they also impact geography, actively writing space itself. This module brings those dynamics to the fore and locates them both in blatantly politicized sites.

Objective
- Become familiar with key thinkers, concepts, theories, and illustrative case studies in political geography and apply key geography concepts to a particular case.
- Situate contemporary political events within global power relations, and political histories of colonialism, imperialism, and gendered violence.
- Cultivate critical, decolonial, and feminist approaches to research, policy, and practice. By critical, we encourage students to question how ‘problems’ are framed rather than start with a ‘problem-solving’ mindset.
- Distinguish scientific, peer-reviewed and research-based knowledge from popular media and disinformation.
- Learn methodological skills necessary for academic research, encompassing considerations of ethics and power relations in the research process.
- Writing skills: write thoroughly researched and concise texts that analyze a case study using geographical concepts and adequate references to the scientific literature.
- Creative communication and Speaking Skills: Use the classroom as a safe space for dialogue and testing ideas respectfully, and apply artistic/creative forms for communicating research (blogs, essays, podcasts, photography, film etc.)

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Objective

Students are able to
- describe the areas, concepts, theories, methods and findings of psychology.
- differentiate scientific psychology from "everyday" psychology.
- structure the conclusions and significance of an experiment according to a theory of psychology.
- formulate a problem for psychological investigation.
- apply basic forms of psychological experiment.

Content

Einführung in die psychologische Forschung und Modellbildung unter besonderer Berücksichtigung der kognitiven Psychologie und des psychologischen Experiments. Themen sind u.a.: Wahrnehmung; Lernen und Entwicklung; Denken und Problemlösen; Kognitive Sozialpsychologie; Risiko und Entscheidung.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Customer Orientation assessed
Leadership and Responsibility assessed
Self-presentation and Social Influence assessed
Sensitivity to Diversity assessed
Negotiation assessed

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

Abstract

Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior.

Objective

Students will be able to,
- explain the decision-making processes underlying the purchasing process
- describe the factors that have an influence on consumer behavior
- develop strategies to influence purchasing behavior

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Social Competencies
Cooperation and Teamwork fostered
Customer Orientation assessed
Sensitivity to Diversity assessed

Personal Competencies
Creative Thinking assessed

Abstract

This course deals with basic questions, concepts, theories, methods, and empirical findings of political science.

Objective

This course deals with basic questions, concepts, theories, methods, and empirical findings of political science.
Communication assessed

This course analyzes the foundations and challenges of Swiss foreign policy. After reviewing the history of foreign policy conceptions since
fostered

Der Kurs basiert auf dem Lehrbuch «Einführung in die Politikwissenschaft», 5. Auflage (2022), von Bernauer, Jahn, Kritzinger, Kuhn,
Walter. Jede Kurseinheit konzentriert sich auf ein bis zwei Kapitel dieses Buches.

The 5. Auflage dieses Lehrbuches ist via Buchhandlungen oder online erhältlich. Übungsfragen und ein Glossar finden Sie hier:
https://ib.ethz.ch/teaching/pwgrundlagen.html

Vor der Sitzung:
1. Alle Kursteilnehmenden lesen vor jeder Kurseinheit das/die betreffenden Buchkapitel (siehe Tabelle unten). Lesen Sie zuerst die
Übungsfragen für das zu studierende Buchkapitel (https://ib.ethz.ch/teaching/pwgrundlagen.html) und erst danach das Kapitel. Sie wissen
danach beim Lesen schon vorweg, auf was Sie besonders genau schauen sollten. Pro Kurseinheit (Woche) sind ca. 30–50 Seiten zu lesen.

Die 5. Auflage dieses Lehrbuches ist via Buchhandlungen oder online erhältlich. Übungsfragen und ein Glossar finden Sie hier:
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2. Teil:
Wir behandeln Übungsfragen, die per Umfrage als besonders schwierig identifiziert wurden.

Der Kurs besteht aus
- einem ersten Teil, der jeweils am Montag, ab 25. September 2023, wöchentlich bis und mit 18. Dezember 2023, 10:15-12:00, vor Ort
auf dem Campus stattfindet (LEE E 101, Leonhardstrasse 21)
- einem zweiten Teil, der jeweils am Montag, ab 25. September 2023, wöchentlich bis und mit 18. Dezember 2023, 12:15-13:00, vor Ort
auf dem Campus stattfindet (LEE E 101, Leonhardstrasse 21)

Der Kurs basiert auf dem Lehrbuch «Einführung in die Politikwissenschaft», 5. Auflage (2022), von Bernauer, Jahn, Kritzinger, Kuhn,
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2. Teil:
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Der Ablauf der Sitzungen ist dann meist wie folgt:
1. Teil:
1. Zu Beginn wird jeweils (in digitaler Form) ein unbekannter Kurztest zum gelesenen Buchinhalt durchgeführt (mehr dazu weiter unten)
und im Anschluss gleich besprochen.
2. Es folgt eine ca. 30-minütige Vorlesung, die den Inhalt des/der gelesenen Buchkapitel kurz zusammenfasst und reflektiert.
3. Danach stellen die Dozierenden eine aktuelle wissenschaftliche Studie vor, die im Bereich des/der jeweils behandelten Themen
liegt (ca. 30 Minuten).

2. Teil:
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853-0038-00L
Swiss Foreign Policy

Content

This course analyzes the foundations and challenges of Swiss foreign policy. After reviewing the history of foreign policy conceptions since
fostered

The course will be supported by an e-learning environment.
This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined. This course will take place on campus (ETH Main Building, HG F.3). There will be no live-streaming, and the course is NOT in hybrid (on-campus plus online) format. However, the lecture will be recorded and the recordings will be made available via the Moodle platform for this course a few days after the respective lecture for students who are unable to attend in person. All electronic correspondence will take place via the ETH mystudies system and Moodle, so please make sure you are properly registered there with a functioning email address/account.

Lecturers

B. Clarysse

Lectures

Reading materials and slides will be available via Moodle.

Literature

Reading materials and slides will be available via Moodle.

Prerequisites / notice

Access / Prerequisites

The course is open to all ETH students and visiting students from other universities. Participation does not require previous coursework in the social sciences or environmental policy. The course will take place on campus (ETH Main Building, HG F.3). There will be no live-streaming, and the course is NOT in hybrid (on-campus plus online) format. However, the lecture will be recorded and the recordings will be made available via the Moodle platform for this course a few days after the respective lecture for students who are unable to attend in person. All electronic correspondence will take place via the ETH mystudies system and Moodle, so please make sure you are properly registered there with a functioning email address/account.

Credits and Exam

After passing a written test at the end of the course (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test). Visiting students (e.g., from the University of Zurich, exchange students) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory. Students who obtain a grade of < 4.0 for the test will have a second chance (see table below). Students who did not participate in the test on 18 December 2023 will not have access to the repeat test unless they submit compelling and documented (e.g. medical, other exam in parallel at ETH) reasons for why they were unable to participate in the first test. It covers all contents of the lectures and the reading assignments. Visiting students (e.g., from the University of Zurich or other universities) are subject to the same conditions. Registration for the course in the mystudies system of ETH is compulsory. No separate registration for the exam is required, registration for the course as such covers everything. The exam will take place on campus, either in the F3 lecture hall or in a computer room. That is, you must be present in person at ETH Zurich on the exam date/time.

Students who obtain a grade of < 4.0 for the test will have a second chance. Students who did not participate in the test on 18 December 2023 will not have access to the repeat test unless they submit compelling and documented reasons for why they were unable to participate in the first test. It covers all contents of the lectures and the reading assignments. Visiting students (e.g., from the University of Zurich or other universities) are subject to the same conditions. Registration for the course in the mystudies system of ETH is compulsory. No separate registration for the exam is required, registration for the course as such covers everything. The exam will take place on campus, either in the F3 lecture hall or in a computer room. That is, you must be present in person at ETH Zurich on the exam date/time.

### Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0786-00L</td>
<td>Mediation in Environmental Planning: Theory and Case Studies</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>K. Siegwart</td>
</tr>
</tbody>
</table>

**Objective**

- Develop comprehension of legal and social responses to environmental conflicts
- Recognize the most important participative techniques and their ranges
- Develop concepts for doing and evaluating mediation processes
- Estimate the potential and limitations of cooperative environmental planning
- Train communicative skills (presentation, moderation, discussion design, negotiation), especially by participating at a mediation

**Content**

To this end, we will look at the most important techniques of mediation and put them into the context of today's legislation, participation and conflict culture. The potential and limitations of the individual techniques will be discussed using current Swiss and international case studies, namely in the field of windenergy as well as landfills and Human-Wildlife Conflict and Coexistence (wolves, bears, elephants). Students can do conflict analyses, for instance, as part of individual and group analyses and a half-day mediation-simulation, develop technique concepts and train their own communicative and negotiation skills.

**Lecture notes**

A reader will be handed out.

**Competencies**

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<td>Sensitivity to Diversity</td>
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<tr>
<td>Problem-solving</td>
<td>Negotiation</td>
<td>Cognitive Skills</td>
<td>Self-presentation and Social Influence</td>
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**351-0778-00L**

**Discovering Management**

*Does not take place this semester.*

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<td>351-0778-00L</td>
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<td>W</td>
<td>3</td>
<td>3G</td>
<td>B. Clarysse, S. Brunori, V. Hoffmann, T. Netland</td>
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</tbody>
</table>

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Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2419 of 2653
Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

**Abstract**

Discovering Management consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. The theory sessions will be assessed via a multiple choice exam.

**Objective**

The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
1. broaden understanding of management principles and frameworks
2. advance insights into the sources of corporate and entrepreneurial success
3. develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

**Content**

The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

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Through small group work, you will develop analyses of each of the cases. The theory sessions will be assessed via a multiple choice exam.

**Lecture notes**

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

**Competencies**

<table>
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<td>Problem-solving</td>
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<td>Social Influence</td>
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<td>Self-direction and Self-management</td>
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</tbody>
</table>

**351-0778-01L Discovering Management (Pitch)**

*Does not take place this semester.*

Complementary exercises for the module Discovering Management.

Prerequisite: Participation and successful completion of the module Discovering Management (351-0778-00L) is mandatory.

**Abstract**

This course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

**Objective**

The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.

**Content**

The exercise consists of delivering and submitting a "pitch" with a clear recommendation for one of the selected cases amongst those seen in Discovering Management, using your insights from Discovering Management, and an extra session on pitching.

Students have the option to either do this alone or in a group of two students.

**Literature**

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle.

**Competencies**

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</table>

**363-0387-00L Corporate Sustainability**

*Does not take place this semester.*

The lecture explores current challenges of corporate sustainability and prepares students to become champions for sustainable business practices. The module combines asynchronous videos, live sessions, with a group work phase between weeks 5-10 of semester during which students deep-dive into one of 10 sustainability challenges.

**Abstract**

The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. The theory sessions will be assessed via a multiple choice exam.

**Lecture notes**

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

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</tbody>
</table>
### Concepts and Theories

**Objective**

- Students foster the development of analytical competencies in students.
- Analytical Competencies are fostered in students.

**Content**

Corporative Sustainability is a flagship course in the Group for Sustainability and Technology at D-MTEC. In this course, students learn about key concepts in corporate sustainability and develop skills to implement them in the real world. The course prepares students for making well-informed sustainability decisions in their future careers.

The course uses constructive alignment to bring the various innovative teaching and learning elements (e.g., case-based experiential learning, reflective thinking and blended learning with videos and quizzes) into a coherent transformational journey. Students can now flexibly, efficiently, and effectively acquire the conceptual foundations that are essential for a substantial understanding of corporate sustainability.

http://www.sustec.ethz.ch/teaching/lectures/corporate-sustainability.html

<table>
<thead>
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<tr>
<td>351-1109-00L</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Wörter, M. Beck</td>
</tr>
</tbody>
</table>

### Startups and Law

**Number**

851-0735-10L

**Title**

Startups and Law

**Objective**

- Students acquire a deeper understanding of basic microeconomic models.

**Abstract**

The students shall obtain a basic knowledge about the legal environment of entrepreneurs. They shall be able to recognize and evaluate legal issues connected to an entrepreneurial activity and suggest possible solutions.

**Method-specific Competencies**

- Concepts and Theories
- Analytical Competencies
- Decision-making
- Problem-solving

**Social Competencies**

- Communication
- Cooperation and Teamwork
- Negotiation

**Personal Competencies**

- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection

### Economics

**Number**

351-1109-00L

**Title**

Introduction to Microeconomics

**Objective**

- Students acquire a reflective and contextual knowledge on how societies use scarce resources to produce goods and services and distribute them among themselves.

**Content**

Market, budget constraint, preferences, utility function, utility maximisation, demand, technology, profit function, cost minimisation, cost functions, perfect competition, information and communication technologies

**Lecture notes**

Course material in e-learning environment https://moodle.app2.let.ethz.ch/auth/shibboleth/login.php

**Literature**


**Prerequisites / notice**

This course "Einführung in die Mikroökonomie" (363-1109-00L) is intended for Bachelor students and LE 363-0503-00 "Principles of Microeconomics" for Master students.
### Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Techniques and Technologies</td>
<td>Communication</td>
<td>Adaptable and Flexibility</td>
</tr>
<tr>
<td>Analytical Competencies</td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
<td>Creative Thinking</td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>Problem-solving</td>
<td>Customer Orientation</td>
<td>Critical Thinking</td>
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<tr>
<td>Project Management</td>
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<td>Leadership and Responsibility</td>
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<td>Sensitivity to Diversity</td>
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<td></td>
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<td>Negotiation</td>
<td></td>
</tr>
</tbody>
</table>

### Literature

- A. Miftakhova, P. Peyrot
- 851-0735-10L: Startups and Law
- 851-0526-01L: International Development Cooperation
- 363-0537-00L: Resource and Environmental Economics

### Data: 15.06.2024 12:39

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## Highly recommended Natural Science and Technical Electives

### For the Specialization in Atmosphere and Climate

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0479-00L</td>
<td>Environmental Fluid Dynamics</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>H. Wernli, L. Papritz</td>
</tr>
</tbody>
</table>

**Abstract**
This course covers the basic physical concepts and mathematical equations used to describe environmental fluid systems on the rotating Earth. Fundamental concepts (e.g. vorticity dynamics and waves) are formally introduced, applied quantitatively and illustrated using examples. Exercises help to deepen knowledge of the material.

**Objective**
- to name the basics, concepts and methods of environmental fluid dynamics.
- to understand and discuss the components of the basic physical equations
- to mathematically solve basic equations for simple problems of environmental fluid dynamics.

**Content**
- Basic physical terminology and mathematical laws:
- Continuum hypothesis, forces, constitutive laws, state equations and basic principles of thermodynamics, kinematics, laws of mass and momentum on rotating earth.
- Concepts and illustrative flow systems: vorticity dynamics, boundary layers, instability, turbulence - with respect to environmental fluid systems.
- Scale analysis: dimensionless variables and dynamical similarity, simplification of the fluid system, e.g. shallow water assumption, geostrophic flow.
- Waves in environmental fluid systems.

**Lecture notes**
In english language

**Literature**
Will be presented in class.
See also: web-site.

### For the Specialization in Biogeochemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0225-00L</td>
<td>Organic Chemistry</td>
<td>W</td>
<td>2</td>
<td>2V+1U</td>
<td>K. McNeill</td>
</tr>
</tbody>
</table>

**Abstract**
Basics of Organic Chemistry.
Reaction mechanisms in organic chemistry: substitutions, additions, eliminations, condensations, rearrangements, electrophilic aromatic substitution

**Objective**
- Students will be able to:
  - Recall basic organic chemistry reactions, including substitution, elimination and addition reactions occurring at sp2- and sp3-hybridized carbon centers.
  - Explain the relative favorability of certain organic chemical structures or certain organic chemical reactions.
  - Apply their understanding of reaction mechanism principles to explain observations.
  - Differentiate the most reactive sites in a given organic chemical.
  - Propose reaction mechanisms to new chemical transformations.

**Content**
- Descriptive chemistry of functional groups (alkyl halides, aikenes, aromatic systems, carbyonls).
- Reaction mechanisms (substitutions, additions, eliminations, condensations, electrophilic aromatic substitution).

**Literature**
Carsten Schmuck, Basisbuch Organische Chemie, Pearson
Der Stoff der Basischemie wird vorausgesetzt.

**Prerequisites / notice**

### For the Specialization in Biogeochemistry

<table>
<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tr>
<td>752-0100-00L</td>
<td>Biochemistry</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>C. Frei</td>
</tr>
</tbody>
</table>

**Abstract**
Basic knowledge of enzymology, in particular the structure, kinetics and chemistry of enzyme-catalysed reaction in vitro and in vivo. Biochemistry of metabolism: Those completing the course are able to describe and understand fundamental cellular metabolic processes.

**Objective**
- Students are able to describe the structure of proteins/enzymes and are able to explain biochemical functions depending on their 3D structures.
- Students are able to assess and propose hypothesis how proteins change during evolution.
- Connections between several metabolic pathways are known and students can evaluate how one pathway is influence by the activity of another pathway.
Content

Program
- Introduction, basics, composition of cells, biochemical units, repetition of relevant organic chemistry
- Structure and function of proteins
- Enzymes and enzyme kinetics
- Catalytic strategies
- Metabolism: Basic concepts and design. Repetition of basic thermodynamics
- Glycolysis, fermentation
- The citric acid cycle
- Oxidative phosphorylation and ATP physiology

Lecture notes
- Horton et al. (Pearson) serves as lecture notes.

Prerequisites / notice
- Basic knowledge in biology and chemistry is a prerequisite.

 Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: assessed
- Problem-solving: assessed

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered

►► For the Specialization in Human-Environment Systems

Number Title Type ECTS Hours Lecturers
401-0625-01L Applied Analysis of Variance and Experimental Design W 5 credits 2V+1U L. Meier

Abstract
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Objective
Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Content
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Literature

Prerequisites / notice
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed

Personal Competencies
- Critical Thinking: assessed

401-0649-00L Applied Statistical Regression W 5 credits 2V+1U M. Dettling

Abstract
This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

Objective
The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

Content
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

Lecture notes
A script will be available.

Literature
Faraway (2005): Linear Models with R
Faraway (2006): Extending the Linear Model with R
Draper & Smith (1998): Applied Regression Analysis
Fox (2008): Applied Regression Analysis and GLMs
Montgomery et al. (2006): Introduction to Linear Regression Analysis

Prerequisites / notice
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.
Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication assessed
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

For the Specialization in Environmental Biology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0399-10L</td>
<td>Physiology and Anatomy for Biomedical Engineers I</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Wyss</td>
</tr>
</tbody>
</table>

Abstract
Students will be able to identify and enumerate important anatomical structures, to describe basic physiological processes of the human body, to use a 3d animation database/software, to use 'anatomical language' to retrieve anatomical structures, to understand basic medical terminology

Objective
To understand basic principles and structure of the human body in consideration of the clinical relevance and the medical terminology used in medical work and research.

Content
- The Human Body: nomenclature, orientations, tissues
- Musculoskeletal system, Muscle contraction
- Blood vessels, Heart, Circulation
- Blood, Immune system
- Respiratory system
- Acid-Base-Homeostasis

Lecture notes
Lecture notes and handouts

Literature
- Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008
- Faller A., Schuenke M. The Human Body; Thieme 2004
- Netter F. Atlas of human anatomy; Elsevier 2014

For the Specialization in Forest and Landscape

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0266-00L</td>
<td>Introduction to Dendrology</td>
<td>W</td>
<td>3 credits</td>
<td>3P</td>
<td>A. Rudow</td>
</tr>
</tbody>
</table>

Abstract
Woody plants are important elements of forest ecosystems and landscapes. The course gives an introduction to dendrology as well as to the identification of native tree and shrub species. It is a highly recommended course for the BSc specialization of Forest and Landscape and it provides the basic requirements for the consecutive course Woody Plants of Central Europe in the spring semester.

Objective
Knowledge of selected native tree and shrub species. Understanding of biological and ecological relations by means of in situ observation of woody plants. Differentiated view on forest ecosystems.

Content
Introduction to dendrology on the basis of concrete examples. Emphasis on identification of tree and shrub species (80 frequent tree and shrub species) and on the understanding of tree structure (morphology of woody plants). The illustrating way of presentation and the relations between different scale levels (organ, individual, stand, ecosystem) provide an attractive insight into forest and landscape topics as well as into environmental biology.

Lecture notes
- Rudow, A., 2023: Dendrologie 1 - Folien (in German).
- Rudow, A., 2011: eBot Dendrologie (Betaversion). E-learning-Tool for the support of dendrology courses at ETHZ (application integrated in eBot, in German).

Literature
- Rudow, A., 2011: eBot Dendrologie (Betaversion). E-learning-Tool for the support of dendrology courses at ETHZ (application integrated in eBot, in German).

Prerequisites / notice
Half of the course will be held in form of excursions and practical training in the forest (ETH Hönggerberg). Besides that 4 half day excursions (Zurich and surroundings, on weekends, dates by arrangement). Weatherproof clothes are presupposed.

The course provides the basic knowledge for the advanced course 701-0316-00L Woody plants of Central Europe (Dendrology 2)
Analytical Competencies fostered

Method-specific Competencies
- Decision-making fostered
- Problem-solving assessed

Social Competencies
- Communication assessed

Personal Competencies
- Adaptability and Flexibility fostered
- Critical Thinking assessed

The course covers the following topics:
- What is GIS? What are spatial data?
- The representation of reality by means of spatial data models: vector, raster, TIN
- The four phases of data modelling: Spatial, conceptual, logical and physical model
- Possibilities of data collection
- Transition of reference frame
- Spatial Analysis I: query and manipulation of vector data
- Spatial Analysis II: operators and functions with raster data
- Digital elevation models and derived products
- Process modelling with vector and raster data
- Presentation possibilities of spatial data

One Friday is reserved for a field trip or guest speaker;

Abstract
Theoretical basics and fundamental concepts of Geographic Information Science are imparted and subsequently further elaborated with the software ArcGIS.

Objective
Students are able to
- elucidate the theoretical and conceptional foundations of geographic information systems (GIS)
- independently perform normal GIS work using commercial software and practical examples

Content
The course covers the following topics:
- What is GIS? What are spatial data?
- The representation of reality by means of spatial data models: vector, raster, TIN
- The four phases of data modelling: Spatial, conceptual, logical and physical model
- Possibilities of data collection
- Transition of reference frame
- Spatial Analysis I: query and manipulation of vector data
- Spatial Analysis II: operators and functions with raster data
- Digital elevation models and derived products
- Process modelling with vector and raster data
- Presentation possibilities of spatial data

Literature


Prerequisites / notice

701-0951-00L GIST - Introduction into Geoinformation Science and Technology

Number Title Type ECTS Hours Lecturers

Natural Science and Technical Electives

Agroecology

Number Title Type ECTS Hours Lecturers

Abstract
Die Grundlagen des Welternährungssystem werden anhand von Fallbeispielen aus der Forschung entlang der Wertschöpfungskette vermittelt.

Objective
 Mit Besuch dieser Lehrveranstaltung soll Verständnis geschaffen werden, was ein Welternährungssystem ist, wo aktuell die großen Herausforderungen liegen, was Elemente und Einflussfaktoren auf die Ernährungssicherheit sind, welche Wechselwirkungen zwischen diesen Elementen und Einflussfaktoren bestehen, und welche potentiellen Lösungsstrategien sich für spezifische Herausforderungen ableiten lassen.

Content

Lecture notes
Skripte und zusätzliches Lernmaterial werden auf Moodle verfügbar gemacht.

Literature
Information zu Büchern und anderer Literatur wird während der Lehrveranstaltung bekanntgegeben.

Prerequisites / notice

Introduction to Agricultural Management

W 2 credits 2V  R. Finger

Abstract
Vermittlung von betriebswirtschaftlichen Grundlagenwissen und Analyse- und Planungsinstrumenten mit Anwendung auf Unternehmen der Agrar- und Ernährungswirtschaft

Objective
Teilnehmer des Kurses sollen am Ende der Vorlesung i) grundlegende Unternehmensentscheide strukturieren und analysieren können, ii) verschiedene Analyse- und Planungsinstrumente auf Fragestellungen der Produktionsplanung, Investition und Finanzierung an Beispielen anwenden zu können, iii) verschiedene Werkzeuge zur unternehmerischen Entscheidungsunterstützung anwenden können und iv) die Spezifika von Unternehmen in der Agrar- und Ernährungswirtschaft kennen.

Content
Die Vorlesung geht auf folgende Inhalte, mit spezifischen Anwendungen im Agrar- und Ernährungssektors ein:

- Grundlagen und Ziele unternehmerischen Entscheidens
- Kosten- und Leistungsrechnung
- Produktions- und Produktionsprogrammplanung
- Investitionsplanung und Finanzierung
- Entscheidungen unter Unsicherheit und Risikomanagement

Lecture notes
Vorlesungsunterlagen werden im Laufe des Semesters zur Verfügung gestellt

Literature

Plant Nutrition I

W 2 credits 2V  E. Frossard

Abstract
The aim of these lecture is to present the processes controlling the uptake and transport of nutrients by the plant, the assimilation of nutrients in the plant, the effect of nutrients on crop yield and quality, the role of the soil as a source of nutrients for crops, and the basic principles of fertilization of different crop types using mineral and organic fertilizers.

Objective
At the end of the lecture, students know how mineral nutrients are taken up through roots and circulate in the plants and what their roles in plants are. They understand the importance of nutrients for yield formation and for crop product quality. They are able to propose fertilization plans adapted for field crops growing under Swiss conditions.

Content
A general introduction explains the needs of appropriately managing nutrients in plant production. Afterwards, we will study the physiology of plant nutrition (nutrient uptake by roots; nutrient transports in the plant; physiological roles of nutrients in the plant). Then the role of nutrients for yield formation and their effects on crop quality is dealt with. Finally, the bases of crop fertilization are taught (availability of nutrient in soil; N, P and K fertilization; different types of fertilizers).

Lecture notes
The slides will be distributed

Literature

Plant Ecophysiology

W 2 credits 2V  N. Buchmann, A. Walter
The general theme of this course is the effect of environmental factors (such as light, temperature, relative humidity, CO2 concentrations, etc.) on plant physiology: water uptake and transport, transpiration, CO2 gas exchange of plants (photosynthesis, respiration), growth and C allocation, yield and production, stress physiology. Working with measurement data and Jupyter Notebooks is included.

Objective
The students will understand the impact of environmental factors on plant physiology and will learn the theoretical basis and terminology of plant ecophysiology that is necessary to analyze yield potentials in agriculture. The students will learn about classical and latest studies in plant ecophysiology. Students will check and implement their knowledge and understanding of ecophysiology using measurement data.

Content

Lecture notes
Handouts stehen online.

Literature
Larcher, 1994, Lambers et al., 2008, Schulze et al., 2019


Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Media and Digital Technologies
- Problem-solving

Assessed

Critical Thinking

Personal Competencies

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

751-5003-00L Sustainable Agroecosystems II

Abstract
This class conveys current topics and methods of agroecological and food systems research through selected case studies from ongoing research of the Sustainable Agroecosystems group. Students will be encouraged to develop critical thinking competencies, through individual and group work, on major agricultural and food system challenges and paths towards agricultural and food system transformation.

Objective
(1) Systematically analyse and discuss case studies from ongoing agroecological and food system research.
(2) Learn and experiment on methods for field and laboratory investigations in agroecology.
(3) Engage with positive and empowering frameworks that motivate critical reflection and action on the types of transformative responses needed to adapt and thrive within agricultural and food systems.
(4) Reflect critically on agricultural and food system transformation tools and methods from the perspective of a food system stakeholder.
(5) Identify and describe institutions in the context of sustainable agricultural development (for Bachelor and Master thesis and internships).

Content
The course will address a wide range of agricultural and food system challenges (e.g. food security, climate crisis, soil degradation, etc.) in both temperate and tropical contexts. In class we will address topics like building food system resilience through innovative measures, improving soil fertility management or understanding the effects of agroforestry systems. Case studies from the on-going research in the Sustainable Agroecosystems Group (sae.ethz.ch) will be presented, covering different scales (e.g. food value-chains, farm dynamics and soil management).

The class is complemented by practical group work conducted with the CSA Meh Als Gmues in Zürich on Measuring and monitoring Agroecological performance.

Students will gain an overview on institutions and actors' roles in the field of sustainable agricultural development. Throughout the group work, students will learn to engage directly with various stakeholders, monitor agroecological transition and communicate their research to a wider audience. Ultimately, this class should provide an overview on methods, tools, innovations and platforms that support a sustainable food transformation.

Prerequisites / notice
Prior participation in the lecture Nachhaltige Agrarökosysteme I (Sustainable Agroecosystems I) 751-5000-00G (spring term) recommended.

Competencies

Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Media and Digital Technologies
- Problem-solving

Method-specific Competencies
- Decision-making
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

751-5005-00L Agroecology

Abstract
Agroecology is a discipline, an agricultural practice, and a political-social movement. Students will attend public lectures by experts from different fields and will reflect on agroecology and its principles. Moreover, students will expand their knowledge with case studies and discuss about the role of agroecology to support sustainable agriculture and food systems.
Students know the thirteen principles of the High-Level Panel of Experts (HLPE) of the Committee on World Food Security as well as the ten elements of agroecology suggested by FAO and can critically reflect on the important properties as well as benefits and trade-offs of agroecological systems and approaches.

Students will be able to transfer their disciplinary and interdisciplinary knowledge about the thirteen principles as guiding principles for policymakers, practitioners, and other stakeholders across the food system in planning, managing, and evaluating agroecological transformation. Students are part of small groups focusing on selected principles of the HLPE. During the course, students discuss the potential and limitations of agroecology and learn about scientific contributions to agroecology. Students form an opinion on the role of agroecology, reflect and argue on the different facets and develop recommendations for real-world applications of agroecology in supporting a transition towards sustainable food systems.

The course is designed as a combination of public lectures/webinars on “Agroecology and the Transformation to Sustainable Food Systems” delivered by national and international experts and scientists as well as sessions in which students reflect on the topics addressed in the lecture series in a group work format. The public lectures bring different perspectives to the discussion and are intended as inputs for the students’ sessions. In the student sessions, the student groups deepen their knowledge of the 13 principles of agroecology proposed by the High-Level Panel of Experts (HLPE) of the Committee on World Food Security. They identify “unknowns” and link to other closely related principles. The groups also work out the perspective of a chosen stakeholder. Finally, the groups will take part in a scientific discussion representing their stakeholder perspective. All groups will synthesize their discussions in a short report.

Handouts will be available on the webpage of the course.

Lecture notes

Prerequisites /

Report of HLPE on agroecology:

- Vaccines, immune-therapeutic interventions
- Hypersensitivities
- Allergies
- Th1 and Th2 cells, regulatory T cells
- Cytotoxic T cells and NK cells
- Autoimmunity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Innate and adaptive immunity, Cells and organs of the immune system
- Basic knowledge of the mechanisms and the regulation of an immune response.
- Basic knowledge of the mechanisms and the regulation of an immune response.

Basic knowledge of the mechanisms and the regulation of an immune response.

Netter F. Atlas of human anatomy; Elsevier 2014

Faller A., Schuenke M. The Human Body; Thieme 2004

Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008

ECTS

3 credits

2 credits

W

Lecturers

M. Kopf, A. Oxenius

M. Wyss

Autumn Semester 2024

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### Soil Sciences

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0533-00L</td>
<td><strong>Soil and Water Chemistry</strong></td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>R. Kretzschmar, D. I. Christl, L. Winkel</td>
</tr>
<tr>
<td>701-0535-00L</td>
<td><strong>Environmental Soil Physics/Vadose Zone Hydrology</strong></td>
<td>W</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>A. Carminati, P. U. Lehmann Grunder</td>
</tr>
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</table>

#### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: fostered
- Decision-making: fostered
- Problem-solving: fostered
- Project Management: fostered

**Social Competencies**
- Communication: fostered

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Critical Thinking: fostered
- Self-direction and Self-management: fostered
INTRODUCTION
Week 1 (September 18)
Presentation of the role of soil physics in environmental sciences and terrestrial ecosystems: soils in the water cycle; soils and vegetation; soils and solute transport. Survey on students' interests and expectations. Presentation of course structure and learning objectives.

BASIC SOIL PROPERTIES
Week 2 (September 25) and Week 3 (October 02)
soil texture, particle size distribution, soil structure, soil surface area, porosity and bulk density
Pore scale consideration (water in a single pore), pore sizes and shapes; surface tension; Young-Laplace equation; capillary rise; contact angle
Friction and laminar flow; Hagen-Poiseuille's law; Washburn equation; numerical lab (REPORT 1)

SOIL HYDRAULIC PROPERTIES
Week (4 October 09) and Week 5 (October 16)
Soil water content and soil water potential - The energy state of soil water; total water potential and its components; volumetric and gravimetric water contents; field capacity and wilting point
Soil water characteristics and pore size distribution
Saturated water flow in soils - Laminar flow in tubes (Poiseuille's Law); Darcy's Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts; effective conductivity; unsaturated hydraulic conductivity; Buckingham law.
Unsaturated water flow in soils - Unsaturated hydraulic conductivity models and applications

TOOLBOX – MEASUREMENTS AND MODELING
Week (6 October 23) and Week 7 (October 30)
Measuring soil hydraulic properties, fitting and interpretation; Lab tour - demonstration of soil physical methods; lecture on HYPROP method; report on Hyprop data (REPORT 2)
Modelling unsaturated water flow based on Richards equation - Using Hydrus1D for simulation of unsaturated flow; simulating HYPROP measurements (REPORT 3)

SOIL IN THE WATER CYCLE
Week 8 (November 06) – Week 9 (November 13)
Water infiltration - steady state solutions for infiltration; approximate solutions to infiltration (Green-Ampt, Philip); infiltration rate and ponding; outlook to preferential flow
Water evaporation - Energy balance and land atmosphere interactions - potential and actual evaporation, evaporation stages;

SOIL PLANT INTERACTIONS
Week 10 (November 20) Week 11 (November 27)
Root water uptake and transpiration – Theory and mechanisms controlling root water uptake; hydraulic properties of rhizosphere; plant and stomatal conductance.
Modelling root water uptake and transpiration; analytical approaches and modeling using Hydrus (REPORT 4)

SOLUTE TRANSPORT
Week 12 (December 04) Week 13 (December 11)
Transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application
Transport of reactive substances, preferential flow, simulations with Hydrus

CLOSURE
Week 14 (December 18)
Summary, course synthesis, connections between the different topics, questions, exam preparation

Content

Literature
Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel

Competencies

Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving

Social Competencies
Communication
Cooperation and Teamwork
Leadership and Responsibility

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Innovative and Creative Thinking

651-0032-00L
Geology and Petrography
W
4 credits
2V+1U
K. Rauchenstein, M. O. Saar

Abstract
This course gives an overview of the basic concepts of geology and petrography and shows some links to the application of these concepts. The course consists of weekly lectures and bi-weekly exercises in groups.

Objective
This course gives an overview of the basic concepts of geology and petrography and shows some links to the application of these concepts.

Content

Lecture notes
Weekly handouts of PPT slides via MyStudies

Literature
The course is based on Press & Siever book Dynamic Earth by Grotzinger et al., available to ETH students via https://link.springer.com/book/10.1007/978-3-662-48342-8

751-3401-00L
Plant Nutrition I
W
2 credits
2V
E. Frossard

Abstract

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2431 of 2653
The aim of these lecture is to present the processes controlling the uptake and transport of nutrients by the plant, the assimilation of nutrients in the plant, the effect of nutrients on crop yield and quality, the role of the soil as a source of nutrients for crops, and the basic principles of fertilization of different crop types using mineral and organic fertilizers.

At the end of the lecture, students know how mineral nutrients are taken up through roots and circulate in the plants and what their roles in plants are. They understand the importance of nutrients for yield formation and for crop product quality. They are able to propose fertilization plans adapted for field crops growing under Swiss conditions.

A general introduction explains the needs of appropriately managing nutrients in plant production. Afterwards, we will study the physiology of plant nutrition (nutrient uptake by roots; nutrient transports in the plant; physiological roles of nutrients in the plant). Then the role of nutrients for yield formation and their effects on crop quality is dealt with. Finally, the bases of crop fertilization are taught (availability of nutrient in soil; N, P and K fertilization; different types of fertilizers).

The slides will be distributed.

Schubert S 2011 Pflanzenernährung Grundwissen Bachelor Ulmer UTB
Richner W. & Sinaj S., 2017. Grundlagen für die Düngung landwirtschaftlicher Kulturen in der Schweiz (GRUD 2017). Agrarforschung Schweiz 8 (6), Spezialpublikation,

**Methods of Statistical Data Analysis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0625-01L</td>
<td>Applied Analysis of Variance and Experimental Design</td>
<td>W</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>L. Meier</td>
</tr>
<tr>
<td>Abstract</td>
<td>Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.</td>
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<tr>
<td>Objective</td>
<td>Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.</td>
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<tr>
<td>Content</td>
<td>Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.</td>
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<tr>
<td>Competencies</td>
<td>Subject-specific Competencies</td>
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<td></td>
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<tr>
<td></td>
<td>Methods-specific Competencies</td>
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<td></td>
<td>Social Competencies</td>
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<td></td>
<td>Personal Competencies</td>
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<tr>
<td>401-0649-00L</td>
<td>Applied Statistical Regression</td>
<td>W</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>M. Dettling</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning &quot;good practice&quot; that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.</td>
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<tr>
<td>Objective</td>
<td>The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.</td>
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<tr>
<td>Content</td>
<td>The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.</td>
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<tr>
<td>The last third of the course is dedicated to an introduction to generalized linear models; this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.</td>
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<tr>
<td>Lecture notes</td>
<td>A script will be available.</td>
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<tr>
<td>Literature</td>
<td>Faraway (2005): Linear Models with R</td>
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<tr>
<td></td>
<td>Faraway (2006): Extending the Linear Model with R</td>
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<td></td>
<td>Draper &amp; Smith (1998): Applied Regression Analysis</td>
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<td></td>
<td>Fox (2006): Applied Regression Analysis and GLMs</td>
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<td></td>
<td>Montgomery et al. (2006): Introduction to Linear Regression Analysis</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.</td>
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<tr>
<td>In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L &quot;Applied Statistical Regression&quot; and 401-3622-00L &quot;Statistical Modelling&quot; are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.</td>
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</tbody>
</table>
The course provides the first part an introduction to the statistical/graphical/data science software R (https://www.r-project.org/) for scientists. Topics covered are data generation and selection, graphical and basic statistical functions, creating simple functions, basic types of objects.

**Objective**
The students will be able to use the software R for simple data analysis and graphics.

**Content**
The course provides the first part of an introduction to the statistical software R for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.

Part I of the course covers the following topics:
- What is R?
- R Basics: reading and writing data from/to files, creating vectors & matrices, selecting elements of dataframes, vectors and matrices, arithmetics;
- Types of data: numeric, character, logical and categorical data, missing values;
- Simple (statistical) functions: summary, mean, var, etc., simple statistical tests;
- Writing simple functions;
- Introduction to graphics: scatter-, boxplots and other high-level plotting functions, embellishing plots by title, axis labels, etc., adding elements (lines, points) to existing plots.

The course focuses on practical work at the computer with R. We will make use of the graphical user interface RStudio: www.rstudio.org

Note: Part I of UsingR is complemented and extended by Part II, which is offered during the second part of the semester and which can be taken independently from Part I.

**Lecture notes**
An Introduction to R. http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf

**Prerequisites / notice**
The course resources will be provided via the Moodle web learning platform. Subscribing via Mystudies "automatically" makes you a student participant of the Moodle course of this lecture, which is at https://moodle-app2.let.ethz.ch/course/view.php?id=20847

**Competencies**

### Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

### Method-specific Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

### Social Competencies
- Adaptable and Flexible
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-awareness and Self-reflection
- Self-direction and Self-management

### Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Negotiation
- Sensitivity to Diversity
- Self-presentation and Social Influence

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401-6217-00L Using R for Data Analysis and Graphics (Part II) W 1.5 credits 1G M. Mächler

**Abstract**
The course provides the second part an introduction to the statistical software R for scientists. Topics are data generation and selection, graphical functions, important statistical functions, types of objects, models, programming and writing functions.

**Objective**
The students will be able to use the software R efficiently for data analysis, graphics and simple programming.

**Content**
The course provides the second part of an introduction to the statistical software R (https://www.r-project.org/) for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.

Part II of the course builds on part I and covers the following additional topics:
- Elements of the R language: control structures (if, else, loops), lists, overview of R objects, attributes of R objects;
- More on R functions;
- Applying functions to elements of vectors, matrices and lists;
- Object oriented programming with R: classes and methods;
- Tayloring R: options;
- Extending basic R: packages

The course focuses on practical work at the computer. We will make use of the graphical user interface RStudio: www.rstudio.org

**Lecture notes**
An Introduction to R. http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf
Basic knowledge of R equivalent to "Using R .. (part 1)" (= 401-6215-00L) is a prerequisite for this course.

The course resources will be provided via the Moodle web learning platform. As from FS 2019, subscribing via Mystudies should "automatically" make you a student participant of the Moodle course of this lecture, which is at https://moodle-app2.let.ethz.ch/course/view.php?id=20848

### Competencies

#### Subject-specific Competencies

- **Concepts and Theories**: assessed
- **Techniques and Technologies**: assessed

#### Method-specific Competencies

- **Analytical Competencies**: assessed
- **Decision-making**: fostered
- **Media and Digital Technologies**: assessed
- **Problem-solving**: assessed

#### Social Competencies

- **Communication**: fostered
- **Cooperation and Teamwork**: fostered

#### Personal Competencies

- **Adaptability and Flexibility**: assessed
- **Creative Thinking**: assessed
- **Critical Thinking**: fostered
- **Self-awareness and Self-reflection**: assessed
- **Self-direction and Self-management**: fostered

### Ecology and Conservation Biology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0266-00L</td>
<td>Introduction to Dendrology</td>
<td>W</td>
<td>3 credits</td>
<td>3P</td>
<td>A. Rudow</td>
</tr>
</tbody>
</table>

**Abstract**

Woody plants are important elements of forest ecosystems and landscapes. The course gives an introduction to dendrology as well as to the identification of native tree and shrub species. It is a highly recomended course for the BSc specialization of Forest and Landscape and it provides the basic requirements for the consecutive course Woody Plants of Central Europe in the spring semester.

**Objective**

Knowledge of selected native tree and shrub species. Understanding of biological and ecological relations by means of in situ observation of woody plants. Differentiated view on forest ecosystems.

**Content**

Introduction to dendrology on the basis of concrete examples. Emphasis on identification of tree and shrub species (80 frequent tree and shrub species) and on the understanding of tree structure (morphology of woody plants). The illustrating way of presentation and the relations between different scale levels (organ, individual, stand, ecosystem) provide an attractive insight into forest and landscape topics as well as into environmental biology.

**Lecture notes**

- Rudow, A., 2023: Dendrologie 1 - Folien (in German).

**Literature**

- Rudow, A., 2011: eBot Dendrologie (Betaversion). E-learning-Tool for the support of dendrology courses at ETHZ (application integrated in eBot, in German).

**Prerequisites / notice**

Half of the course will be held in form of excursions and practical training in the forest (ETH Hönggerberg). Besides that 4 half day excursions (Zurich and surroundings, on weekends, dates by arrangement). Weatherproof clothes are presupposed.

The course provides the basic knowledge for the advanced course 701-0316-00L Woody Plants of Central Europe (Dendrology 2)

### Vertebrate Ecology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0305-00L</td>
<td>Vertebrate Ecology</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>K. Bollmann, U. Kormann</td>
</tr>
</tbody>
</table>

**Abstract**

The course covers the ecology of birds and mammals. Important concepts of nutrition, physiology, behavioural ecology, population biology, biogeography and community ecology will be linked to applications in conservation and management. A worldwide perspective will be complemented by a focus on the Central European fauna and its dynamics.

**Objective**

The students are familiar with important topics in animal ecology of vertebrates, with an emphasis on birds and mammals. They are able to link theoretical concepts with ecological phenomena and view them against an evolutionary backdrop. They can thus appraise applied aspects of the conservation and the use of animal populations, such as the influence of body size on the energy demand and nutrition, relationships between resource availability on habitat use of birds and mammals as well as between predators and prey species, or of herbivores on vegetation, and the effects of hunting and environmental change on animal populations. Students understand the biogeographical characteristics of the Central European vertebrate fauna and its temporal and spatial dynamics.
The course deals with a number of topics that include feeding and resource use, spatial behaviour and migrations, reproduction, population dynamics, competition and predation, parasites and diseases, biodiversity and distributions, and dynamics of the Central European fauna. There is an emphasis on linking theory with management issues in conservation and management of wildlife populations. During the first half of the course, examples will be drawn worldwide whereas during the second half, the course will focus more strongly on the European fauna, particularly of the Alpine region. Although the course is not designed to teach species knowledge and determination, examples will cover much of the taxonomic range of the European fauna.

The course includes a field excursion (7.12.2024, Alternative date: 14.12.24).

Program (Lecturers: Kurt Bollmann (KB), Urs Koramnn (UK)):

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.09.24</td>
<td>Birds and mammals: similarities &amp; differences, endothermy &amp; body isolation, moult in birds (KB)</td>
</tr>
<tr>
<td>30.09.24</td>
<td>Feeding I: Food, metabolism (KB)</td>
</tr>
<tr>
<td>07.10.24</td>
<td>Feeding II: Energetic needs, foraging, digestion (KB)</td>
</tr>
<tr>
<td>14.10.24</td>
<td>Distribution and habitat use, migration (UK)</td>
</tr>
<tr>
<td>21.10.24</td>
<td>Reproduction, litter and clutch size, breeding systems (UK)</td>
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<tr>
<td>28.10.24</td>
<td>Population dynamics (KB)</td>
</tr>
<tr>
<td>04.11.24</td>
<td>Predation, predator-prey-cycles (KB)</td>
</tr>
<tr>
<td>11.11.24</td>
<td>Competition (UK), Parasitism and diseases (self-study)</td>
</tr>
<tr>
<td>18.11.24</td>
<td>Biogeography of central European birds and mammals, return of ungulates and large predators (KB)</td>
</tr>
<tr>
<td>25.11.24</td>
<td>Herbivores as landscape engineers: the Serengeti ecosystem (Guest lecturer)</td>
</tr>
<tr>
<td>02.12.24</td>
<td>Exploitation of wild birds and mammals (KB)</td>
</tr>
<tr>
<td>09.12.24</td>
<td>Threats and conservation biology of selected species (UK)</td>
</tr>
<tr>
<td>16.12.24</td>
<td>Mammals and climate change (case study on roe deer) + questions and pilot test (KB)</td>
</tr>
</tbody>
</table>

Lecture notes: Lecture notes and handouts will be available digitally.

Literature: Literature will be listed in the lecture notes. Some additional papers will be distributed.

Some books relevant to the course are (optional reading):
- Suter, W. 2017. Ökologie der Wirbeltiere. Vögel und Säugetiere. UTB/Haupt, Bern. This book is based on the course. It is in German.

Competencies:

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>fostered</td>
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<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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</tbody>
</table>

Social Competencies:

<table>
<thead>
<tr>
<th>Communication</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
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</table>

Personal Competencies:

<table>
<thead>
<tr>
<th>Adaptability and Flexibility</th>
<th>fostered</th>
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<tbody>
<tr>
<td>Creative Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td>Self-awareness and Self-reflection</td>
<td>fostered</td>
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<tr>
<td>Self-direction and Self-management</td>
<td>fostered</td>
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</tbody>
</table>


Abstract: This course deals with river ecosystems, their fundamental ecological characteristics, anthropogenic impacts and changes. We discuss concepts and interdisciplinary approaches (hydraulic engineering and ecology) for sustainable management. The students organize themselves in working groups (lecture and moderation of a discussion on a date of choice, writing of a report).

Objective: Understanding the basics of the functioning of river ecosystems:
- Basics of sustainable management of rivers
- Application of these principles to case studies
- Critical analyses, organization in discussion groups

Content:
1) Planning, working groups, working methods
2) Water protection act and techniques for moderating discussions
3) Project implementation/realization
4) Floodplain management and revitalization
5) Restoration of sediment dynamics
6) Rivers under changing climate
7) River widening and ramps
8) Effects of restoration projects
9) Altered flow and temperature regimes in rivers and lakes
10) Water and health
11) Fish migration in rivers
12) Visitor control/recreational management
13) Peatland protection
14) Conclusion/evaluation

Lecture notes: Themenspezifische Unterlagen (Vorlesung Dozierende, Literatur) werden verteilt und auf Moodle zugänglich gemacht (Link folgt).

Literature: Literaturlisten zu den Gruppenarbeiten (Vortrag und Moderation einer ausgewählten Vorlesungsstunde, sowie Bericht) werden abgegeben und auf Moodle zugänglich gemacht (Link folgt).

Prerequisites / notice: Students will organize discussion groups (preparation of presentation and moderation, report).
The students are able to assess

Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies

- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

751-3700-00L  Plant Ecophysiology  W  2 credits  2V  N. Buchmann, A. Walter

Abstract

The general theme of this course is the effect of environmental factors (such as light, temperature, relative humidity, CO2 concentrations, etc.) on plant physiology: water uptake and transport, transpiration, CO2 gas exchange of plants (photosynthesis, respiration), growth and C allocation, yield and production, stress physiology. Working with measurement data and Jupyter Notebooks is included.

Objective

The students will understand the impact of environmental factors on plant physiology and will learn the theoretical basis and terminology of plant ecophysiology that is necessary to analyze yield potentials in agriculture. The students will learn about classical and latest studies in plant ecophysiology. Students will check and implement their knowledge and understanding of ecophysiology using measurement data.

Content


Lecture notes

Handouts stehen online.

Literature


Prerequisites / notice

This course is based on basics of plant identification and plant physiology. It is the basis for the courses Plant Production, Part Forage Production and Grassland Systems.

Competencies

- Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Media and Digital Technologies
- Problem-solving

- Personal Competencies
- Critical Thinking

701-0201-00L  Introduction to Environmental Organic Chemistry  W  3 credits  2G  M. Sander, K. McNeill

Abstract

Important organic environmental pollutants are presented. The physical and chemical basics required for understanding the environmental behavior of such pollutants are taught and deepened in exercises.

Objective

- The students are able to
- name and recognize the most important classes of environmentally relevant anthropogenic chemicals and identify chemical moieties governing their fate processes.
- explain, on the basis of physical-chemical foundations, the most important processes (i.e., partitioning and substitution and elimination reactions) which determine the environmental behavior of organic pollutants.
- identify, on the basis of chemical structure, the processes relevant for the environmental behavior of a compound.
- critically evaluate published work and data.

Content

- Overview of the most important classes of environmental organic pollutants
- Molecular interactions that determine the partitioning behavior (adsorption and absorption processes) of organic compounds between different environmental compartments (gas, liquid, solid)
- Physical-chemical properties (vapor pressure, aqueous solubility, air-water partition constant, organic solvent-water partition constants, etc) and partitioning behavior of organic compounds between environmentally relevant phases (air, aerosols, soil, water, biota)
- Chemical transformation reactions of organic pollutants in aquatic and in terrestrial environments (hydrolysis, elimination, addition)

Lecture notes

Script will be distributed

Literature


Prerequisites / notice

Die Lehrveranstaltung richtet sich nicht nur an jene Studierenden, welche sich später chemisch vertiefen wollen, sondern ausdrücklich auch an alle jene, welche sich mit der Problematik von organischen Schadstoffen in der Umwelt vertraut machen wollen, um dieses Wissen in anderen Vertiefungen anzuwenden.
701-0225-00L  Organic Chemistry  W  2 credits  2V+1U  K. McNeill

Abstract

Objective
Students will be able to:
• Recall basic organic chemistry reactions, including substitution, elimination and addition reactions occurring at sp2- and sp3-hybridized carbon centers.
• Explain the relative favorability of certain organic chemical structures or certain organic chemical reactions.
• Apply their understanding of reaction mechanism principles to explain observations.
• Differentiate the most reactive sites in a given organic chemical.
• Propose reaction mechanisms to new chemical transformations.

Content
Descriptive chemistry of functional groups (alkyl halides, alkenes, aromatic systems, carbonyls). Reaction mechanisms (substitutions, additions, eliminations, condensations, electrophilic aromatic substitution).

Literature
Carsten Schmuck, Basisbuch Organische Chemie, Pearson

Prerequisites / notice
Der Stoff der Basischemie wird vorausgesetzt.

Competencies
Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

752-0100-00L  Biochemistry  W  2 credits  2V  C. Frei

Abstract
Basic knowledge of enzymology, in particular the structure, kinetics and chemistry of enzyme-catalysed reaction in vitro and in vivo. Biochemistry of metabolism: Those completing the course are able to describe and understand fundamental cellular metabolic processes.

Objective
Students are able to describe the structure of proteins/enzymes and are able to explain biochemical functions depending on their 3D structures.

Connections between several metabolic pathways are known and students can evaluate how one pathway is influence by the activity of another pathway

Content
Program
Introduction, basics, composition of cells, biochemical units, repetition of relevant organic chemistry
Structures and function of proteins
Enzymes and enzyme kinetics
Catalytic strategies
Metabolism: Basic concepts and design. Repetition of basic thermodynamics
Glycolysis, fermentation
The citric acid cycle
Oxidative phosphorylation and ATP physiology

Lecture notes
Horton et al. (Pearson) serves as lecture notes.

Prerequisites / notice
Basic knowledge in biology and chemistry is a prerequisite.
Environmental Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0479-00L</td>
<td>Environmental Fluid Dynamics</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>H. Wernli, L. Papritz</td>
</tr>
<tr>
<td>101-0203-01L</td>
<td>Hydraulics I</td>
<td>W</td>
<td>5 credits</td>
<td>3V+1U</td>
<td>R. Stocker</td>
</tr>
<tr>
<td>651-3561-00L</td>
<td>Cryosphere</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>M. Huss, D. Farinotti, H. J. Horgan</td>
</tr>
</tbody>
</table>

Abstract

- **Environmental Fluid Dynamics**: This course covers the basic physical concepts and mathematical equations used to describe environmental fluid systems on the rotating Earth. Fundamental concepts (e.g., vorticity dynamics and waves) are formally introduced, applied quantitatively and illustrated using examples. Exercises help to deepen knowledge of the material.

- **Hydraulics I**: The course teaches the basics of hydromechanics, relevant for civil and environmental engineers. In the course "Hydraulics I", the competency of process understanding is taught, applied and examined. Furthermore system understanding and measurement methods are taught.

- **Cryosphere**: The course introduces the different components of the cryosphere - snow, glaciers, ice sheets, sea ice and lake ice, and permafrost - and their respective roles in the climate system. For each subsystem, essential physical aspects are emphasized, and their dynamics are described quantitatively and using examples.

Objective

- **Environmental Fluid Dynamics**: Students are able to:
  - name the basics, concepts and methods of environmental fluid dynamics.
  - understand and discuss the components of the basic physical equations.
  - mathematically solve basic equations for simple problems of environmental fluid dynamics.

- **Hydraulics I**: In the course "Hydraulics I", the competency of process understanding is taught, applied and examined.

- **Cryosphere**: The competencies of process understanding and system understanding are taught, applied and examined.

Content

- **Environmental Fluid Dynamics**: Continuum hypothesis, forces, constitutive laws, state equations and basic principles of thermodynamics, kinematics, laws of mass and momentum on rotating earth.
- **Hydraulics I**: Properties of water, hydrostatics, stability of floating bodies, continuity, Euler equation of motion, Navier-Stokes equations, similarity, Bernoulli principle, momentum equation for finite volumes, potential flows, ideal fluids vs. real fluids, boundary layer, pipe flow, open channel flow, flow measurements, demonstration experiments in the lecture hall.
- **Cryosphere**: The course provides an introduction into the various components of the cryosphere: snow, glaciers, ice sheets, sea ice and lake ice, permafrost, and their roles in the climate system. Essential physical aspects are emphasized for each subsystem: e.g. the material properties of ice, mass balance and dynamics of glaciers, or the energy balance of sea ice.

Literature

- **Environmental Fluid Dynamics**: See also: web-site.
- **Hydraulics I**: Script and collection of previous problems
- **Cryosphere**: Bolirich, Technische Hydromechanik 1, Verlag Bauwesen, Berlin

Further literature will be indicated during the lecture.
### Environmental Planning

101-0515-00 Projektmanagement and 103-0313-00 Raum- und Landschaftsentwicklung are prerequisites for the Master's degree programme in Spatial Development and Infrastructure Systems and should be successfully completed in the Bachelor's degree if possible.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-0009-00L</td>
<td>Tackling Environmental Problems III n</td>
<td>W</td>
<td>3</td>
<td>4U</td>
<td>M. Mader, C. E. Pohl</td>
</tr>
<tr>
<td>Abstract</td>
<td>Students put the measures they developed during the courses Tackling Environmental Problems II into practice, in collaboration with partners from civil society, the public and the private sector.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Students are able to put the measures they developed to address sustainability problems into practice.</td>
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<tr>
<td>Content</td>
<td>In Tackling Environmental Problems I &amp; II, students analyze a sustainability topic, identify a specific problem within it, develop measures to address the problem and test the measures for feasibility by presenting them to concerned stakeholders. Some of the students develop their measures to such a degree, that the measures could actually be implemented. Tackling Environmental Problems III provides the opportunity to do so. Together with partners from civil society, the private and the public sector, students agree on the implementation plan, the financial and legal aspects and put the measure into practice.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Tackling Environmental Problems I &amp; II is a prerequisite for taking the course Tackling Environmental Problems III.</td>
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<tr>
<td>Competencies</td>
<td>Method-specific Competencies</td>
<td>Decision-making</td>
<td>fostered</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
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<tr>
<td>Content</td>
<td>Social Competencies</td>
<td>Adaptability and Flexibility</td>
<td>fostered</td>
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<tr>
<td>Competencies</td>
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</tr>
</tbody>
</table>

701-0951-00L | GIST - Introduction into Geoinformation Science and Technology | W | 5 | 2V+3P | M. A. M. Niederhuber

**Abstract**
Theoretical basics and fundamental concepts of Geographic Information Science are imparted and subsequently further elaborated with the software ArcGIS. At the end, the students will be able to independently solve basic realistic GIS problems.

**Objective**
Students are able to:
- elucidate the theoretical and conceptional foundations of geographic information systems (GIS)
- independently perform normal GIS work using commercial software and practical examples

**Content**
The course covers the following topics:
- What is GIS? What are spatial data?
- The representation of reality by means of spatial data models: vector, raster, TIN
- The four phases of data modelling: Spatial, conceptual, logical and physical model
- Possibilities of data collection
- Transition of reference frame
- Spatial Analysis I: query and manipulation of vector data
- Spatial Analysis II: operators and functions with raster data
- Digital elevation models and derived products
- Process modelling with vector and raster data
- Presentation possibilities of spatial data

**Literature**


**Prerequisites / notice**
Aufgrund der Grösse des verfügbaren EDV-Schulungsräums ist die Teilnehmerzahl auf 50 Studierende beschränkt! Für die Übungen werden die Studierenden auf zwei, max. drei Zeitenfenster aufgeteilt. Pro Zeitenfenster können maximal 25 Studierende betreut werden.

701-0967-00L | Project Development in Renewable Energies | W | 2 | 2G | R. Rechsteiner, A. Appenzeller

| Competencies | Subject-specific Competencies | Concepts and Theories | assessed |       |                         |
| Social Competencies | Cooperation and Teamwork | fostered |       |       |                         |
| Personal Competencies | Creative Thinking | fostered |       |       |                         |
Abstract
The focus is on the implementation of projects:
- photovoltaics
- wind energy
- hydropower
You will learn about new business models, including storage and sector coupling, discuss framework conditions, economic efficiency, security of supply, market organization and business risks. Guidance from experts with many years of political and project experience.

Objective
You will receive a practice-oriented introduction to the regulatory and economic requirements for renewable energy projects.
You will be familiar with the options for integrating fluctuating energy production in an environment of volatile prices.
You will be familiar with the opportunities and risks and strategies for economic security.

Content
Detailed program
https://www.rechtscheiner-basel.ch/lehre/01L

Lecture notes
PPT presentation will be distributed (in German)

Literature
Literaturliste mit funktionierenden Links:
https://www.rechtscheiner-basel.ch/lehre/01L

Rudolf Rechsteiner: Die Energiewende im Wartesaal, Verlag Zocher & Peter, Zürich 2021 (wird als PDF abgegeben)

Faktenblätter Bundesamt für Energie:
- Stromgesetz: Zusammenfassung
- Faktenblatt zu Verordnungsentwürfen
- Solar-Contracting
- Investitionsbeiträge für Klein- und Grosswasserkraftanlagen
- Investitionsbeiträge für Windenergieanlagen
- Faktenblatt Marktprämie 2022
- Temporäres Reservekraftwerk Berr

Bundesamt für Energie: Handbuch Eigenverbrauch
Bundesverband Windenergie: Mit einer grünen Anlage schwarze Zahlen schreiben
REN21: Renewables 2024 Global Status Report (global overview)
IEA PVPS: TRENDS IN PHOTOVOLTAIC APPLICATIONS Snapshots 2024
http://www.iea-pvps.org

Bundesamt für Energie: Perspektiven für die Grosswasserkraft in der Schweiz
http://www.news.admin.ch/NSBSubscriber/message/attachments/33263.pdf

Windenergie-Report Deutschland
http://windmonitor."

Unterlagen Kleinwasserkraft-Projekte
https://www.bfe.admin.ch/bfe/de/home/versorgung/erneuerbare-energien/wasserkraft/kleinwasserkraft.html

Unterlagen Windkraft-Projekte
https://www.bfe.admin.ch/bfe/de/home/versorgung/erneuerbare-energien/windenergie.html

Leitfaden zur Beglaubigung von Anlagendaten der Pronovo
https://pronovo.ch/download/leitfaden-zur-beglaubigung-von-anlage-und-produktionsdaten/?wpdmdl=7339

Prerequisites / notice
For group exercise and presentation reasons the number of participants is limited at 30 students.
For exercises students build learning and presentational groups. Credit points are based on group performance.

Competencies
Subject-specific Competencies
Concepts and Theories fostered
Method-specific Competencies
Analytical Competencies fostered
Decision-making fostered
Problem-solving fostered
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

101-0415-01L Public Transport and Railways W 3 credits 2G F. Corman

Abstract
Fundamentals of public and collective transport, in its different forms.
Categorization of performance dimensions of public transport systems, and their implications to their design and operations.

Objective
Teaches the basic principles of public transport network and topology design, to understand the main characteristics and differences of public transport networks, based on buses, railways, or other technologies.
Teaches students to recognize the interactions between the infrastructure design and the production processes, and various performance criteria based on various perspective and stakeholders.

At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate different choices of technologies to suitable cases; optimize the use of resources in public transport.

Content
Fundamentals: Infrastructures and vehicle technologies of public transport systems; interaction between track and vehicles; passengers and goods as infrastructure users; management and financing of networks.

Infrastructure: Planning processes and decision levels in network development and infrastructure planning, planning of topologies; tracks and roadways, station infrastructures; Fundamentals of the infrastructure design for lines; track geometries; switches and crossings

Vehicles: Classification, design and suitability for different goals
Network design: design dilemmas, conceptual models for passenger transport on long distance, urban regional transport.

Operations: Passenger/Supply requirements for line operations; timetabling, measures of realized operations, capacity

Lecture notes
Slides, in English, are made available some days before each lecture.

Literature
Reference material books are provided in German and English (list disseminated at lecture), plus Skript Bahlinfrastruktur; System- und Netzplanung
Spatial Planning and Landscape Development  

**Abstract**  
The lecture introduces the main-features of Swiss spatial planning. Core subjects are e.g., spatial planning as a federal responsibility, spatial planning instruments (federal, cantonal, municipal), as well as systematic problem solving techniques and methodologies of spatial planning. The lecture is complemented with in-depth topics and comparative international examples.

**Objective**  
- Grundzüge der Raumplanung und ihre wichtigsten Instrumente kennenlernen  
- Erarbeiten der Fähigkeit, räumliche Probleme zu erkennen und Problemlösungsverfahren auf diese anzuwenden  
- Planung und Landnutzungsmanagement als interaktiven und akteursbezogenen Prozess kennenlernen und anwenden  
- Verstehen der mit Ressourcen und Boden verbundenen Potentiale, Nutzungen und Prozesse  
- Das vermittelte theoretische Wissen direkt an konkreten, praxisorientierten Übungsaufgaben umsetzen können

**Content**  
- Was ist Raumplanung (Definitionen und Begriffe)  
- Aktuelle Herausforderungen, Entwicklungen und Tendenzen der Raumplanung  
- Grundprinzipien, historische Entwicklung und Gesetzgebungen der Schweizer Raumplanung  
- Die Raumplanung als staatliche Aufgabe – Raumordnungspolitik auf Bundesebene  
- Instrumente der Raumplanung auf nationaler, kantonaler, regionaler und kommunaler Ebene (u.a. Sachpläne und Konzepte, Richtplanung, Nutzungsplanung, Sondernutzungsplanung, Mehrwertausgleich)  
- Problemlösungsverfahren in der Raumplanung – systemtechnisches Vorgehen  
- Thematische Vertiefungen: Siedlungsentwicklung nach innen; Klimaangepasste Raumplanung; Grundeigentum und kooperative Planung; Raumbeobachtung


**Lecture notes**  
Skript und einzelne Dokumente werden ausgegeben. Unterlagen zur Vorlesung werden auf der SPUR-Kursseite und/oder auf Moodle direkt zur Verfügung gestellt.

**Literature**  
- EspaceSuisse (2021): Lehrbuch Einführung in die Raumplanung, Bern.
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Project Management

W 2 credits 2G C. G. C. Marxt

Abstract
The course gives a detailed introduction on various aspects of professional project management out of theory and practice. Established concepts and methods for project organization, planning, execution and evaluation are introduced and major challenges discussed. The course includes an introduction to specialized project management software as well as agile project management concepts.

Objective
Projects are not only the base of work in modern enterprises, but also the primary type of cooperation with customers. Students of ETH will often work in or manage projects in the course of their career. Good project management knowledge is not only a guarantee for individual, but also for company-wide success.

The goal of this course is to give a detailed introduction into project management. The students should learn to plan and execute a project.

Content
Project planning (aims, appointments, capacities, efforts and costs), project organization, scheduling and risk analysis, project execution, supervision and control, project evaluation, termination and documentation, conflict management, multinational project management, IT support as well as agile project management methods such as SCRUM.

Lecture notes
No.
The lecture slides and other additional material will be available for download from Moodle a week before each class.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving fostered
Project Management assessed

Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility assessed
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered
Negotiation assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management assessed

Specialization in an Environmental System
Atmosphere and Climate

The following courses are highly recommended as preparation for the Specialization in Atmosphere and Climate:

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0459-00L</td>
<td>Seminar for Bachelor Students: Atmosphere and Climate</td>
<td>W</td>
<td>3</td>
<td>2S</td>
<td>M. Windisch, S. I. Seneviratne, O. Stebler</td>
</tr>
</tbody>
</table>

Abstract
The seminar brings together students in the field of atmosphere and climate. Based on classic and current scientific articles, presentation techniques (presentations, poster presentations) are practised and students get a first insight into research in the field of atmosphere and climate.

Objective
In this seminar, students learn how to read scientific publications and how to transfer the scientific knowledge to a broader audience by means of oral and poster presentations. Students also get insight into the different research areas at the Institute for Atmospheric and Climate Science.
### Atmospheric Chemistry

**Abstract**

This course covers the chemical and physical processes controlling the composition of the troposphere and stratosphere and introduces the relevant fundamentals for processes in the gas phase, in aerosols and clouds. These concepts are explored in the context of key environmental issues, such as urban air pollution, stratospheric ozone depletion, and air quality connections to climate change.

**Objective**

At the end of this course, students are able to:

1. describe the structure of the atmosphere and list atmospheric components and their main properties
2. define and describe the chemical and physical processes in the stratosphere and troposphere, follow reaction mechanisms, and apply rate laws
3. describe the physical and chemical principles of air pollution and summarize the most important legislative measures
4. discuss the local, regional, and global aspects of interactions between air quality, ecosystem health, and climate

**Content**

- Origin and properties of the atmosphere: composition (gases and aerosols), atmospheric structure, UV radiation, transport timescales
- Kinetics of gas phase reactions: rate laws, mechanisms of bimolecular and termolecular reactions.
- Stratospheric chemistry: Chapman cycle, catalytic ozone destruction cycles, polar ozone hole, Montreal protocol
- Tropospheric chemistry: oxidizing capacity of the troposphere, and the role of OH, oxidation and global budgets of CO and CH4, role of NOx, and the global tropospheric O3 budget
- Surface ozone chemistry: HOx-NOx cycle, role of VOCs, O3 isopeth, ozone production efficiency
- Aerosols: primary and secondary sources, composition, quantities and measurements, connections to climate
- Multiphase chemistry: solubility of gases, Raoult's Law and hygroscopicity, kinetics of gas to particle transfer, N2O5 chemistry, aqueous phase sulfur chemistry, secondary organic aerosol formation
- Air quality: role of planetary boundary layer, deposition processes, summer- versus winter-smog, environmental problems, legislation, long-term trends
- Global aspects: air quality - climate interactions

**Lecture notes**

Lecture materials (slides) are provided continuously during the semester, at least 2 days before each lecture. Annotations and corrections are provided at the latest within the same week.

**Prerequisites / notice**

Attendance of the lecture "Atmosphäre" LV 701-0023-00L or equivalent knowledge is a pre-requisite, and basic courses in physics and chemistry are expected.

**Competencies**

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies

**Social Competencies**

- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity

**Personal Competencies**

- Creative Thinking
- Critical Thinking

---

### Weather Systems

**Abstract**

Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; Potential Vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer; water isotopes

**Objective**

The students are able to:

1. explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
2. to discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
3. to explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
4. to explain how mountains influence the atmospheric flow on different scales

**Content**

- Basic understanding of stable water isotopes as tracers for moist adiabatic processes in weather systems
- Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; Potential Vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer; water vapour transport in the atmosphere; water isotopes

**Lecture notes**

Lecture notes and slides

**Prerequisites / notice**

Basic physics

**Competencies**

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies
- Problem-solving

**Social Competencies**

- Cooperation and Teamwork

**Personal Competencies**

- Creative Thinking
- Critical Thinking
The course starts by introducing selected concepts of thermodynamics for atmospheric processes: the students learn the concept of thermodynamic equilibrium and derive the Clausius-Clayperon equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Students also learn to use thermodynamic charts (tephigrams) and to identify cloud base, cloud top, available convective energy in radiosonde ascents. Atmospheric mixing processes are introduced as a basis for fog formation. The concept of an air parcel is used to understand convection.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter, cloud microphysical processes including ice nucleation are discussed.

With these basics, the different forms of precipitation (convective vs. stratiform) are discussed and how they can be identified in radar images. Students will also learn under which conditions severe convective storms (especially supercells with tornados) can form.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

**Lecture notes**

Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=20400

**Literature**


An electronic version of this book can be obtained via the ETH library.

pdf-files of the revised book will be provided on moodle on a chapter-by-chapter basis.

**Prerequisites / notice**

We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments.

There is an additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.

**Competencies**

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>fostered</td>
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<tr>
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<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
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</tbody>
</table>

### Biogeochemistry

The following courses are highly recommended as preparation for the Specialization in Biogeochemistry:

- 701-0225-00L Organic Chemistry (Autumn semester)
- 752-0100-00L Biochemie (Autumn semester)
- 752-1300-00L Introduction to Toxicology (Spring semester)

These courses should be successfully completed during the second year.

<table>
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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>701-0201-00L</td>
<td>Introduction to Environmental Organic Chemistry</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Sander, K. McNeill</td>
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**Abstract**

Important organic environmental pollutants are presented. The physical and chemical basics required for understanding the environmental behavior of such pollutants are taught and deepened in exercises.

**Objective**

The students are able to
- name and recognize the most important classes of environmentally relevant anthropogenic chemicals and identify chemical moieties governing their fate processes.
- explain, on the basis of physical-chemical foundations, the most important processes (i.e., partitioning and substitution and elimination reactions) which determine the environmental behavior of organic pollutants.
- identify, on the basis of chemical structure, the processes relevant for the environmental behavior of a compound.
- critically evaluate published work and data.

**Content**

- Overview of the most important classes of environmental organic pollutants
- Molecular interactions that determine the partitioning behavior (adsorption and absorption processes) of organic compounds between different environmental compartments (gas, liquid, solid)
- Physical-chemical properties (vapor pressure, aqueous solubility, air-water partition constant, organic solvent-water partition constants, etc) and partitioning behavior of organic compounds between environmentally relevant phases (air, aerosols, soil, water, biota)
- Chemical transformation reactions of organic pollutants in aquatic and in terrestrial environments (hydrolysis, elimination, addition)

**Lecture notes**

Script will be distributed

**Literature**


**Prerequisites / notice**

Die Lehrveranstaltung richtet sich nicht nur an jene Studierenden, welche sich später chemisch vertiefen wollen, sondern ausdrücklich auch an alle jene, welche sich mit der Problematik von organischen Schadstoffen in der Umwelt vertraut machen wollen, um dieses Wissen in anderen Vertiefungen anzuwenden.
Soil and Water Chemistry

W 3 credits 2G  

R. Kretzschmar, D. I. Christl, L. Winkel

Abstract

This course covers chemical and biogeochemical processes in soils and water and their influence on the behavior and cycling of nutrients and pollutants in terrestrial and aquatic systems. Approaches for quantitative modeling of the processes are introduced and applied in selected examples.

Objective

1. Understanding of important chemical properties and processes of soils and water and their influence on the behavior (e.g., chemical speciation, bioavailability, mobility) of nutrients and pollutants.
2. Quantitative applications of chemical equilibria to processes in natural systems.

Content

Chemical equilibria in aqueous solutions, gas equilibria, precipitation and dissolution of mineral phases, silicate weathering, weathering kinetics, formation of secondary minerals (clay minerals, oxides, sulfides), redox processes in natural systems, pH buffering and acidification, salinity and salinization, environmental behavior of selected essential and toxic trace elements.

Lecture notes

Lecture slides on Moodle

Literature

–Chapters 1, 3, 4, 6, 7 and 11 in Sigg/Stumm – Aquatische Chemie, 6. Auflage, vdf, 2016.

Prerequisites / notice

Restriction: only students enrolled in the environmental sciences bachelor’s programm can register for this course.

Deadline for enrollment is the FIRST day of the semester. Later enrollment can only be accepted in exceptional cases and under certain conditions (e.g., restricted choice of topics and dates).

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<tr>
<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Project Management</td>
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<td>Social Competencies</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Negotiation</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Self-direction and Self-management</td>
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Abstract
The course provides theoretical and practical foundations for understanding and characterizing physical soil properties and processes and their relevance for terrestrial ecosystems, plant growth, hydrological processes and atmospheric-land gas exchange, across all relevant scales.

Objective
Students are able to:
- Characterize the different soils based on their key textural and structural properties.
- Simulate and predict soil water retention and flow under varying environmental conditions and understand the key driving forces (capillarity, gravity, friction) and related water properties (surface tension and viscosity).
- Predict soil hydraulic properties for varying soil textural classes.
- Predict solute transport in soils for varying environmental conditions.
- Predict energy balance and temperature dynamics in soils.
- Predict conditions for plant water stress
- Estimate the impact of soil properties on the hydrological cycle and on plant growth.

Content
INTRODUCTION
Week 1 (September 18)
Presentation of the role of soil physics in environmental sciences and terrestrial ecosystems: soils in the water cycle; soils and vegetation; soils and solute transport. Survey on students' interests and expectations. Presentation of course structure and learning objectives.

BASIC SOIL PROPERTIES
Week 2 (September 25) and Week 3 (October 02)
soil texture, particle size distribution, soil structure, soil surface area, porosity and bulk density
Pore scale consideration (water in a single pore), pore sizes and shapes; surface tension; Young-Laplace equation; capillary rise; contact angle
Friction and laminar flow; Hagen-Poiseuille’s law; Washburn equation; numerical lab (REPORT 1)

SOIL HYDRAULIC PROPERTIES
Week 4 (October 09) and Week 5 (October 16)
Soil water content and soil water potential - The energy state of soil water; total water potential and its components; volumetric and gravimetric water contents; field capacity and wilting point
Soil water characteristics and pore size distribution
Saturated water flow in soils - Laminar flow in tubes (Poiseuille’s Law); Darcy's Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts; effective conductivity; unsaturated hydraulic conductivity; Buckingham law.
Unsaturated water flow in soils - Unsaturated hydraulic conductivity models and applications

TOOLBOX – MEASUREMENTS AND MODELING
Week 6 (October 23) and Week 7 (October 30)
Measuring soil hydraulic properties, fitting and interpretation; Lab tour - demonstration of soil physical methods; lecture on HYPROP method; report on Hyprop data (REPORT 2)
Modelling unsaturated water flow based on Richards equation - Using Hydrus1D for simulation of unsaturated flow; simulating HYPROP measurements (REPORT 3)

SOIL IN THE WATER CYCLE
Week 8 (November 06) – Week 9 (November 13)
Water infiltration - steady state solutions for infiltration; approximate solutions to infiltration (Green-Ampt, Philip); infiltration rate and ponding; outlook to preferential flow
Water evaporation - Energy balance and land atmosphere interactions - potential and actual evaporation, evaporation stages;

SOIL PLANT INTERACTIONS
Week 10 (November 20) Week 11 (November 27)
Root water uptake and transpiration – Theory and mechanisms controlling root water uptake; hydraulic properties of rhizosphere; plant and stomatal conductance.
Modelling root water uptake and transpiration; analytical approaches and modeling using Hydrus (REPORT 4)

SOLUTE TRANSPORT
Week 12 (December 04) Week 13 (December 11)
Transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application
Transport of reactive substances, preferential flow, simulations with Hydrus

CLOSURE
Week 14 (December 18)
Summary, course synthesis, connections between the different topics, questions, exam preparation

Literature
Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel

Competencies
Subject-specific Competencies assessed
Concepts and Theories
Techniques and Technologies
Analytical Competencies assessed
Decision-making
Problem-solving
Project Management fostered

Method-specific Competencies assessed

Social Competencies fostered
Communication
Cooperation and Teamwork
Leadership and Responsibility

Personal Competencies fostered
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Human-Environment Systems
The following courses are highly recommended as preparation for the Specialization in Human-Environment Systems:
401-0625-01L Applied Analysis of Variance and Experimental Design
401-0649-00L Applied Statistical Regression; Prerequisite: 701-0105-00L Mathematics VI: Applied Statistics for Environmental Sciences

Number Title Type ECTS Hours Lecturers

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Seminar for Bachelor Students: Human Environment Systems

Objective
The students learn to read, understand, summarize and present current research papers related to human-environment systems. Furthermore, students train the critical discussion of these papers. The students also get to know a number of innovative approaches for such presentations.

Content
Research in human-environment systems is characterised by a broad range of topics and methods. This is illustrated by the research papers that are discussed in this seminar. Students choose a paper from a list and present it to the seminar participants. Furthermore, they lead the discussion and train questions and answers related to such presentations. In the first three lessons, inputs to presentation techniques and innovative approaches to presentations are provided and discussed.

Literature
Will be provided in the seminar.

Prerequisites / notice
None

Compencies
Subject-specific Competencies: Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies: Analytical Competencies assessed
Social Competencies: Communication assessed
Personal Competencies: Creative Thinking assessed
Critical Thinking assessed

Resource and Environmental Economics

Objective
A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

Content
The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure: external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit-analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power. When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the oversee of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

Literature

Compencies
Subject-specific Competencies: Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies: Analytical Competencies assessed

Applied Statistical Regression

Objective
The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

Content
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

Literature
Faraway (2005): Linear Models with R
Faraway (2006): Extending the Linear Model with R
Draper & Smith (1998): Applied Regression Analysis
Fox (2008): Applied Regression Analysis and GLMs
Montgomery et al. (2006): Introduction to Linear Regression Analysis

Prerequisites / notice
In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

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851-0577-00L

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<td>Bernauer, T., Brügge, C., Rhein, S.</td>
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**Zusammenfassung**


**Prerequisites / Notice**

Siehe Syllabus im Moodle
This course provides the ecological systems' knowledge needed to question applied sustainability solutions. We will critically assess the

In the seminar, students explore a specific topic in environmental biology (ecology, evolution, health). They find and read scientific articles,

Students will acquire skills in:
- finding literature in scientific databases
- structuring a scientific topic through research questions
- giving a clear scientific presentation
- contributing constructively to a scientific discussion

In the first 3-5 weeks, the course will center around learning and discussing the skills needed to participate in scientific presentations:
- contributing constructively to a scientific discussion
- giving a clear scientific presentation
- structuring a scientific topic through research questions
- finding literature in scientific databases

At the end of the course...

...you have an overview of the methods of ecosystem research and have a deeper insight into some of them, e.g. ecosystem observation, manipulation and modelling.
...you have reflected on ecology as a young discipline at the heart of significant applied questions.
...you know how to structure your inquiry and how to proceed the analysis when faced with a complex environmental issue. You can formulate the relevant questions, find answers (supported by discussions, input from the lecturers and the literature), and you are able to present your conclusions clearly and cautiously.
...you understand the complexity of interactions and structures in ecosystems. You know how ecosystem processes, functions and services interact and feed back across multiple spatio-temporal scales (in general, plus in depth case examples).
...you understand that biodiversity and the interaction between organisms are an integral part of ecosystems. You are aware that the link between biodiversity and process/function/service is rarely fully understood. You know how to honestly deal with this lack of understanding and can nevertheless find, critically analyse and communicate solutions.
...you understand the importance of ecosystem services for society.
...you have an overview of the methods of ecosystem research and have a deeper insight into some of them, e.g. ecosystem observation, manipulation and modelling.
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...you know how to structure your inquiry and how to proceed the analysis when faced with a complex environmental issue. You can formulate the relevant questions, find answers (supported by discussions, input from the lecturers and the literature), and you are able to present your conclusions clearly and cautiously.
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Abstract
Conservation and restoration are interdisciplinarity sciences that nonetheless are founded on fundamental ecological concepts. The course will explore the theoretical underpinnings of conservation and restoration science that inform planning and implementation, and consequent outcomes. New concepts and emerging technologies will be explored, alongside case studies that inform discussions.

Objective
Through the course, students will:

● Understand the theoretical underpinnings of conservation and restoration science.
● Consider alternative conservation concepts and approaches, and the role of science and evidence in implementing these ideas in practice.
● Appraise different conservation strategies, drawing on case studies and examples from around the world.
● Explore new and emerging technologies that can be useful to guide responsible decision making in land management decisions.
● Evaluate the future direction of conservation science, in terms of new concepts (resilience, restoration, rewilding, natural capital, de-extinction) and emerging technologies (remote sensing, AI, genetics).
● Explore conservation and restoration science and practice in the context of current societal pressures, and the prospects for biodiversity conservation in coming decades.
● Understand how responsible restoration and conservation goals should integrate local practices, customs, cultures, and economic requirements.

In this course, students will:

● Learn about the historical development of thinking in conservation and restoration ecology.
● Learn about the ecological theories underpinning conservation and restoration ecology.
● Learn about emerging statistical and analytical tools to guide effectively responsible conservation and restoration initiatives.
● Learn about the practical challenges and trade-offs in decision making that ultimately govern the success of conservation and restoration challenges around the world.
● Understand, through the exploration of case studies and site visits, differing normative and management perspectives on landscape scale conservation and restoration.

Content
2021 marked the start of the UN Decade on Ecosystem Restoration, a global initiative to conserve and restore nature for the benefit of climate change, biodiversity, and human wellbeing. As an emerging workforce enters this exponentially growing field, we hope that they will be armed with the fundamental principles that are necessary to enhance the likelihood of success.

Conservation and restoration science is a relatively young discipline, yet it has undergone substantial change in recent decades on account of changing environmental realities, new conceptual framings, and opportunities afforded by emerging technologies. As a rapidly evolving discipline, with considerable relevance and impact to environment, policy, and society, it is essential that environmental science students understand the role of science for conservation practice.

This course will explore how science and technology provide the conceptual structure and knowledge base for new approaches to conservation of biodiversity, habitats, and resources. The course will begin by examining the theoretical foundations of conservation science, and how these concepts have developed over the past century. It will examine alternative approaches to conservation ranging from traditional protected area and wildlife management systems, through to more recent concepts and approaches, including ecosystem services, natural capital, restoration, and rewilding. It will emphasize the role of new technological and analytical methods, including Earth observation, monitoring systems, AI, and genetics. Finally, the students will use a horizon scanning approach to determine the future opportunities, priorities, and constraints for conservation science and practice in our rapidly changing world.

Students will evaluate several general questions, including:

● What is conservation, and what do we want to conserve?
● What ecological theories frame conservation and restoration practice, and how can science guide conservation decisions?
● What new concepts (ecological, societal, economical) shape conservation and restoration theory and practice, and what conflicts do they engender?
● What prospects does technology offer for future conservation and restoration efforts?

Ecosystem Conservation and Restoration will provide an excellent foundation on how theoretical and applied natural and social sciences are, and can be, coupled to emerging technologies and data science to conserve and restore biodiversity and ecological functions in landscapes. For students wishing to acquire a deeper level of understanding of both science and practice in conservation and restoration, this course will serve as the prerequisite for a two-week Masters-level field course (tentatively titled Conservation, Restoration, and Landscape Management) to Scotland, being developed by the Ghazoul and Crowther labs and planned for 2023. The field course will challenge students to apply the conceptual and technical understanding gained from the Ecosystem Conservation and Restoration course, specifically by working with a variety of stakeholders involved in selected forest and landscape restoration processes in Scotland.

Literature
Current literature will be provided in due course.

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Competencies

Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies

- Analytical Competencies: fostered
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: fostered
- Project Management: assessed

Social Competencies

- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies

- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

701-1413-00L  Population and Quantitative Genetics

**Abstract**

This course is an introduction to the rapidly developing fields of population and quantitative genetics, emphasizing the major concepts and ideas over mathematical formalism. An overview is given of how mutation, genetic drift, gene flow, mating systems, and selection affect the genetic structure of populations. Evolutionary processes affecting quantitative and Mendelian characters are discussed.

**Objective**

Students are able to
- describe types and sources of genetic variation.
- describe fundamental concepts and methods of quantitative genetics.
- use basic mathematical formalism to describe major population genetic concepts.
- discuss the main topics and developments in population and quantitative genetics.
- model population genetic processes using specific computer programs.

**Content**

Population Genetics:
- Types and sources of genetic variation; randomly mating populations and the Hardy-Weinberg equilibrium; effects of inbreeding; natural selection; random genetic drift and effective population size; gene flow and hierarchical population structure; molecular population genetics: neutral theory of molecular evolution and basics of coalescent theory.

Quantitative Genetics:
- Continuous variation; measurement of quant. characters; genes, environments and their interactions; measuring their influence; response to selection; inbreeding and crossbreeding, effects on fitness; Fisher's fundamental theorem.

**Lecture notes**

Handouts

**Literature**


701-1413-01L  Ecological Genetics

**Abstract**

This course focuses on fundamental concepts and methods in ecological genetics. Topics covered include genetic diversity, natural selection, adaptation, reproductive isolation, hybridization and speciation.

**Objective**

Students are familiar with fundamental concepts in ecological genetics and with current scientific methods. They can propose strategies to study evolutionary processes in natural populations by combining their knowledge from different disciplines, including population and quantitative genetics, ecology and evolution.

**Content**

Concepts and methods for the study of genetic diversity, biodiversity, natural selection, adaptation, reproductive isolation, hybridization and speciation.

**Lecture notes**

Handouts will be provided electronically.

**Prerequisites / notice**

We recommend that you also follow the course 701-1413-00L - Population and Quantitative Genetics either in advance or in parallel.

701-0535-00L  Environmental Soil Physics/Vadose Zone Hydrology

**Abstract**

The course provides theoretical and practical foundations for understanding and characterizing physical soil properties and processes and their relevance for terrestrial ecosystems, plant growth, hydrological processes and atmospheric-gas exchange, across all relevant scales.
Objective

Students are able to:
- Characterize the different soils based on their key textural and structural properties.
- Simulate and predict soil water retention and flow under varying environmental conditions and understand the key driving forces (capillarity, gravity, friction) and related water properties (surface tension and viscosity).
- Predict soil hydraulic properties for varying soil textural classes.
- Predict solute transport in soils for varying environmental conditions.
- Predict energy balance and temperature dynamics in soils.
- Predict conditions for plant water stress
- Estimate the impact of soil properties on the hydrological cycle and on plant growth.

Content

INTRODUCTION
Week 1 (September 18)
Presentation of the role of soil physics in environmental sciences and terrestrial ecosystems: soils in the water cycle; soils and vegetation; soils and solute transport. Survey on students’ interests and expectations. Presentation of course structure and learning objectives.

BASIC SOIL PROPERTIES
Week 2 (September 25) and Week 3 (October 02)
soil texture, particle size distribution, soil structure, soil surface area, porosity and bulk density
Pore scale consideration (water in a single pore), pore sizes and shapes; surface tension; Young-Laplace equation; capillary rise; contact angle
Friction and laminar flow; Hagen-Poiseuille’s law; Washburn equation; numerical lab (REPORT 1)

SOIL HYDRAULIC PROPERTIES
Week 4 (October 09) and Week 5 (October 16)
Soil water content and soil water potential - The energy state of soil water; total water potential and its components; volumetric and gravimetric water contents; field capacity and wilting point
Soil water characteristics and pore size distribution
Saturated water flow in soils - Laminar flow in tubes (Poiseuille’s Law); Darcy’s Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts; effective conductivity; unsaturated hydraulic conductivity; Buckingham law.
Unsaturated water flow in soils - Unsaturated hydraulic conductivity models and applications

TOOLBOX – MEASUREMENTS AND MODELING
Week 6 (October 23) and Week 7 (October 30)
Measuring soil hydraulic properties, fitting and interpretation; Lab tour - demonstration of soil physical methods; lecture on HYPROP method; report on Hyprop data (REPORT 2)
Modelling unsaturated water flow based on Richards equation - Using Hydrus1D for simulation of unsaturated flow; simulating HYPROP measurements (REPORT 3)

SOIL IN THE WATER CYCLE
Week 8 (November 06) – Week 9 (November 13)
Water infiltration - steady state solutions for infiltration; approximate solutions to infiltration (Green-Ampt, Philip); infiltration rate and ponding; outlook to preferential flow
Water evaporation - Energy balance and land atmosphere interactions - potential and actual evaporation, evaporation stages;

SOIL PLANT INTERACTIONS
Week 10 (November 20) Week 11 (November 27)
Root water uptake and transpiration – Theory and mechanisms controlling root water uptake; hydraulic properties of rhizosphere; plant and stomatal conductance.
Modelling root water uptake and transpiration; analytical approaches and modeling using Hydrus (REPORT 4)

SOLUTE TRANSPORT
Week 12 (December 04) Week 13 (December 11)
Transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application
Transport of reactive substances, preferential flow, simulations with Hydrus

CLOSURE
Week 14 (December 18)
Summary, course synthesis, connections between the different topics, questions, exam preparation

Literature

Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Leadership and Responsibility: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Abstract

The course is an introduction to Landscape Ecology and Landscape Modelling and provides various practical applications of Landscape Ecology in nature and landscape management.

Objective

The students are able to:
- to explain and apply the concepts and methods of landscape analysis using examples,
- to explain causes and effects of changes in landscape using examples and simulations,
- to describe practical applications of Landscape Ecology in the management of nature and landscape.
Contents of the lecture:
- important terms and concepts of Landscape Ecology,
- analysis of landscape pattern (metrics),
- landscape modelling,
- perception of landscapes,
- landscape inventories used for nature and landscape protection.

Lecture notes
The course is offered via a MOOC (Edx)

In the MOOC

This lecture is coordinated with a MOOC.

It is advantageous but not required to have some GIS knowledge for this lecture and the practical ‘Praktikum Wald und Landschaft’ (spring semester) which is loosely linked with this lecture.

Seminar for Bachelor Students: Forest and Landscape

Abstract
Interdisciplinary seminar on forest and landscape issues with particular emphasis on the key processes shaping the development of forest ecosystems and landscapes. Students perform literature researches, and train presentation and moderation techniques as well as a constructive feedback culture.

Objective
- To critically analyze and discuss original scientific articles for selected processes and methods in relation to forest and landscape.
- Scientific exchange with subject-specific experts.
- Learn standard rhetoric and moderation methods through training in the seminar.
- Effective feedback regarding the independent development of presentation and moderation competencies.

Content
Seminars will deal with the following topics: 1) Biological, ecological and physical processes, and technical aspects in forest ecosystems with effects on the community, ecosystem and landscape; 2) Social and political processes and institutions with relation to land use; 3) Products and services of forest ecosystems and landscapes and 4) Forest management systems. The contributions will be grouped by topics. Furthermore, the seminar teaches rhetoric and moderation methods, which will serve to deepen the above topics through presentations and discussions.

Literature references will be provided by the lecturers.

The credits are assigned if the following requirements are met
a) Independent literature research on the topic and exchange with experts for preparing for the presentation
b) Presentation with questions and answers (15-20 min)
c) Moderation of the scientific discussion (20-35 min)
d) Actively contributing to the feedback of students' presentations, moderation and discussions.

The presentations can be made in German or English. We expect a regular and active participation.

Competencies

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<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
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<td>Techniques and Technologies</td>
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<td></td>
<td>Analytical Competencies</td>
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<td></td>
<td>Media and Digital Technologies</td>
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<td>Communication</td>
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<td>Social Competencies</td>
<td>Cooperation and Teamwork</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Personal Competencies</td>
<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Self-awareness and Self-reflection</td>
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<td></td>
<td>Self-direction and Self-management</td>
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</table>

Forest Ecology

Abstract
This course conveys the basics of forest ecology with an emphasis on trees as those organisms that dominate the physiognomy and the dynamics of forest ecosystems. Based on this course, students have a good grasp of the qualitative and quantitative importance of forest ecosystems at the global and regional scales, with a focus on central Europe.

Objectives
Students are able to
- summarize the fundamentals of forest ecology at the autecological, demecological and synecological level
- explain how trees dominate the physiognomy and dynamics of forest ecosystems
- describe the qualitative and quantitative importance of forest ecosystems at the global and regional scales, with an emphasis on central Europe and Alpine region.

Overall, the competences of process understanding, system understanding, modeling, concept development and data analysis & interpretation are taught and examined in this course.

Content
Introduction and overview of the forests of the world
- Forest ecosystem ecology: Production ecology of forests
- Autecology: light, temperature, wind, water, and nutrients
- Demecology: regeneration ecology, forest growth, mortality
- Demography: fundamentals of trophic interactions (forest-ungulate interactions), succession

Lecture notes
Handouts are available for download from https://fe.ethz.ch/studium/lehrmaterialien/bachelor/waldoekologie.html.

Literature

The contents of the following courses of the 2nd year of the USYS BSc are required:
- Pedosphere, Hydrosphere, Fundamentals of biology and ecology, IntRODUCTION to dendrology (knowledge of European tree species).

Competencies

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<tr>
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<td>Techniques and Technologies</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
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</table>

Principles of Natural Hazard Management

Abstract
This course provides an overview of the main natural hazards and their importance in a national and international context. The probability, risk and implications of various natural hazards will be discussed, along with potential management options. The course consists of introductory lectures and exercises, seminars with guest lectures by experts and a field trip.
By the end of the course, students will be able to:

- explain the main natural hazards, their processes and their importance in different contexts.
- describe the likelihood, risk, and consequences of natural hazards and their management options.
- identify and discuss the development of natural hazards in the context of climate change.

The Bachelor's thesis is written either in the area of "Social Sciences and Humanities" or in the area of "Natural Sciences and Technology".

A Bachelor's thesis in the field of "Social Sciences and Humanities" usually deals with a question at the interface of these sciences and the environment and sustainability. Social science and humanities methods of data collection, analysis and interpretation are used. A Bachelor's thesis in the field of "Natural Sciences" deals with a topic at the interface of the natural sciences and the environment and sustainability. Natural science methods of data collection, analysis and interpretation are used. A thesis in the field of "technology" deals with the environmental impact of a use. It can be an analysis, an assessment or the future design of a use.

In interdisciplinary or transdisciplinary work, findings from different disciplines are brought together on the basis of an overarching question, or social actors are included in the work.
<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Environmental Sciences Master
► Major in Atmosphere and Climate
► Prerequisites

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0471-01L</td>
<td>Atmospheric Chemistry</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Ammann, C. Heald, C. Mohr</td>
</tr>
</tbody>
</table>

**Abstract**
This course covers the chemical and physical processes controlling the composition of the troposphere and stratosphere and introduces the relevant fundamentals for processes in the gas phase, in aerosols and clouds. These concepts are explored in the context of key environmental issues, such as urban air pollution, stratospheric ozone depletion, and air quality connections to climate change.

**Objective**
At the end of this course, students are able to:
1. describe the structure of the atmosphere and list atmospheric components and their main properties
2. define and describe the chemical and physical processes in the stratosphere and troposphere, follow reaction mechanisms, and apply rate laws
3. describe the physical and chemical principles of air pollution and summarize the most important legislative measures
4. discuss the local, regional, and global aspects of interactions between air quality, ecosystem health, and climate

**Content**
- Origin and properties of the atmosphere: composition (gases and aerosols), atmospheric structure, UV radiation, transport timescales
- Kinetics of gas phase reactions: rate laws, mechanisms of bimolecular and termolecular reactions.
- Stratospheric chemistry: Chapman cycle, catalytic ozone destruction cycles, polar ozone hole, Montreal protocol
- Tropospheric chemistry: oxidizing capacity of the troposphere and the role of OH, oxidation and global budgets of CO and CH4, role of NOx, and the global tropospheric O3 budget
- Surface ozone chemistry; HOx-NOx cycle, role of VOCs, O3 isopleth, ozone production efficiency
- Aerosols: primary and secondary sources, composition, quantities and measures, connections to climate
- Multiphase chemistry: solubility of gases, Raoult’s Law and hygroscopicity, kinetics of gas to particle transfer, N2O5 chemistry, aqueous phase sulfur chemistry, secondary organic aerosol formation

**Lecture notes**
Lecture materials (slides) are provided continuously during the semester, at least 2 days before each lecture. Annotations and corrections are provided at the latest within the same week.

**Prerequisites / notice**
Attendance of the lecture "Atmosphäre" LV 701-0023-00L or equivalent knowledge is a pre-requisite, and basic courses in physics and chemistry are expected.

**Competencies**
- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies
- Personal Competencies: Creative Thinking

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<tr>
<th>Number</th>
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<tr>
<td>701-0473-00L</td>
<td>Satellite Systems</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. A. Sprenger, I. Thurnherr</td>
</tr>
</tbody>
</table>

**Abstract**
Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; Potential Vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer; water isotopes

**Objective**
The students are able to:
- Explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- To explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
- To explain how mountains influence the atmospheric flow on different scales
- To discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- To explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
- To explain how mountains influence the atmospheric flow on different scales
- Basic understanding of stable water isotopes as tracers for moist adiabatic processes in weather systems

**Content**
Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; Potential Vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer; water vapour transport in the atmosphere; water isotopes

**Lecture notes**
Lecture notes and slides

**Prerequisites / notice**
Basic physics

**Competencies**
- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies
- Social Competencies: Cooperation and Teamwork
- Personal Competencies: Creative Thinking

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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>701-0475-00L</td>
<td>Atmospheric Physics</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>U. Lohmann</td>
</tr>
</tbody>
</table>

**Abstract**
This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation, especially prediction of showers and severe convective storms, and optical phenomena

**Objective**
Students are able to:
- Explain the mechanisms of convective storm formation using knowledge of thermodynamics and cloud microphysics.
- To interpret precipitation radar images
- To explain the significance of clouds and aerosol particles for artificial weather modification

In the course "Atmospheric Physics", the competencies of process understanding, system understanding and data analysis & interpretation are taught, applied and examined. Measurement methods are taught as well.
Content

The course starts with introducing selected concepts of thermodynamics for atmospheric processes; The students learn the concept of the thermodynamic equilibrium and derive the Clausius-Clayperon equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Students also learn to use thermodynamic charts (tephigrams) and to identify cloud base, cloud top, available convective energy in radiosonde ascents. Atmospheric mixing processes are introduced as a basis for fog formation. The concept of an air parcel is used to understand convection.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

With these basics, the different forms of precipitation (convective vs. stratiform) are discussed and how they can be identified in radar images. Students will also learn under which conditions severe convective storms (especially supercells with tornados) can form.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

The students are exposed to different atmospheric science topics and learn how to take part in scientific discussions.

We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments. There is an additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.

Prerequisites / notice

pdf-files of the revised book will be provided on moodle on a chapter-by-chapter basis.

Lecture notes

Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=20400

Literature


An electronic version of this book can be obtained via the ETH library.

Introduction Course to Master Studies Atmosphere and Climate

Students take part of the scientific discussions.

In several self-assessment and networking workshops they get to know each other and obtain general information and guidance about the organisation of the MSc programme.

We assess students' needs and discuss options for training and education of soft-skills during the Master program and to give an overview of the study options in general.

Mandatory Courses

Introduction Course

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<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-1213-00L</td>
<td>Introduction Course to Master Studies Atmosphere and Climate</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>H. Joos</td>
</tr>
</tbody>
</table>

Abstract

New master students are introduced to the atmospheric and climate research field through keynotes given by the programme's professors. In several self-assessment and networking workshops they get to know each other and obtain general information and guidance about the organisation of the MSc programme.

Objective

The aims of this course are i) to welcome all students to the master program and to ETH, ii) to acquaint students with the faculty teaching in the field of atmospheric and climate science at ETH and at the University of Bern, iii) that the students get to know each other and iv) to assess needs and discuss options for training and education of soft-skills during the Master program and to give an overview of the study options in general.

Colloquia

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<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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</table>

Abstract

The colloquium is a series of scientific talks by prominent invited speakers assembling interested students and researchers from around Zürich. Students take part of the scientific discussions.

Objective

The students are exposed to different atmospheric science topics and learn how to take part in scientific discussions.

Colloquium Atmosphere and Climate 2

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
</table>

Abstract

The colloquium is a series of scientific talks by prominent invited speakers assembling interested students and researchers from around Zürich. Students take part of the scientific discussions.

Objective

The students are exposed to different atmospheric science topics and learn how to take part in scientific discussions.

Colloquium Atmosphere and Climate 3

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<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
</table>
The colloquium is a series of scientific talks by prominent invited speakers assembling interested students and researchers from around Zürich. Students take part of the scientific discussions.

The students are exposed to different atmospheric science topics and learn how to take part in scientific discussions.

- **Seminars**

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<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-1211-01L</td>
<td>Master’s Seminar: Atmosphere and Climate 1</td>
<td>O</td>
<td>3 credits</td>
<td>2S</td>
<td>H. Joos, R. Knutti, A. Merrifield Könz, M. A. Wüest</td>
</tr>
<tr>
<td>701-1211-02L</td>
<td>Master’s Seminar: Atmosphere and Climate 2</td>
<td>O</td>
<td>3 credits</td>
<td>2S</td>
<td>H. Joos, R. Knutti, A. Merrifield Könz, M. A. Wüest</td>
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</table>

- **Weather Systems and Atmospheric Dynamics**

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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-1221-00L</td>
<td>Dynamics of Large-Scale Atmospheric Flow</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>H. Wernli, J. Riboldi</td>
</tr>
</tbody>
</table>

Data: 15.06.2024 12:39          Autumn Semester 2024          Page 2458 of 2653
The Planetary Boundary Layer (PBL) constitutes the lower part of the atmosphere, is characterized by turbulent mixing and ensures the exchange of energy, mass and momentum between the Earth’s surface and the atmosphere. The course provides the theoretical background for understanding the structure and dynamics of the PBL. Idealized concepts are reviewed and contrasted to real world applications.

**Objective**

Students are able to:
- Name the basic approaches needed to describe planetary boundary layer flows and associated turbulent exchange processes.
- Apply these concepts to answer comprehension questions and solve simple problems related to the structure and dynamics of the PBL.
- Independently judge the applicability of learned concepts and tools to real-world situations.

**Content**

- Introduction
- PBL structure and stability
- Turbulence and turbulent transport
- Scaling and similarity theory
- Spectral characteristics
- Conservation equations in a turbulent flow
- Closure problem and closure assumptions
- Rough surfaces and the roughness sublayer
- Complex terrain

**Prerequisites / notice**

Umwelt-Fluidodynamik (701-0479-00L) (environment fluid dynamics) or equivalent and basic knowledge in atmospheric science

**Competencies**

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies
- Decision-making
- Problem-solving

**Personal Competencies**

- Creative Thinking

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**Climate Processes and Feedbacks**

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</thead>
<tbody>
<tr>
<td>701-1235-00L</td>
<td>Cloud Microphysics</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>Z. A. Kanji, J. Chen, C. Zhang</td>
</tr>
</tbody>
</table>

The lecture takes place if a minimum of 7 students register for it.

Priority is given to PhD students majoring in Atmospheric and Climate Sciences, and remaining open spaces will be offered to the following groups:
- Msc in Atmospheric and Climate Science
- MSc in Environmental Sciences
- Fachstudent, University of Bern / MSc in Climate Sciences, University of Bern
- Mobility-Students: Earth and Climate Sciences
- Mobility-Students: Environmental Sciences

All participants will be on the waiting list at first. All students will be informed on September 18th, 2023, if they can participate in the lecture. Students still on the waiting list on September 18, are nonetheless encouraged to come to the introductory lecture on September 19. If more spaces become available later in the week due to drop outs, waitlisted students will be admitted into the course.

**Abstract**

Clouds are a fascinating atmospheric phenomenon central to the hydrological cycle and the Earth’s climate. Interactions between cloud particles can result in precipitation, glaciation or evaporation of the cloud depending on its microstructure and microphysical processes.

**Objective**

The learning objective of this course is that students understand the formation of clouds and precipitation and can apply learned principles to interpret atmospheric observations of clouds and precipitation.

**Content**


**Lecture notes**

This course will be designed as a reading course in 1-2 small groups of 10-12 students maximum. It will be based on the textbook below.

**Literature**

Lamb and Verlinde: PHYSICS AND CHEMISTRY OF CLOUDS, Cambridge University Press, 2011

**Prerequisites / notice**

Target group: Doctoral and Master students in Atmosphere and Climate. A couple spots will be reserved for mobility students.

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**Climate Processes and Feedbacks**

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<th>Number</th>
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</thead>
<tbody>
<tr>
<td>701-1251-00L</td>
<td>Land-Climate Dynamics</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>S. I. Seneviratne, R. Padrón Flasher, P. Sieber</td>
</tr>
</tbody>
</table>

The purpose of this course is to provide fundamental background on the role of land surface processes (vegetation, soil moisture dynamics, land energy, water and carbon balances) in the climate system. The course consists of 2 contact hours per week, including lectures, group projects and computer exercises.

**Objective**

The students can understand the role of land processes and associated feedbacks in the climate system.

**Lecture notes**

Powerpoint slides will be made available
Prerequisites / notice
Prerequisites: Introductory lectures in atmospheric and climate science
and/or

Atmospheric Composition and Cycles

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<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1239-00L</td>
<td>Aerosols I: Physical and Chemical Principles</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>M. Gysel Beer, D. Bell, E. Weingartner</td>
</tr>
</tbody>
</table>

Abstract
Aerosols I deals with basic physical and chemical properties of aerosol particles. The importance of aerosols in the atmosphere and in other fields is discussed.

Objective
Physical and chemical principles:
The students...
- know the processes and physical laws of aerosol dynamics.
- understand the thermodynamics of phase equilibria and chemical equilibria.
- know the photo-chemical formation of particulate matter from inorganic and organic precursor gases.

Experimental methods:
The students...
- know the most important chemical and physical measurement instruments.
- understand the underlying chemistry and physics.

Environmental impacts:
The students...
- know the major sources of atmospheric aerosols, their chemical composition and key physical properties.
- know the most important climate impacts of atmospheric aerosols.
- are aware of the health impacts of atmospheric aerosols.

Lecture notes
material is distributed during the lecture

Literature

Climate History and Paleoclimatology

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<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>651-4057-00L</td>
<td>Climate History and Palaeoclimatology</td>
<td>W</td>
<td>4 credits</td>
<td>2G</td>
<td>H. Stoll, I. Hernández Almeida</td>
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</tbody>
</table>

Abstract
Climate history and paleoclimatology explores how the major features of the earth's climate system have varied in the past, and the driving forces and feedbacks for these changes. The major topics include the earth's CO2 concentration and mean temperature, the size and stability of ice sheets and sea level, the amount and distribution of precipitation, and the ocean heat transport.

Objective
The student will be able to describe the natural factors that led to variations in the earth's mean temperature, the growth and retreat of ice sheets, and variations in ocean and atmospheric circulation patterns, including feedback processes. Students will be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geological records. Students will be able to use data from climate proxies to test if a given hypothesized mechanism for the climate change is supported or refuted. Students will be able to compare the magnitudes and rates of past changes in the carbon cycle, ice sheets, hydrological cycle, and ocean circulation, with predictions for climate changes over the next century to millennia.
The course spans 5 thematic modules:

1. Cyclic variation in the earth's orbit and the rise and demise of ice sheets. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth's ice sheets and the consequent effect on sea level? How do cyclic variations in the earth's orbit affect the size of ice sheets under modern climate and under past warmer climates? What conditions the mean size and stability or fragility of the large polar ice caps and is their evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? How stable or fragile is the ocean heat conveyor, past and present?
2. Feedbacks on climate cycles from CO2 and methane. What drives CO2 and methane variations over glacial cycles? What are the feedbacks with ocean circulation and the terrestrial biosphere?
3. Atmospheric circulation and variations in the earth's hydrological cycle - How variable are the earth's precipitation regimes? How large are the orbital scale variations in global monsoon systems?
4. Century-scale droughts and civil catastrophes. Will mean climate change El Nino frequency and intensity? What factors drive change in mid and high-latitude precipitation systems? Is there evidence that changes in water availability have played a role in the rise, demise, or dispersion of past civilizations?
5. How sensitive is Earth's long term climate to CO2 and cloud feedbacks? What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years?

The weekly two hour lecture periods will feature lecture on these themes interspersed with short interactive tasks to apply new knowledge. Over the semester, student teams will each present in class one debate based on two scientific articles of contrasting interpretations. With flexible scheduling, students will participate in a laboratory activity to generate a new paleoclimatic record from stalagmites. Student teams will be supported by an individual tutorial meeting to assist in debate preparation and another to assist in the interpretation of the lab activity data.

Competencies

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<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Techniques and Technologies</td>
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Method-specific Competencies

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<tr>
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<tr>
<td>Problem-solving</td>
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Social Competencies

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<tr>
<th>Communication</th>
<th>assessed</th>
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<tr>
<td>Cooperation and Teamwork</td>
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Personal Competencies

| Creative Thinking | assessed |
| Critical Thinking |         |

Hydrology and Water Cycle

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tr>
<td>701-1251-00L</td>
<td>Land-Climate Dynamics</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>S. I. Seneviratne, R. Padrón Flasher, P. Sieber</td>
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</table>

Abstract

The purpose of this course is to provide fundamental background on the role of land surface processes (vegetation, soil moisture dynamics, land energy, water and carbon balances) in the climate system. The course consists of 2 contact hours per week, including lectures, group projects and computer exercises.

Objective

The students can understand the role of land processes and associated feedbacks in the climate system.

Lecture notes

Powerpoint slides will be made available.

Prerequisites / notice

Prerequisites: Introductory lectures in atmospheric and climate science

Atmospheric physics -> [link](http://www.vvz.ethz.ch/Vorlesungsverzeichnis/lerneinheitPre.do?lerneinheitId=112225&semkez=2017S&lang=en)

Climate systems -> [link](http://www.vvz.ethz.ch/Vorlesungsverzeichnis/lerneinheitPre.do?lerneinheitId=112972&semkez=2017S&lang=en)

701-1253-00L | Analysis of Climate and Weather Data | W | 3 credits | 2G | F. Isotta, R. Jinglin Wills, to be announced |

Abstract

An introduction to methods of statistical data analysis in meteorology and climatology. Applications of hypothesis testing, extreme value analysis, evaluation of predictions, principal component analysis.

Course goals: Participants understand the theoretical concepts and purpose of methods, can apply them independently, and know how to interpret results professionally.

Objective

Students understand the theoretical foundations and probabilistic concepts of advanced analysis tools in meteorology and climatology. They can conduct such analyses independently, and they develop an attitude of scrutiny and an awareness of uncertainty when interpreting results. Participants improve skills in understanding technical literature that uses modern statistical data analyses.

Content

The course introduces several advanced methods of statistical data analysis frequently used in meteorology and climatology. It introduces the theoretical background of the methods, illustrates their application with example datasets, and discusses complications from assumptions and uncertainties. Generally, the course shall empower students to conduct data analysis thoughtfully and to interpret results critically.

Topics covered: exploratory methods, hypothesis testing, analysis of climate trends, measuring the skill of deterministic and probabilistic predictions, analysis of extremes, principal component analysis and maximum covariance analysis, detection and attribution.

The course is divided into lectures and computer workshops. Hands-on experimentation with example data shall encourage students in the practical application of methods and train professional interpretation of results.

R (a free software environment for statistical computing) will be used during the workshop. A short introduction into R will be provided during the course.

Lecture notes

Documentation and supporting material:
- slides used during the lecture
- exercise sets and solutions
- R-packages with software and example datasets for workshop sessions

All material is made available via the lecture web-page.

Literature

For complementary reading:

Prerequisites / notice

Prerequisites: Basics in exploratory data analysis, probability calculus and statistics (incl linear regression) (e.g. Mathematik IV: Statistik (401-0624-00L) and Mathematik VI: Angewandte Statistik für Umwelt Naturwissenschaften (701-0105-00L)). Some experience in programming (ideally in R). Some elementary background in atmospheric physics and climatology.

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Mountain Hydrology

**Abstract**
This course presents a process-based view of the hydrology of mountain streams. Students learn how to integrate process knowledge, data, and models to understand how landscapes regulate the fluxes of water, sediment, nutrients, and pollutants in streams, and to anticipate how streams will respond to changes in land use, water use, and climate.

**Objective**
Main learning objective: Describe the main elements and processes and their interlinkages of the water cycle in mountain catchments and analyze their characteristics and changes.

**Objective 1:** Identify and describe the important components of the water cycle and their influencing factors and discuss how changes in these influencing factors may affect different parts of the hydrological cycle.

**Objective 2:** Analyse, visualize, and interpret climate and hydrological time series data.

**Objective 3:** Explain how hydrological data are collected, how hydrological models work, how they are calibrated, and how they are evaluated.

**Content**
Streams are integrated monitors of the health and functioning of their surrounding landscapes. Streams integrate the fluxes of water, solutes, and sediment from their contributing catchment area, thus they reflect the spatially integrated hydrological, ecophysiological, biogeochemical, and geomorphological processes in the surrounding landscape. At a practical level, there is a significant public interest in managing upland landscapes to provide a reliable supply of high-quality surface water and to minimize the risk of catastrophic flooding and debris flows, but the scientific background for such management advice is still evolving.

Using a combination of lectures, field exercises, and data analysis, we explore the processes controlling the delivery of water, solutes, and sediment to streams, and how those processes are affected by changes in land cover, land use, and climate. We review the connections between process understanding and predictive modeling in these complex environmental systems. Practical problems to be considered include the effects of land use and climate on streamflow and water quality, illustrated with data from experimental watersheds in North America and Europe.

**Lecture notes**
Handouts will be available through moodle.

**Literature**
Recommended and required reading will be specified at the first class session (with possible modifications as the semester proceeds).

**Competencies**

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<tr>
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<td>Problem-solving</td>
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<td>Social Competencies</td>
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<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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**Watershed Modelling**

**Abstract**
Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

**Objective**
The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies. A comprehensive exercise task block builds on the lectures with a series of 4 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 50% by performance in the graded exercises and 50% by a semester-end oral examination (30 mins) on watershed modelling concepts.

**Content**
The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models, students build their own simple bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focused on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models at larger scales. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns.

**Lecture notes**
There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

**Literature**
Literature consists of collections from standard hydrological textbooks and research papers, collected by the instructors on the course moodle page.

**Prerequisites / notice**
Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences), Basic knowledge of Matlab (Python), ArcGIS (Q-GIS).

**Competencies**

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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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The Planetary Boundary Layer (PBL) constitutes the lower part of the atmosphere, is characterized by turbulent mixing and ensures the exchange of energy, mass and momentum between the Earth’s surface and the atmosphere. The course provides the theoretical background for understanding the structure and dynamics of the PBL. Idealized concepts are reviewed and contrasted to real world applications.

Students are able to:
- Name the basic approaches needed to describe planetary boundary layer flows and associated turbulent exchange processes.
- Apply these concepts to answer comprehension questions and solve simple problems related to the structure and dynamics of the PBL.
- Independently judge the applicability of learned concepts and tools to real-world situations.

At the end of this course, participants should:

Creative Thinking:
- Introduction
- PBL structure and stability
- Turbulence and turbulent transport
- Scaling and similarity theory
- Spectral characteristics
- Conservation equations in a turbulent flow
- Closure problem and closure assumptions
- Rough surfaces and the roughness sublayer
- Complex terrain

Prerequisites / notice
Umwelt-Fluiddynamik (701-0479-00L) (environment fluid dynamics) or equivalent and basic knowledge in atmospheric science

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<tr>
<td>701-1257-00L</td>
<td>European Climate Change</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>E. Fischer, J. Rajczak, S. C. Scherrer</td>
</tr>
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</table>

Abstract
The lecture provides an overview of climate change in Europe, from a physical and atmospheric science perspective. It covers the following topics:
- observational datasets, observation and detection of climate change;
- underlying physical processes and feedbacks;
- numerical and statistical approaches;
- currently available projections.

Objective
At the end of this course, participants should:
- understand the key physical processes shaping climate change in Europe;
- know about the methodologies used in climate change studies, encompassing observational, numerical, as well as statistical approaches;
- be familiar with relevant observational and modeling data sets;
- be able to tackle simple climate change questions using available data sets.

Content
Contents:
- global context
- observational data sets, analysis of climate trends and climate variability in Europe
- global and regional climate modeling
- statistical downscaling
- key aspects of European climate change: intensification of the water cycle, Polar and Mediterranean amplification, changes in extreme events, changes in hydrology and snow cover, topographic effects
- projections of European and Alpine climate change

Lecture notes
Slides and lecture notes will be made available at http://www.iac.ethz.ch/edu/courses/master/electives/european-climate-change.html

Prerequisites / notice
Participants should have a background in natural sciences, and have attended introductory lectures in atmospheric sciences or meteorology.

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<tr>
<td>651-4041-00L</td>
<td>Sedimentology I: Physical Processes and Sedimentary Systems</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>V. Picotti</td>
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Abstract
Sediments preserved a record of past landscapes. This course focuses on understanding the processes that modify sedimentary landcapes with time and how we can read this changes in the sedimentary record.

Objective
The students learn basic concepts of modern sedimentology and stratigraphy in the context of sequence stratigraphy and sea level change.
They discuss the advantages and pitfalls of the method and look beyond. In particular we pay attention to introducing the importance of considering entire sediment routing systems and understanding their functioning.

Content
Details on the program will be handed out during the first lecture.

Literature
The sedimentary record of sea-level change
Angela Coe, the Open University. Cambridge University Press

Prerequisites / notice
The grading of students is based on in-class exercises and end-semester examination.

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<tbody>
<tr>
<td>651-4043-00L</td>
<td>Sedimentology II: Biological and Chemical Processes in Lacustrine and Marine Systems</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>V. Picotti, A. Gilli, I. Hernández Almeida, H. Stoll</td>
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</table>

Pre requisite: Successful completion of the MSc-course "Sedimentology I" (651-4041-00L).
Abstract
The course will focus on biological and chemical aspects of sedimentation in marine environments. Marine sedimentation will be traced from coast to deep-sea. The use of stable isotopes for palaeoceanography will be discussed. Neritic, hemipelagic and pelagic sediments will be used as proxies for environmental change during times of major perturbations of climate and oceanography.

Objective
- You will understand the chemistry and biology of marine carbonate systems.
- You will be able to relate carbonate mineralogy with facies and environmental conditions.
- You will be familiar with cool-water and warm-water carbonate facies.
- You will see carbonate and organic-carbon rich sediments as part of the global carbon cycle.
- You will be able to recognize links between climate and marine carbonate systems (e.g., acidification of oceans and reef growth).
- You will be able to use geological archives as sources of information on global change.
- You will have an overview of marine sedimentation through time.

Content
- Carbonates, chemistry, mineralogy, biology
- Carbonate sedimentation from the shelf to the deep sea
- Carbonate facies
- Cool-water and warm-water carbonates
- Organic-carbon and black shales
- C-cycle, carbonates, Corg : CO2 sources and sinks
- Carbonates: their geochemical proxies for environmental change: stable isotopes, Mg/Ca, Sr
- Marine sediments through geological time
- Carbonates and evaporites
- Lacustrine carbonates
- Economic aspects of limestone

Lecture notes
No script. Scientific articles will be distributed during the course.

Prerequisites / notice
We will read and critically discuss scientific articles relevant for "biological and chemical processes in marine and lacustrine systems".

651-4049-00L Conceptual and Quantitative Methods in Geochemistry

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<tr>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>G. De Souza, B. J. Peters</th>
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</table>

Abstract
This course will introduce some of the main quantitative methods available for the quantitative treatment of geochemical data, as well as the main modelling tools. Emphasis will both be on conceptual understanding of these methods as well as on their practical application, using key software packages to analyse real geochemical datasets.

Objective
Development of a basic knowledge and understanding of the main tools available for the quantitative analysis of geochemical data.

Content
The following approaches will be discussed in detail: major and trace element modelling of magmas, with application to igneous systems; major element modelling of weathering products; isotopic applications in tectonics.

651-4901-00L Quaternary Dating Methods

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<th>W</th>
<th>2 credits</th>
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<th>I. Hajdas</th>
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Abstract
Reconstruction of time scales is critical for all Quaternary studies in Geology and Archeology. Various methods are applied depending on the time range of interest and the archive studied. In this lecture, we focus on the last 50 ka and the methods that are most frequently used for dating Quaternary sediments and landforms in this time range.

Objective
Students will be made familiar with the details of the six dating methods through lectures on basic principles, analysis of case studies, solving of problem sets for age calculation and visits to dating laboratories.

Content
1. Introduction: Isotopes and decay
2. Radiocarbon dating: principles and applications
3. AMS technique and its application in Quaternary geochronology
4. U-series disequilibrium dating
5. Luminescence dating
6. Introduction to incremental: varve counting, dendrochronology, and ice cores chronologies
7. Dating anthropogenic records

Prerequisites / notice
Visit to radiocarbon lab, cosmogenic nuclide lab, and accelerator (AMS) facility.

Optional (individual): 1-5 days of hands-on radiocarbon dating at the 14C lab, ETH Hoengerberg.
The course provides theoretical and practical foundations for understanding and characterizing physical soil properties and processes and their relevance for terrestrial ecosystems, plant growth, hydrological processes and atmospheric-land gas exchange, across all relevant scales.

Objective

Students are able to:
- Characterize the different soils based on their key textural and structural properties.
- Simulate and predict soil water retention and flow under varying environmental conditions and understand the key driving forces (capillarity, gravity, friction) and related water properties (surface tension and viscosity).
- Predict soil hydraulic properties for varying soil textural classes.
- Predict solute transport in soils for varying environmental conditions.
- Predict energy balance and temperature dynamics in soils.
- Predict conditions for plant water stress
- Estimate the impact of soil properties on the hydrological cycle and on plant growth.

Content

INTRODUCTION
Week 1 (September 18)
Presentation of the role of soil physics in environmental sciences and terrestrial ecosystems: soils in the water cycle; soils and vegetation; soils and solute transport. Survey on students’ interests and expectations. Presentation of course structure and learning objectives.

BASIC SOIL PROPERTIES
Week 2 (September 25) and Week 3 (October 02)
Soil texture, particle size distribution, soil structure, soil surface area, porosity and bulk density
Pore scale consideration (water in a single pore), pore sizes and shapes; surface tension; Young-Laplace equation; capillary rise; contact angle
Friction and laminar flow; Hagen-Poiseuille’s law; Washburn equation; numerical lab (REPORT 1)

SOIL HYDRAULIC PROPERTIES
Week 4 (October 09) and Week 5 (October 16)
Soil water content and soil water potential - The energy state of soil water; total water potential and its components; volumetric and gravimetric water contents; field capacity and wilting point
Soil water characteristics and pore size distribution
Saturated water flow in soils - Laminar flow in tubes (Poiseuille’s Law); Darcy's Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts; effective conductivity; unsaturated hydraulic conductivity; Buckingham law.
Unsaturated water flow in soils - Unsaturated hydraulic conductivity models and applications

TOOLBOX – MEASUREMENTS AND MODELING
Week 6 (October 23) and Week 7 (October 30)
Measuring soil hydraulic properties, fitting and interpretation; Lab tour - demonstration of soil physical methods; lecture on HYPROP method; report on Hyprop data (REPORT 2)
Modelling unsaturated water flow based on Richards equation - Using Hydrus1D for simulation of unsaturated flow; simulating HYPROP measurements (REPORT 3)

SOIL IN THE WATER CYCLE
Week 8 (November 06) – Week 9 (November 13)
Water infiltration - steady state solutions for infiltration; approximate solutions to infiltration (Green-Ampt, Philip); infiltration rate and ponding; outlook to preferential flow
Water evaporation - Energy balance and land atmosphere interactions - potential and actual evaporation, evaporation stages;

SOIL PLANT INTERACTIONS
Week 10 (November 20) Week 11 (November 27)
Root water uptake and transpiration – Theory and mechanisms controlling root water uptake; hydraulic properties of rhizosphere; plant and stomatal conductance.
Modelling root water uptake and transpiration; analytical approaches and modeling using Hydrus (REPORT 4)

SOLUTE TRANSPORT
Week 12 (December 04) Week 13 (December 11)
Transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application
Transport of reactive substances, preferential flow, simulations with Hydrus

CLOSURE
Week 14 (December 18)
Summary, course synthesis, connections between the different topics, questions, exam preparation

Literature
Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Leadership and Responsibility fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

102-0287-00L River Basin Erosion W 3 credits 2G P. Molnar
The course presents a view of the catchment processes of sediment production and transport that shape the landscape. Focus is on sediment fluxes from sources on hillslopes to the river network. Students learn about how a fluvial system functions, how to identify sediment sources and sinks, how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change.

Objective

The course has two fundamental aims: (1) The first aim is to provide environmental engineers with the physical process basis needed to understand fluvial forms and processes and geomorphic concepts of landscape change, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, self-organised criticality, etc. are presented. (2) Landscape evolution modelling as a tool for describing the shape of the land surface. Soil formation and sediment production at long timescales. (3) The processes of sediment production, upland sheet-riparian erosion, basin sediment yield, rainfall-triggered landsliding, sediment budgets, and the modelling of the individual processes involved. Here we combine model concepts with field observations and look at many examples. (4) Processes in the river, floodplain and riparian zone, including river network topology, channel geometry, aquatic habitat, role of riparian vegetation, including basics of fluvial system management. The main focus of the course is on the hydrology-sediment connections at the field and catchment scale.

Content

The course consists of four sections: (1) Introduction to fluvial forms and processes and geomorphic concepts of landscape change, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, self-organised criticality, etc. are presented. (2) Landscape evolution modelling as a tool for describing the shape of the land surface. Soil formation and sediment production at long timescales. (3) The processes of sediment production, upland sheet-riparian erosion, basin sediment yield, rainfall-triggered landsliding, sediment budgets, and the modelling of the individual processes involved. Here we combine model concepts with field observations and look at many examples. (4) Processes in the river, floodplain and riparian zone, including river network topology, channel geometry, aquatic habitat, role of riparian vegetation, including basics of fluvial system management. The main focus of the course is on the hydrology-sediment connections at the field and catchment scale.

Abstract

The course provides an introduction into quantitative analysis of groundwater flow and solute transport. It is focused on understanding, formulating, and solving groundwater flow and solute transport problems.

Objective

a) Students understand the basic concepts of groundwater flow and solute transport and boundary conditions.

b) Students are able to formulate simple, practical groundwater flow and solute transport problems.

c) Students are able to understand and apply simple analytical and/or numerical solutions to fluid flow and solute transport problems.

Content

1. Introduction to groundwater problems. Concepts to quantify properties of aquifers.

2. Flow equation. The generalised Darcy law.

3. The water balance equation and basic concepts of poroelasticity.


5. Analytical solutions to flow problems

6. Finite difference scheme solution for simple flow problems.


10. Analytical solutions to transport problems.

11. Fractured and karst aquifers.

12. The unsaturated zone and capillary pressure.

13. Examples of applied hydrogeology from Switzerland and around the world. (Given by Dr. Beatrice Marti from hydrosolutions GmbH)

Lecture notes

Handouts of slides.

Literature


de Marsily G., Quantitative Hydrogeology, Academic Press, 1986

Competencies

Subject-specific Competencies: Understanding of groundwater flow and transport processes, ability to solve simple groundwater problems using analytical or numerical methods.

Concepts and Theories: Knowledge of groundwater flow and transport theories, including Darcy's law, water balance, and mass balance equations.

Additional Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1241-00L</td>
<td>Atmospheric Remote Sensing</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>J. Gröbner, S. Kazantzis</td>
</tr>
</tbody>
</table>

Abstract

The course will provide advanced physical understanding on the fundamentals of passive and active remote sensing, measuring sensors and retrieval methods. A series of diverse remote sensing applications will be presented, including measurements/retrievals of various atmospheric composition parameters (ozone, aerosols, clouds, etc.) from surface based and satellite based instruments.

Objective

Main objectives of the course and what the students will be able to explain and use at the end of it are:

- The major atmospheric laws used for the retrieval of atmospheric composition and solar radiation parameters
- Ground based and satellite based retrieval examples for major atmospheric constituents
- Practical and experimental aspects on measuring atmospheric aerosols through the use of relevant instrumentation
- Explore major atmospheric measurement databases and use of the available data
- Interpretation of measurement and retrieval related results on atmospheric composition and solar radiation based on using combined retrieval data products
Atmospheric passive and active remote sensing is connected with a large number of applications including: atmospheric composition, Earth-atmosphere radiative balance, atmospheric and weather prediction model assimilation, agriculture, energy and health related applications and many others.

The proposed lesson is divided in three sections including exercises:

- Fundamentals of remote sensing
- Sensors (surface based and satellites) and retrieval methods
- Applications

The first aim of the lecture is to provide an in-depth understand of the physical aspects and basic laws on the fundamentals of remote sensing to the students. The lectures will provide a basic to intermediate understanding of radiative transfer of electromagnetic radiation through the atmosphere, covering the spectrum from UV to thermal. Examples of atmospheric components that will be addressed are: ozone, aerosols, greenhouse gases, clouds, water vapor.

In addition, measuring sensors used from the surface or from satellites and the relevant retrieval methods based on passive and active remote sensing of atmospheric composition will be presented (e.g. Spectroradiometers, filter radiometers, Lidars and others).

Finally, we aim to demonstrate a series of diverse remote sensing applications, including atmospheric composition measurements and retrievals from surface- and satellite-based instruments, including calibration and validation aspects.

The exercises will be embedded in the overall course lectures to provide hands-on experience with the measurements and retrieval methods conducting measurements and organizing small field experiments. Also with the use of atmospheric datasets available from specific instruments (e.g. satellite sensors) and networks (e.g. AERONET, GAWPFRR).

More specific the course include:

- 7 courses including remote sensing techniques on solar UV measurements, total column ozone, trace gases, greenhouse gases, aerosols, cloud retrievals and lidar active remote sensing.
- 3 exercises:
  a. Conducting sun photometric measurements in the field and retrieve aerosol optical depth, including a visit in Davos, World Calibration Center
  b. Exploring ground and satellite based solar UV, Ozone and aerosol measurements
  c. Using radiative transfer modeling tools

Finally, students are involved on presenting scientific literature on subjects they are interested in. All exercises are conducted in student-forming teams.

Lecture notes
Lecture slides will be provided via Moodle before every lecture.

Prerequisites / notice
none

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed
Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management fostered

Social Competencies
- Communication assessed
- Cooperation and Teamwork assessed
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

Abstract
This course offers a systematic introduction to statistical and machine learning methods with focus on applications in atmospheric and climate science. Focus is on the theoretical and mathematical basis of supervised statistical learning (advanced regression, nonparametric methods) and their application in practice with hands-on exercises.

Objective
Students:
- Understand the theoretical basis of machine learning
- Are familiar with overarching concepts such as bias-variance trade-off, cost-functions, hyper parameters, cross-validation
- Have good command of the theoretical basis of selected machine learning tools
- Are able to select the appropriate statistical learning tools to tackle atmospheric and climate research problems
- Can apply methods of statistical learning in atmospheric and climate research
- Data in atmospheric and climate research (data types, observations, models)
- Exploring properties of atmospheric and climate data (data in space and time, multivariate data)
- Concepts of supervised learning (bias variance trade-off, overfitting, cross-validation)
- Advanced linear regression (multiple linear regression, regularization)
- Non-linear regression (local linear regression, regression trees, gradient boosting, random forests, neural networks)
- Bootstrapping
- Keynote speakers showcasing recent topics in statistical learning and high-level applications for atmospheric and climate research
Students are introduced to advanced data science where environmental data are analyzed using state of the art machine learning methods. Starting from known statistical approaches, they learn the principle of more advanced machine learning methods with practical application. This course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

**Objective**

- frame a data science problem and build a hypothesis
- describe the steps from data preparation to running and evaluating models
- conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
- critically think about the limits and implications of a method
- visualise data and results throughout the workflow
- access online resources to keep up with the latest data science methodology and deepen their understanding

**Content**

- The data science workflow
- Access and handle (large) datasets
- Prepare and clean data
- Analysis: data exploratory steps
- Analysis: machine learning and computational methods
- Evaluate results and analyse uncertainty
- Visualisation and communication

**Prerequisites / notice**

- Basic experience in a programming language
- Overview on the climate system
- Knowledge of introductory statistics
- Access online resources to keep up with the latest data science methodology and deepen their understanding

**Literature**


**Competencies**

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Social Competencies**

- Communication
- Cooperation and Teamwork
- Leadership and Responsibility

**Personal Competencies**

- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-direction and Self-management

**701-3001-00L Environmental Systems Data Science: Data Processing**

- **Abstract**
  Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

- **Objective**
  The students are able to:
  - frame a data science problem and build a hypothesis
  - describe the steps from data preparation to running and evaluating models
  - conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
  - critically think about the limits and implications of a method
  - visualise data and results throughout the workflow
  - access online resources to keep up with the latest data science methodology and deepen their understanding

- **Content**
  - The data science workflow
  - Access and handle (large) datasets
  - Prepare and clean data
  - Analysis: data exploratory steps
  - Analysis: machine learning and computational methods
  - Evaluate results and analyse uncertainty
  - Visualisation and communication

- **Prerequisites / notice**
  - 252-0840-02L Anwendungsnahes Programmieren mit Python
  - 401-0624-00L Mathematik IV: Statistik
  - 401-6215-00L Using R for Data Analysis and Graphics (Part I)
  - 401-6217-00L Using R for Data Analysis and Graphics (Part II)
  - 701-0105-00L Mathematik VI: Angewandte Statistik für Umweltnaturwissenschaften

**701-3003-00L Environmental Systems Data Science: Machine Learning**

- **Abstract**
  Students are introduced to advanced data science where environmental data are analyzed using state of the art machine learning methods. Starting from known statistical approaches, they learn the principle of more advanced machine learning methods with practical application. The course enables students to plan their own data science project in their specialization and to apply machine learning methods.

- **Objective**
  The students are able to:
  - select an appropriate model related to a research question and dataset
  - describe the steps from data preparation to running and evaluating models
  - prepare data for running machine learning with dependent and independent variable
  - build and validate regressions and neural network models
  - understand convolution and deep learning models
  - access online resources to keep up with the latest data science methodology and deepen their understanding

- **Content**
  - The data science workflow
  - Data preparation for running and validating machine learning models
  - Get to know machine learning approaches including regression, random forest and neural network
  - Model complexity and hyperparameters
  - Model parameterization and loss
  - Model evaluations and uncertainty
  - Deep learning with convolutions

- **Literature**
  - Building on existing data science resources

- **Prerequisites / notice**
  - Math IV, VI (Statistics); R, Python; ESDS I

**402-0621-00L Introduction to Accelerator Mass Spectrometry**

- **Abstract**
  This course gives an introduction into Accelerator Mass Spectrometry (AMS), the most sensitive method for measuring long-lived radionuclides in natural samples.

- **Objective**
  Students learn the basic concepts of Accelerator Mass Spectrometry. Based on the underlying physics of ion matter interaction they learn the measurement methods and interpretation of the results for most of the important AMS radionuclides, e.g. radiocarbon (14C), the cosmogenic radionuclides 10Be, 26Al, 36Cl, and anthropogenic nuclides 129I, 236U other actinides.
Content

Introduction into the physics of ion matter interaction: ion stopping, ion scattering and charge exchange.

Ion optics and ion acceleration.

Mass separation, molecular destruction and isobar separation.

Ion detection and identification.

The measurement methods for all the important radionuclides and the interpretation of their results are discussed on a few examples from the application:

- 14C – radiocarbon dating and environmental studies
- 10Be, 26Al, 36Cl – cosmogenic dating and ice core research
- 129I, 238U, actinides – anthropogenic tracers in the environment
- 14C, 41Ca – biomedical studies
- 60Fe, 244Pu – astrophysics

Alternative methods: ICP-MS, RIMS, ATTA

A visit to the Tandem accelerator and AMS facilities at ETH Hönggerberg is organized as part of lectures and exercises.

Lecture notes

Lecture notes will be distributed in pdf

651-4273-00L Numerical Modelling in Fortran (Project) W 3 credits 2V P. Tackley

Abstract

This course gives an introduction to programming in Fortran, and is suitable for students who have only minimal programming experience. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts.

Objective

Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in this language, and is suitable for students who have only minimal programming experience, for example with MATLAB scripts. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts, using example scientific problems relevant to Earth science.

Lecture notes

See http://jupiter.ethz.ch/~pjt/FORTRAN/FortranClass.html

Competencies

Subject-specific Competencies: Techniques and Technologies assessed

Method-specific Competencies: Media and Digital Technologies assessed

Problem-solving assessed

651-4273-01L Numerical Modelling in Fortran (Project) W 1 credit 1U P. Tackley

Prerequisite: 651-4273-00L Numerical Modelling in Fortran

Abstract

This course gives an introduction to programming in Fortran, and is suitable for students who have only minimal programming experience. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts.

Objective

Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in this language, and is suitable for students who have only minimal programming experience, for example with MATLAB scripts. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts, using example scientific problems relevant to Earth science.

Content

The project consists of writing a Fortran program to solve a problem agreed upon between the instructor and student; the topic is often related to (and helps to advance) the student’s Masters or PhD research. The project is typically started towards the end of the end of the main Fortran class when the student has acquired sufficient programming skills, and is due by the end of Semesterprüfung week.

Lecture notes

See http://jupiter.ethz.ch/~pjt/FORTRAN/FortranProject.html

Main Courses

Biogeochemistry of Trace Elements

Biogeochemical Processes

Isotopes and Biomarkers in Biogeochemistry

Biogeochemistry of Trace Elements

701-1313-00L Isotopes and Biomarkers in Biogeochemistry W 3 credits 2G C. Schubert, N. Casacuberta Arola, R. Kipfer

Abstract

The course introduces the scientific concepts and typical applications of tracers in biogeochemistry. The course covers stable and radioactive isotopes, geochronometric tracers and biomarkers and their application in biogeochemical processes as well as regional and global cycles. The course provides essential theoretical background for the lab course "Isotopic and Organic Tracers Laboratory".

Objective

The course aims at understanding the fractionation of stable isotopes in biogeochemical processes. Students learn to know the origin and decay modes of relevant radionuclides. They discover the spectrum of possible geochemical tracers and biomarkers, their potential and limitations and get familiar with important applications

Content

Geogenic and cosmogenic radionuclides (sources, decay chains);
stable isotopes in biogeochemistry (natural abundance, fractionation);
geochronometric tracers for processes such as erosion, productivity, redox fronts; biomarkers for specific microbial processes.

Lecture notes

Handouts will be provided for every chapter

Literature

A list of relevant books and papers will be provided

Prerequisites / notice

Students should have a basic knowledge of biogeochemical processes (BSc course on Biogeochemical processes in aquatic systems or equivalent)

701-1315-00L Biogeochemistry of Trace Elements W 3 credits 2G A. Voegelin, D. Janssen, L. Winkel

Abstract

The course addresses the biogeochemical classification and behavior of trace elements, including key processes driving the cycling of important trace elements in aquatic and terrestrial environments and the coupling of abiotic and biotic transformation processes of trace elements. Examples of the role of trace elements in natural or engineered systems will be presented and discussed in the course.

Objective

The students are familiar with the chemical characteristics, the environmental behavior and fate, and the biogeochemical reactivity of different groups of trace elements. They are able to apply their knowledge on the interaction of trace elements with geosphere components and on abiotic and biotic transformation processes of trace elements to discuss and evaluate the behavior and impact of trace elements in aquatic and terrestrial systems.

Content

(i) Definition, importance and biogeochemical classification of trace elements. (ii) Key biogeochemical processes controlling the cycling of different trace elements (base metals, redox-sensitive and chalcophile elements, volatile trace elements) in natural and engineered environments. (iii) Abiotic and biotic processes that determine the environmental fate and impact of selected trace elements.

Lecture notes

Selected handouts (lecture notes, literature, exercises) will be distributed during the course.
Applications

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>701-1346-00L</td>
<td>Climate Change Mitigation: Carbon Dioxide Removal</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>N. Gruber, C. Brunner</td>
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<tr>
<td>701-1351-00L</td>
<td>Anthropogenic Particles in the Environment</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>B. Nowack, T. Bucheli, D. Mitrano</td>
</tr>
<tr>
<td>101-0339-00L</td>
<td>Environmental Geotechnics – Polluted Sites and Waste Disposal</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Plötze</td>
</tr>
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</table>

Objective

Future climate change can only kept within reasonable bounds when CO2 emissions are drastically reduced. In this course, we will discuss a portfolio of options involving the alteration of natural carbon sinks and carbon sequestration. The course includes introductory lectures, presentations from guest speakers from industry and the public sector, and final presentations by the students. The results of this research will then be presented to the other students, the involved faculty, and discussed in detail by the whole group.

Content

From the large number of carbon sequestration/mitigation options, a few options will be selected and then investigated in detail by the students.

Literature

Will be provided during lecture

Competencies

- Subject-specific Competencies:
  - Concepts and Theories
  - Techniques and Technologies
- Method-specific Competencies:
  - Analytical Competencies
  - Decision-making
  - Problem-solving
- Social Competencies:
  - Communication
  - Cooperation and Teamwork
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
  - Negotiation
- Personal Competencies:
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics

Lecture notes

None

Prerequisites / notice

Exam: No final exam. Pass/No-Pass is assigned based on the quality of the presentation and ensuing discussion.

The practice of landfilling, remediation of polluted sites and the disposal of radioactive waste are based on the same concepts of environmental protection. Understanding the contaminants behaviour and how to reduce their release to the environment is the key to remediating polluted sites and designing multi-barrier systems.

On successful completion of this course students will be able to

- Assess the risk to the environment from landfills, contaminated sites and radioactive waste repositories in terms of the fate and transport of contaminants.
- Describe the technologies available to minimise environmental contamination
- Describe the principles of dealing with polluted sites and propose and evaluate appropriate remediation techniques
- Explain the concepts underlying radioactive waste management practices.
**Methods and Tools: Lab Courses**

### Biogeochemistry of Trace Elements Laboratory

**Number:** 701-1331-00L  
**Title:** Biogeochemistry of Trace Elements Laboratory  
**Type:** W  
**ECTS:** 3 credits  
**Hours:** 4P  
**Lecturers:** P. Lefebvre, A. Grigg, M. Le Bars

**Abstract:** The course offers a practical introduction into the investigation of the biogeochemistry of trace elements. Laboratory experiments are performed to study a selected environmental process. Advanced techniques for the analysis of total element contents and element speciation are used. The experimental findings are interpreted and discussed in their environmental context.

**Objective:** The objective of this course is to offer students a practical introduction into the investigation of the biogeochemistry of trace elements. During the course, students will become familiar with some of the key experimental approaches typically used in the investigation of the biogeochemistry of trace elements in the laboratory. In addition, students will learn to use different advanced analytical techniques to measure the total content and the speciation of trace elements in both liquid and solid samples. The students will interpret and discuss their experimental findings in the context of the studied environmental system.

**Content:** Laboratory experiments are designed and performed to study the interplay of various biogeochemical processes in a specific environmental system. Moreover, the effect of these processes on the biogeochemical cycling of trace elements in the environment will be considered. Advanced techniques for the analysis of total element contents and element speciation are used. The experimental findings are interpreted and discussed in the context of the the environmental system under investigation.

**Lecture notes:** Selected handouts will be distributed during the course.

**Literature:** All necessary literature will be uploaded to moodle during the course.

**Prerequisites / notice:** Pre- or corequisite: Lecture "Biogeochemistry of Trace Elements".

**Competencies**

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Techniques and Technologies</th>
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<td>Method-specific Competencies</td>
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<td>Social Competencies</td>
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<td>Personal Competencies</td>
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### Isotopes and Biomarkers in Biogeochemistry Laboratory

**Number:** 701-1333-00L  
**Title:** Isotopes and Biomarkers in Biogeochemistry Laboratory  
**Type:** W  
**ECTS:** 3 credits  
**Hours:** 4P  
**Lecturers:** C. Schubert, R. Kipfer

**Abstract:** This course will illustrate how different tracers and isotopes are used in natural systems. Here especially the processes (transformation, timescales) that take place and can be revealed by tracers/isotopes will be demonstrated.

**Objective:** Students know how to use tracers/isotopes to investigate/understand ecosystems  
They will understand the methods and analysis related to tracer/isotope work  
Have a feeling for timescales on which natural processes occur  
Students will be able to apply different sampling techniques in aquatic sciences

**Content:** Basics:  
O,H isotopes as tracers for mixing in aquatic systems  
Carbon isotopes as tracer for methane oxidation  
210Pb, 137Cs as a tracer for sedimentation rate/mixing  
SF6, Neon, He as tracers for exchange processes at the air/water interface

**Case assessment:**  
Sampling of a Swiss lake (Rotsee)  
Sampling techniques for different elements  
Sample preparation for different techniques  
Measurements at isotope mass spectrometer/gamma counter

**Prerequisites / notice:** Sampling will take place in Rotsee (Lucerne). We will have 3 laboratory days at Eawag Kastanienbaum, 1 laboratory day at Eawag Duebendorf, and 2 days of preparation of a presentation and the presentation itself at ETH (Center). The presentation will be evaluated and is necessary to pass the class.

### Forest Soils in a Changing Environment

**Number:** 701-1337-00L  
**Title:** Forest Soils in a Changing Environment  
**Type:** W  
**ECTS:** 3 credits  
**Hours:** 4P  
**Lecturers:** F. Hagedorn, P. F. Schleppi

**Abstract:** The students are measuring carbon and nutrient fluxes in forest soils under a changing climate and land-use. In laboratory and field experiments, they are manipulating climatic conditions (temperature, drought) and quantify the response of C and N fluxes in soils, and plant-soil interactions. The results will be interpreted and discussed in the context of changes in climate and land-use.
Objective

The students get first-hand experience with field and laboratory methods to measure carbon and nutrient fluxes and the application of stable isotope techniques. They shall learn about physicochemical properties of Swiss forest soils, how these properties determine the ecological functions of soils and how soils respond to changes in climate and land-use. Finally the students shall interpret, discuss and present their experimental data.

Content

1. Introduction to the ecological functions of Swiss forest soils
2. Measurement of soil CO2 efflux, carbon and nutrient leaching in forest and grassland soils
3. Sampling and preparation of litter and soil samples from selected soil profiles under different land-uses
4. Setting-up laboratory experiments in microcosms. Measurement of soil respiration and leaching of carbon, nutrients and/or contaminants in climate chambers under different environmental conditions.
5. Analyses of litter, soil, and soil water for selected physical and chemical properties.
7. Interpretation and final presentation of data

Lecture notes

A manual will be distributed during the course.

Literature

Selected publications will be distributed during the course.

701-1339-00L Soil Solids Laboratory W 3 credits 4G M. Plötze

Abstract

The main part of the course is the investigation of real samples of soils/sediments in the lab working in groups. A brief theoretical introduction into the overall principle and the meaning of physical, mineralogical and chemical parameters of soils and sediments and into each analytical method for their investigation will be given in advance.

Objective

Upon successful completion of this course students are able to:
- describe structural, mineralogical and chemical properties of the inorganic solid part of soils and sediments,
- propose and apply different advanced methods and techniques to measure these properties,
- critically assess the data and explain the relationships between them,
- communicate the results in a scientific report.

The competencies of process understanding, system understanding, concept development, and measurement methods are taught and assessed.

Content

Basic introduction to mineralogy and texture of soils
Analytical techniques
Practical exercises in sample preparation
Measurement and evaluation of the data:
- physical parameters (grain size distribution, surface, densities, porosity, (micro)structur)
- mineralogical/geochemical parameters (quantitative mineralogical composition, thermal analysis, cation exchange etc.)

Lecture notes

Selected handouts will be distributed during the course.

Literature


Prerequisites / notice

In order to allow for effective lab work not more than 12 students can join the course.

701-1673-00L Environmental Measurement Laboratory W 5 credits 4G P. U. Lehmann Grunder, A. Carminati

Abstract

Measurements are the sole judge of scientific truth and provide access to unpredictable information, enabling the characterization and monitoring of complex terrestrial systems. Based on lectures and field- and laboratory training, the students learn to apply modern methods to determine forest inventory parameters and to measure subsurface properties and processes.

Objective

The students will be able to:
- explain measurement principles that are used for characterization of landscapes and terrestrial systems
- select appropriate measurement methods and sampling design to quantify key variables and processes above ground and in the subsurface
- deploy sensors in the field
- interpret collected laboratory and field data and report main conclusions deduced from measurements
Content

Week 1: Plant-Soil interactions – short introduction before sensor demonstration and installation in forest lab; Scholander pressure bomb (suction in leaves); LiCOR soil chamber

Weeks 2 to 6 - Experimental Methods for Soil Health Assessment

Week 2: Lecture on soil health and soil indicators; defining measurable soil health indicators for case studies for different soil threats and climate regions

Week 3: Short lecture on sampling, sensors and data logging; preparing sensors and data loggers in the lab; measurements on water content and temperature in the lab

Week 4: Short introduction on field installation; sensor installation at field site Hönggerberg

Week 5: Lecture on geophysical methods on subsurface characterization: basic principles of ERT, GPR, and EM; planning of field experiment to assess soil health

Week 6: Short introduction on data analysis; field sampling and conducting field experiment to assess soil health

Week 7: Analysis of experimental data and soil health assessment; poster presentation and discussion

Week 8: Lecture on plant soil relationship; connecting information below and above ground – data analysis

Weeks 9 and 10: Forest characterization/ inventory: Principles of LiDAR; structures and features of the tree crowns, size/volume of the leaf area tree positions and diameters at breast height

Weeks 11 and 12: Eddy covariance methods -Principles for field measurement of water vapor, carbon dioxide, and energy exchange between terrestrial surfaces and the atmosphere; Analysis of measured time series to determine evaporation rate and CO2-fluxes

Week 13: Swiss Soil Monitoring networks – Monitoring of soil water content and potential; climate change and droughts

Week 14: Global data – Global modeling and data interpretation; SoilGrids and OpenLandMap; exercises on Budyko analysis

Literature

Lecture material will be online for registered students using moodle

Prerequisites / notice

The details of the schedule will be optimized based on the number of students; some blocks of the course will be offered as well to students of Environmental Engineering

Competencies

Subject-specific Competencies

Concepts and Theories fostered
Techniques and Technologies fostered

Method-specific Competencies

Decision-making fostered
Problem-solving fostered
Project Management fostered

Social Competencies

Communication fostered
Cooperation and Teamwork fostered

Personal Competencies

Creative Thinking fostered
Critical Thinking fostered
Integrity and Work Ethics fostered

Seminar and Semester Paper

Number Title Type ECTS Hours Lecturers

Abstract

This class is the 2nd part of a series and participation is conditional on the successful completion of "Term Paper 1: Writing". The results from the term paper written during the previous term are presented to the other students and advisors and discussed with the audience.

Objective

The goal of the term paper seminars is to train the student's ability to communicate (scientific) results to a wider audience and the ability to respond to questions and comments.

Content

Each student presents the results of their term paper to fellow students and advisors and responds to questions and comments from the audience.

Lecture notes

Guidelines and supplementary material are distributed on the Moodle platform.

Prerequisites / notice

There is no final exam. Grade is assigned based on the quality of the presentation and ensuing discussion.

To obtain the credits, it is mandatory to attend at least 60% of all seminar dates offered in the fall and spring semester. Active participation in discussion and feedback rounds is expected.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies fostered

Method-specific Competencies

Analytical Competencies assessed
Media and Digital Technologies fostered

Social Competencies

Communication assessed

Personal Competencies

Creative Thinking fostered
Critical Thinking assessed


Abstract

The ability to critically evaluate original (scientific) literature and to summarise the information in a succinct manner is an important skill for any student. This course aims to practice this ability, requiring each student to write a term paper of scientific quality on a topic of relevance for research in the areas of biogeochemistry and pollutant dynamics.
The goal of the term paper is to train the student's ability to critically evaluate scientific literature and to summarise the findings concisely in a paper addressing a research question.

At the end of the course, students will be able to:
- narrow down a research question.
- identify relevant literature to address the research question.
- concisely summarise and critically evaluate their findings.
- formulate key outstanding questions.

Each student is expected to write a paper with a length of approximately 15-20 pages. The students can choose from a list of topics prepared by the tutors, but the final topic will be determined based on a balance of choice and availability. The students will be guided and advised by their tutors throughout the term.

The paper itself should contain the following elements:
- Motivation and context of the given topic (25%)
- Concise presentation and critical evaluation of the state of the science (60%)
- Identification of open questions and perhaps opportunities for further research (20%)
- Declaration and reflection on the use of technical tools (5%)

In addition, the accurate use of citations, attribution of ideas, and the judicious use of figures, tables, equations and references are critical components of a successful paper. Specialised knowledge is not expected, nor required; neither is new research.

Results from the term paper will be presented to fellow students and involved faculty in the following semester ("Term Paper 2: Seminar").

Each student submits a term paper that will be reviewed by one fellow student and one faculty. The submission of the term paper and a written review of another student’s term paper are a condition for obtaining the credit points.

There is no final exam. The grade is assigned based on the quality of the term paper and the submitted review as well as on the presentation in the following term.

The term paper course is primarily aimed at master students majoring in biogeochemistry & pollutant dynamics and ISTP students with a solid background in natural sciences and a strong interest in biogeochemistry & pollutant dynamics.

The data science workflow

Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

The students are able to
- frame a data science problem and build a hypothesis
- describe the steps of a typical data science project workflow
- conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
- critically think about the limits and implications of a method
- visualise data and results throughout the workflow
- access online resources to keep up with the latest data science methodology and deepen their understanding

The data science workflow
- Access and handle (large) datasets
- Prepare and clean data
- Analysis: data exploratory steps
- Analysis: machine learning and computational methods
- Evaluate results and analyse uncertainty
- Visualisation and communication

Environmental Systems Data Science: Machine Learning

Students are introduced to advanced data science where environmental data are analyzed using state of the art machine learning methods. Starting from known statistical approaches, they learn the principle of more advanced machine learning methods with practical application. The course enables students to plan their own data science project in their specialization and to apply machine learning mode

The students are able to
- select an appropriate model related to a research question and dataset
- describe the steps from data preparation to running and evaluating models
- prepare data for running machine learning with dependent and independent variable
- build and validate regressions and neural network models
- understand convolution and deep learning models
- access online resources to keep up with the latest data science methodology and deepen their understanding

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<th>Number</th>
<th>Title</th>
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<td>Environmental Systems Data Science: Data Processing</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>L. Pellissier, C. P. Albouy, M. Volpi</td>
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<tr>
<td>701-3003-00L</td>
<td>Environmental Systems Data Science: Machine Learning</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>L. Pellissier, C. P. Albouy, M. Volpi</td>
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Autumn Semester 2024
Major in Ecology and Evolution

A. Fundamentals

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
---|---|---|---|---|---
701-0328-00L | Advanced Ecological Processes | W | 4 credits | 2V | J. Hille Ris Lambers

**Abstract**
This course presents a broad overview of the key processes structuring ecological populations and communities, with a particular focus on understanding and managing global change impacts.

**Objective**
In this course, students will develop an integrated knowledge of how ecological theory can help us understand and manage ecological responses to global change. Specifically, the course goals are to:

- Introduce students to the major ecological processes that together shape the composition and abundance of species within ecological communities,
- Provide insight to students on the ecological impacts of anthropogenic change, and how an understanding of ecological processes can help us predict these ecological impacts and design conservation / restoration actions to mitigate their negative impacts,
- Teach students to critically summarize and analyze primary ecological literature, understanding how ecological studies contribute to our knowledge, how to critically evaluate their strengths and weaknesses, and practice designing follow up studies.

**Learning Objectives**
The learning objectives follow from the course goals. After attending this course, students should be able to:

- Describe key processes affecting the size of populations and abundance of species within ecological communities.
- Critically evaluate evidence and conclusions presented in primary ecological literature based on your understanding of these ecological processes.
- Apply knowledge of ecological processes to make predictions about the major responses of ecological communities to anthropogenic perturbations.

**Content**
We will explore how ecological theories can provide insight into the effects of anthropogenic change as well as guide management to undo undesired impacts. Collectively, this requires us to focus on classic problems in ecology (for examples, competitive coexistence, top-down impacts of predators, diversity-ecosystem function relationships, the role of dispersal in spread).

The course is taught in a flipped format. Generally (with the exception of a few weeks), there will be online materials for students to watch or read during the first hour of class (lecture videos, readings), and the class will meet in person for the second half of class. The in person portions of the class will have students participate in activities to learn the content, including paper discussions, groupwork, and presentations. Students are also required to submit a written assignment.

**Lecture Notes**
All course materials (videos, lecture notes, primary literature) will be provided on the course moodle.

**Competencies**

- **Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Analytical Competencies: assessed
  - Problem-solving: fostered

- **Method-specific Competencies**
  - Communication: assessed
  - Cooperation and Teamwork: fostered
  - Critical Thinking: assessed
  - Integrity and Work Ethics: fostered

**B. Concept Courses and Applications**

**Advanced Concept Classes**

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
---|---|---|---|---|---
701-0263-01L | Seminar in Evolutionary Ecology of Infectious Diseases | W | 3 credits | 2G | R. R. Regös, S. Bonhoeffer

**Abstract**
Students of this course will discuss current topics from the field of infectious disease biology. From a list of publications, each student chooses some themes that he/she is going to explain and discuss with all other participants and under supervision. The actual topics will change from year to year corresponding to the progress and new results occurring in the field.

**Objective**
This is an advanced course that will require significant student participation. Students will learn how to evaluate and present scientific literature and trace the development of ideas related to understanding the ecology and evolutionary biology of infectious diseases.

**Content**
A core set of ~10 classic publications encompassing unifying themes in infectious disease ecology and evolution, such as virulence, resistance, metapopulations, networks, and competition will be presented and discussed. Pathogens will include bacteria, viruses and fungi. Hosts will include animals, plants and humans.

**Lecture Notes**
Publications and class notes can be downloaded from a web page announced during the lecture.

**Literature**
Papers will be assigned and downloaded from a web page announced during the lecture.
701-1409-00L  Research Seminar: Ecological Genetics

Abstract
In this research seminar we will critically discuss recent publications on current topics in Ecological Genetics.

Objective
It is our aim that participants gain insight into current research topics and approaches in Ecological Genetics and learn to critically assess and appreciate scientific publications in this field.

Prerequisites / notice
Minimum number of participants is 5.

701-1471-00L  Ecological Parasitology

Abstract
The course does not take place this semester.

Objective
1. Identify common macroparasites in invertebrates.
2. Understand ecological and evolutionary processes in host-parasite interactions.
3. Conduct parasitological research

Content
Lectures:
1. Diversity and natural history of parasites (i.e. systematic groups and life-cycles).
2. Ecology of host-parasite interactions (e.g. parasite communities, effects of environmental changes).
3. Human macroparasites (schistosomiasis, malaria).

Prerequisites / notice
The three practicals will take place at the 03.10.2023, the 17.10.2023 and the 07.11.2023 at Eawag Dübendorf from 08:15 - 12:00. Note that each practical takes 2 hours longer than the weekly lecture.

701-1676-01L  Genomics of Environmental Adaptation

Abstract
This five-day winter school aims at teaching advanced Master students, PhD students and postdoctoral researchers on aspects of the genomics of environmental adaptation. It provides both theoretical background and hands-on exercises on major topics of contemporary environmental genomics such as signatures of selection, outlier analysis, genotype-environment associations, or GWAS.
The genomics of environmental adaptation is an evolving scientific field of both basic and applied interest. Researchers make increasing use of diverse methodological approaches built on concepts from ecology, evolutionary biology and population genomics. This five-day winter school introduces students to some major concepts and methods of environmental genomics, i.e., (i) how the environment and adaptive genetic variation are related and (ii) how signatures of genomic adaptation can be detected in natural populations. The winter school focuses on current methods and hands-on exercises, emphasizing an understanding of the underlying concepts and a discussion of benefits, limitations and pitfalls of environmental genomics. It is specifically aimed at the needs of advanced Master students, PhD students and early postdoctoral researchers.

### Competencies

**Subject-specific Competencies**
- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**
- Analytical Competencies
- Problem-solving
- Project Management

**Social Competencies**
- Communication
- Cooperation and Teamwork

**Personal Competencies**
- Creative Thinking
- Critical Thinking

### Literature

- Schmid Hempel 2011 Evolutionary Parasitology
- Stearns & Medzhitov 2016 Evolutionary Medicine
- Autumn Semester 2024
- Computational Biology
  - W 6 credits
  - 636-0017-00L
  - T. Vaughan, C. Magnus, T. Stadler
  - The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.
  - Students will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:
    - stochastic models in molecular evolution
    - phylogenetic & phylodynamic inference
    - maximum likelihood and Bayesian statistics
  - Attendees will apply these concepts to a number of applications yielding biological insight into:
    - epidemiology
    - pathogen evolution
    - macroevolution of species
- Autumn Semester 2024
- Computational Biology
  - W 6 credits
  - 636-0017-00L
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    - phylogenetic & phylodynamic inference
    - maximum likelihood and Bayesian statistics
  - Attendees will apply these concepts to a number of applications yielding biological insight into:
    - epidemiology
    - pathogen evolution
    - macroevolution of species
Content

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestorial relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes

Lecture slides will be available on moodle.

Literature

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

* Yang, Z. 2006. Computational Molecular Evolution.
* Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.

Prerequisites / notice

Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). In case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place in Basel before the start of the semester.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Decision-making

Problem-solving

Personal Competencies

Creative Thinking

Critical Thinking

751-5101-00L Biogeochemistry and Sustainable Management

W 3 credits 2G I. Feigenwinter, N. Buchmann, K.-M. Kohonen

Abstract

This course focuses on the interactions between ecology, biogeochemistry and management of agro- and forest ecosystems, thus, coupled human-environmental systems. Students learn how human impacts on ecosystems via management or global change are mainly driven by effects on biogeochemical cycles and thus ecosystem functioning, but also about feedback mechanisms of terrestrial ecosystems.

Objective

Students will analyse and understand the complex and interacting processes of ecology, biogeochemistry and management of agroecosystems. They will use their theoretical knowledge in two flipped classroom exercises, but also set up small weather stations to programme a data logger to collect meteorological variables, analyze large meteorological and flux data sets, and evaluate the impacts of weather events and management practices on the ecosystem greenhouse gas exchange. Thus, students will expand their computational competences. Moreover, students will be able to coordinate and work successfully in small (interdisciplinary) teams.

Content

Agroecosystems play a major role in all landscapes, either for production purposes, ecological areas or for recreation. The human impact of any management on the environment is mainly driven by effects on biogeochemical cycles. Effects of global change impacts will also act via biogeochemistry at the soil-biosphere-atmosphere-interface. Thus, ecosystem functioning, i.e., the interactions between ecology, biogeochemistry and management of terrestrial systems, is the science topic for this course.

Students will gain profound knowledge about biogeochemical cycles and greenhouse gas fluxes in managed grassland and/or cropland ecosystems as well as expand their computational competences. Responses of agroecosystems to the environment, i.e., to climate and weather events, but also to management will be studied. Two flipped class-room exercises include the assessment of an ecosystem disturbance and the experimental design of an own study. Dataloggers will be programmed, and a small weather station will be set up. Different meteorological and greenhouse gas flux data will be analysed (using R) and assessed in terms of production, greenhouse gas budgets, and carbon sequestration. Thus, students will learn how to collect, analyse and interpret data about the complex interactions of a coupled human-environmental system.

Students will work in groups (3-4 persons per group) with data from a small weather station (dedicated to the course), as well as data from the long-term measurement network Swiss FluxNet and from global databases. Data from the intensively managed grassland site Chamau will be used to investigate the biosphere-atmosphere exchange of CO2, H2O, N2O and CH4. Functional relationships will be identified, greenhouse gas budgets will be calculated for different time periods and in relation to management over the course of a year.

Lecture notes

Handouts will be available in moodle.

Prerequisites / notice

Prerequisites: Attendance of introductory courses in plant ecophysiology, ecology, and grassland or forest sciences. Knowledge of data analyses in R and statistics. Course will be taught in English.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Decision-making

Problem-solving

Project Management

Social Competencies

Cooperation and Teamwork

Personal Competencies

Critical Thinking

Self-direction and Self-management

Applications

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<tr>
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<td>701-1453-00L</td>
<td>Ecological Assessment and Evaluation</td>
<td>W</td>
<td>3</td>
<td>3G</td>
<td>F. Knaus</td>
</tr>
</tbody>
</table>

Abstract

The course provides methods and tools for ecological evaluations dealing with nature conservation or landscape planning. It covers census methods, ecological criteria, indicators, indices and critically appraises objectivity and accuracy of the available methods, tools and procedures. Birds and plants are used as main example guiding through different case studies.

Objective

Students will be able to:
1) critically consider biological data books and local, regional, and national inventories;
2) evaluate the validity of ecological criteria used in decision making processes;
3) critically appraise the handling of ecological data and criteria used in the process of evaluation
4) perform an ecological evaluation project from the field survey up to the decision making and planning.

Lecture notes

Powerpoint slides are available on the moodle page. Additional documents are handed out as copies.

Literature

Basic literature and references are listed on the webpage.
Prerequisites / notice
The course structure changes between lecture parts, seminars and discussions. The didactic atmosphere is intended as working group.

Suggested prerequisites for attending this course are skills and knowledge equivalent to those taught in the following ETH courses:
- Pflanzen- und Vegetationsökologie
- Systematische Botanik
- Raum- und Regionalentwicklung
- Naturschutz und Naturschutzbiologie

Competencies

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<th>Method-specific Competencies</th>
<th>Social Competencies</th>
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<td>Self-direction and Self-management</td>
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Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed
- Analytical Competencies assessed
- Problem-solving assessed
- Project Management fostered
- Communication fostered
- Cooperation and Teamwork assessed
- Negotiation fostered
- Adaptability and Flexibility fostered
- Critical Thinking assessed
- Self-direction and Self-management fostered

Abstract
This course introduces landscapes as socially perceived, spatially and temporally dynamic entities that are shaped by natural and societal factors. Concepts and qualitative and quantitative methods to study landscapes from an ecological and societal perspective are presented. The course consists of a mixture of theoretical lectures and exercises or practical sessions.

Objective
Students will learn:
- The use of spatial data and analyses for quantifying patterns and processes in landscapes
- Concepts and methods to quantify functional connectivity in landscapes and seascapes.
- The use of remote sensing (satellites images, drones) to extract information about landscape structure and change, with a focus on land-use.
- The use of landscape genetics and its application to biodiversity conservation.
- To computationally optimize land-use planning problems.
- Concepts and methods in scenario-based land-use change modelling.
- Concepts of social preference of landscapes and related measurement methods.
- The role of landscape features in influencing human well-being.
- Approaches of actively influencing attitudes and behavior toward landscapes as well as their scientific evaluation.

Content

1. Ecological quantification of landscape patterns:
   - Landscape resources and green infrastructure (e.g., ecological conservation areas).
   - Landscape and seascape connectivity.
   - Landscape genetics and conservation applications.
   - Concepts of spatial quantitative methods: least cost paths, resistance surfaces, Circuitscape, land-use change models, various statistical methods.
   - Image processing from remote sensing from satellites and drones.
   - Modelling future land-use.
   - Spatial optimization and trade-offs relative to biodiversity, agriculture and energy production.

2. Social perception and use of landscapes:
   - Theories on landscape preference and place identity.
   - Role of landscapes for recreation, health and well-being.
   - Methods of investigating the human-landscape relationship and evaluating interventions.

Lecture notes
Handouts will be available in the course and for download.

Prerequisites / notice
Basic Landscape Ecology courses at Bachelor level
Traditional management systems focus on extraction of natural resources, and their manipulation and governance. However, traditional management has frequently resulted in catastrophic failures such as, for example, the collapse of fish stocks and biodiversity loss. These failures have stimulated the development of alternative ecosystem management approaches that emphasise the functionality of human-dominated systems. Inherent to such approaches are system-wide perspectives and a focus on ecological processes and services, multiple spatial and temporal scales, as well as the need to incorporate diverse stakeholder interests in decision making. Thus, ecosystem management is the science and practice of managing natural resources, biodiversity and ecological processes, to meet multiple demands of society. It can be local, regional or global in scope, and addresses critical issues in developed and developing countries relating to economic and environmental security and sustainability.

This course provides an introduction to ecosystem management, and in particular the importance of integrating ecology into management systems to meet multiple societal demands. The course explores the extent to which human-managed terrestrial systems depend on underlying ecological processes, and the consequences of degradation of these processes for human welfare and environmental well-being. Building upon a theoretical foundation, the course will tackle issues in resource ecology and management, notably forests, agriculture and wild resources within the broader context of sustainability, biodiversity conservation and poverty alleviation or economic development. Case studies from tropical and temperate regions will be used to explore these issues. Dealing with ecological and economic uncertainty, and how this affects decision making, will be discussed. Strategies for conservation and management of terrestrial ecosystems will give consideration to landscape ecology, protected area systems, and community management, paying particular attention to alternative livelihood options and marketing strategies of common pool resources.

### Competencies

**Subject-specific Competencies**

- Concepts and Theories
- Decision-making
- Problem-solving
- Project Management

**Method-specific Competencies**

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Social Competencies**

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

**Personal Competencies**

- Initiative, timeliness, independence, etc. of the student (1/3 of total grade). The personal supervisor is charged with grading the student's paper. The submission deadline is the first day of the spring semester, implying that much of the actual writing will be performed in January and February. Grading is based on the quality of the submitted review paper (2/3 of total grade), and on the "soft skills" such as the level of initiative, timeliness, independence, etc. of the student (1/3 of total grade). The personal supervisor is charged with grading the student's performance.

### Literature


### Competencies

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### Abstract

Individual writing of an essay-type review paper about a specialized topic in the field of ecology and evolution, based on substantial reading of original literature and discussions with a senior scientist.

### Objective

- Students acquire a thorough knowledge on a topic in which they are particularly interested
- They learn to assess the relevance of original literature and synthesize information
- They make the experience of becoming "experts" on a topic and develop their own perspective
- They practise academic writing according to professional standards in English

### Content

Topics for the essays are proposed by the professors and lecturers of the major in Ecology and Evolution at a joint meeting at the beginning of the semester (the date will be communicated by e-mail to registered students).

### Lecture notes

Reading of articles in scientific journals

### Prerequisites / notice

The "Term Paper" requires considerable time set aside to read and digest original scientific literature, culminating in the writing of a review paper. The submission deadline is the first day of the spring semester, implying that much of the actual writing will be performed in January and February. Grading is based on the quality of the submitted review paper (2/3 of total grade), and on the "soft skills" such as the level of initiative, timeliness, independence, etc. of the student (1/3 of total grade). The personal supervisor is charged with grading the student's performance.
**Quantitative Vegetation Dynamics: Models from Tree to Globe**

**Abstract**

The course introduces basic concepts and applications of dynamic vegetation models at various temporal and spatial scales. Different modeling approaches and underlying principles are presented and critically discussed during the lectures. In the integrated exercise parts, students work in a number of small projects with some of the introduced models to gain practical experience.

**Objective**

- be enabled to understand, assess and evaluate the fundamental properties of dynamic systems using vegetation models as case studies
- obtain an overview of dynamic modelling techniques and their applications from the individual plant to the global level
- understand the basic assumptions of the various model types, which dictate the applicability and limitations of the respective model
- be enabled to work with such model types on their own
- appreciate the methodological basis for impact assessments of future climate change and other environmental changes on ecosystems.

**Content**

Models of individuals
- Deriving single-plant models from inventory measurements
- Plant models based on 'first principles'

Models at the stand scale
- Simple approaches: matrix models
- Competition for light and other resources as central mechanisms
- Individual-based stand models: distance-dependent and distance-independent
- Theoretical models

Models at the landscape scale
- Simple approaches: cellular automata
- Dispersal and disturbances (windthrow, fire, bark beetles) as key mechanisms
- Landscape models

Global models
- Sacrificing local detail to attain global coverage: processes and entities
- Dynamic Global Vegetation Models (DGVMs)
- DGVMs as components of Earth System Models

**Lecture notes**

Handouts will be available in the course and for download

**Literature**

Will be indicated at the beginning of the course

**Prerequisites / notice**

- Ideally basic experiences in modelling and systems analysis
- Basic knowledge of programming, ideally in R
- Good knowledge of general ecology, ideally of vegetation dynamics and forest systems

**Number**

701-1677-00L

**Title**

Quantitative Vegetation Dynamics: Models from Tree to Globe

**Type**

W

**ECTS**

3 credits

**Hours**

3G

**Lecturers**

H. Lischke, U. Hiltner, B. Rohner

K. Deiner, A. Frossard

--

**Laboratory and Field Expertise**

**Number**

701-1425-01L

**Title**

Genetic Diversity: Techniques

**Type**

W

**ECTS**

2 credits

**Hours**

4P

**Lecturers**

A. M. Minder Pfyli

**Abstract**

This course provides laboratory training for advanced students (master, doctoral or post-doctoral level). Various DNA/RNA extraction protocols, quality control measurements, SNP genotyping and gene expression techniques will be addressed. This is a course for practitioners.

**Objective**

To learn and improve on standard and modern methods of genetic data collection. With a focus on: Use of different DNA/RNA extraction protocols, techniques for DNA/RNA quality control measurements, gene expression and SNP genotyping techniques.
Content

After an introduction (one afternoon), students have 3 weeks to work independently in groups of two on different protocols. At the end of this practical part, the whole class meets for another afternoon to present the techniques/results and to discuss the advantages and disadvantages of the different techniques.

Techniques addressed: RNA/DNA extractions and quality control, SNP genotyping and real-time qPCR.

Lecture notes

Material will be handed out in the course.

Literature

Material will be handed out in the course.

Prerequisites / notice

There will be two afternoons in class. The lab work in between the afternoons is done by the students according to their own schedule but with the support of the teacher and must be completed after 3 weeks. The workload is approximately 1-2 full days per week, depending on the student's ability. Students must know how to pipette.

Competencies

Subject-specific Competencies
- Concepts and Theories: fostered
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: fostered
- Communication: fostered
- Cooperation and Teamwork: fostered

Social Competencies
- Critical Thinking: fostered

Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

701-1437-00L Aquatic Ecology I

W 3 credits 3V A. Narwani, F. Altermatt, F. Pomati, C. T. Robinson, to be announced

Abstract

This course combines Limnology (the study of inland waters in its broad sense) with ecological and evolutionary concepts. It deals with rivers, groundwater and lakes.

Objective

During this course you will get an overview of the world’s typical freshwater ecosystems. After this course you will be able to understand how aquatic organisms have adapted to their habitat and how the interactions (e.g. food web) between organisms work.

Content

The lectures cover ecology and evolution of aquatic organisms in lentic and lotic waters. Topics include: Adaptations, distribution patterns, biotic interactions, and conceptual paradigms in freshwater ecosystems. Important aspects regarding ecosystem metabolism and habitat properties of freshwaters. Applied case studies and experiments testing ecological and evolutionary processes in freshwaters. The lectures are given by Anita Narwani (Eawag), Florian Altermatt (UNI, Eawag), Chris Robinson (Eawag), Francesco Pomati (Eawag), Alexandra Weber (Eawag) and specialists from the Aquatic Ecology department of Eawag and University of Zurich.

Lecture notes

Course notes and power point presentations provided during the course.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: fostered
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed

Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

Personal Competencies
- Negotiation: fostered
- Negotiation: fostered
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: assessed

701-1437-03L Aquatic Ecology II

W 5 credits 6U A. Narwani, F. Altematt, F. Pomati, C. T. Robinson

Number of participants is limited. The maximal participating number of students is 8 from D-USYS and 16 from D-BIOL (ETH & UZH). Target groups only: Bachelor Biology, Master Environmental Sciences and UZH MNF Biology.

Students have to enroll together with the lecture Aquatic Ecology I (701-1437-00L) and the Practical Course Macroinvertebrates (701-1437-01L) and Identification Course Freshwater Algae and Aquatic Microinvertebrates (701-1437-02L).

Abstract

This course builds on Aquatic Ecology I and cannot be taken separately. It aims on extending the covered concepts and apply them to natural and experimental systems.

The course contains research projects, a 1-day excursion to a lake as well as a 3-day excursion to a river.

Objective

During the research project you will learn the principles of doing research to observe interrelations in aquatic ecosystems. You will measure and interpret biological and physical data (e.g. during experiments, field work). You will present the collected knowledge and write a report about it.

During the excursions you will get to know a lake system as well as a river system. The main goal of the excursions is that the students as a team conduct their own field research project and collect data in the field.

Content

The field excursions contain a 1-day excursion to a lake (Greifensee) and a 3-day excursion to a river (Glatt, Niederuzwil).

The experimental part contains research projects in small groups within research groups at Eawag.

Lecture notes

Course notes and power point presentations provided during the course.

Prerequisites / notice

This course can only be taken together with "701-1437-00 Aquatic Ecology I", "701-1437-01 Bestimmungskurs aquatische Makroinvertebraten" and "701-1437-02 Bestimmungskurs Süsswasseragen und aquatische Mikroinvertebraten".

The maximal participating number of students is 8 from D-USYS and 16 from D-BIOL (ETH & UNI). Registration for the course until 12.08.2024, free places will be distributed after that. Students registering later cannot be guaranteed a place in the course.

The course includes a mandatory field trip to Greifensee (19.09.2024) and a three-day excursion to the river Glatt (25.-27.09. 2024).
Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management assessed

Social Competencies
- Communication assessed
- Cooperation and Teamwork assessed
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

Expertise in Biological Diversity

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<td>701-1437-01L</td>
<td><strong>Practical Course Macroinvertebrates</strong></td>
<td>W</td>
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<td>2P</td>
<td>J. Jokela</td>
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The maximal participating number of students is 12 from D-USYS and 16 from D-BIOL. In case of too many students, those that simultaneously participate in the courses "701-1437-00 Aquatic Ecology I", "701-1437-02 Aquatic Ecology II" and "701-1437-02 Bestimmungskurs Süßwasseralgen und aquatische Mikroinvertebraten" are given priority. Sign in until 12.08.2024, free places will be distributed after that. Students registrating later cannot be guaranteed a place in the course.

Abstract
This course gives an overview of the typical aquatic macroinvertebrate groups in Switzerland. Beside a theoretical background on the different groups the focus is laid on the determination of the most important species groups and their indentification traits, also using identification keys. Practical experience in bentic sampling techniques is collected during an excursion.

Objective
During this course you will get an overview of the typical aquatic macroinvertebrates in Switzerland and the common sampling and preservation techniques. After this course you will be able to identify the most important aquatic species groups at the level of order/family and know the most important identification traits. You will also be able to use identification literature commonly used in Switzerland. During an excursion, you will apply the theoretical identification knowledge to field situations.

Content
The taxonomic part will cover macroinvertebrates (e.g. Crustacean, aquatic insects). The goal is to get to know the most common aquatic taxa in Switzerland, to identify them with commonly used identification literature, and to get an idea how these organisms are used in research and practice. (language: German, translation of the most important things during the course possible)

The field excursion takes place Tuesday 22.10.2024.

Lecture notes
Course notes and power point presentations provided during the course.

Prerequisites / notice
The maximal participating number of students is 12 from D-USYS and 16 from D-BIOL. In case of too many students, those that simultaneously participate in the courses "701-1437-00 Aquatic Ecology I", "701-1437-02 Aquatic Ecology II" and "701-1437-02 Bestimmungskurs Süßwasseralgen und aquatische Mikroinvertebraten" are given priority. Sign in until 12.08.2024, free places will be distributed after that. Students registrating later can not be guaranteed a place in the course.

The field excursion takes place Tuesday afternoon 22.10.2024 from 1pm-5pm.

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

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<tr>
<td>701-1437-02L</td>
<td><strong>Identification Course Freshwater Algae and Aquatic Microinvertebrates</strong></td>
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The maximal participating number of students is 12 from D-USYS and 16 from D-BIOL. In case of too many students, those that simultaneously participate in the courses "701-1437-00 Aquatic Ecology I", "701-1437-02 Aquatic Ecology II", and "701-1437-01 Bestimmungskurs aquatischer Makroinvertebraten" are given priority. Sign in until 12.08.2024, free places will be distributed after that. Students registrating later cannot be guaranteed a place in the course.
Abstract
This course gives an overview of the typical aquatic microinvertebrate and freshwater algae groups in Switzerland. Beside a theoretical background of the different groups the focus is laid on the recognition of the most important species groups and their identification traits. Practical experience is collected during an excursion.

Objective
During this course you will get an overview of the typical aquatic microinvertebrates (e.g. zooplankton) and algae in Switzerland. You will also get to know commonly used sampling techniques. After this course you will know the most important aquatic species groups and the most important identification traits. You will apply the theoretical knowledge during an excursion.

Content
The taxonomic part will cover microinvertebrates and freshwater algae. The goal is to get to know the most common aquatic taxa in Switzerland, to identify them and to get an idea how these organisms are used in research and practice. (language: German, translation of the most important things during the course possible)

Lecture notes
The identification exercise takes place Thursday 17.10.2024 from 1pm-5pm.

Prerequisites / notice
The maximal participating number of students is 12 from D-USYS and 16 from D-BIOL. In case of too many students, those that simultaneously participate in the courses "701-1437-00 Aquatic Ecology I" and "701-1437-01 Bestimmungskurs aquatischer Makroinvertebraten" are given priority. Sign in until 12.08.2024 free places will be distributed after that. Students registering later can not be guaranteed a place in the course.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication fostered
Cooperation and Teamwork fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered

Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking fostered
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-direction and Self-management fostered

Electives

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<td>701-0290-00L</td>
<td>Seminar in Microbial Evolution and Ecology (HS)</td>
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<td>G. Velicer</td>
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<td>Seminar of the groups Molecular Microbial</td>
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<tr>
<td>Abstract</td>
<td>Ecology, Theoretical Biology, Experimental Biology, Evolutionary Biology. Talks given by members of these groups and external visitors.</td>
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<td>Objective</td>
<td>In-depth introduction into microbial evolution and ecology, especially the aspects that are the focus of on-going research in this area at Department of Environmental Systems Science.</td>
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701-3001-00L Environmental Systems Data Science: Data Processing

Abstract
Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

Objective
The students are able to
● frame a data science problem and build a hypothesis
● describe the steps of a typical data science project workflow
● conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
● critically think about the limits and implications of a method
● visualise data and results throughout the workflow
● access online resources to keep up with the latest data science methodology and deepen their understanding

Content
● The data science workflow
● Access and handle (large) datasets
● Prepare and clean data
● Analysis: data exploratory steps
● Analysis: machine learning and computational methods
● Evaluate results and analyse uncertainty
● Visualisation and communication
Environmental Systems Data Science: Machine Learning

Prerequisites / notice
- 252-0840-02L  Anwendungsnahes Programmieren mit Python
- 401-0624-00L  Mathematik IV: Statistik
- 401-6215-00L  Using R for Data Analysis and Graphics (Part I)
- 401-6217-00L  Using R for Data Analysis and Graphics (Part II)
- 701-0105-00L  Mathematik VI: Angewandte Statistik für Umweltwissenschaften

Abstract
Students are introduced to advanced data science where environmental data are analyzed using state-of-the-art machine learning methods. Starting from known statistical approaches, they learn the principle of more advanced machine learning methods with practical application. The course enables students to plan their own data science project in their specialization and to apply machine learning methods.

Objective
The students are able to:
- select an appropriate model related to a research question and dataset
- describe the steps from data preparation to running and evaluating models
- prepare data for running machine learning with dependent and independent variables
- build and validate regressions and neural network models
- understand convolution and deep learning models
- access online resources to keep up with the latest data science methodology and deepen their understanding

Content
- The data science workflow
- Data preparation for running and validating machine learning models
- Get to know machine learning approaches including regression, random forest and neural network
- Model complexity and hyperparameters
- Model parameterization and loss
- Model evaluations and uncertainty
- Deep learning with convolutions

Literature
Building on existing data science resources
- Math IV, VI (Statistics); R, Python; ESDS I

Challenges in Plant Sciences

Prerequisites / notice
- 551-0205-00L  Challenges in Plant Sciences

Abstract
The colloquium “Challenges in Plant Sciences” is a core class of the Zurich-Basel Plant Science Center’s PhD program. The colloquium introduces participants to the broad spectrum of plant sciences within the network. The course offers the opportunity to approach interdisciplinary topics in the field of plant sciences.

Objective
Objectives of the colloquium are:
- Introduction to recent research in all fields of plant sciences
- Working in interdisciplinary teams on the topics
- Developing presentation and discussion skills

Content
The topics encompass integrated knowledge on current plant research, ranging from the molecular level to the ecosystem level, and from basic to applied science while making use of the synergies between the different research groups within the PSC.

More information on the content: https://www.plantsciences.uzh.ch/en/teaching/masters/colloquium.html

Competencies
- Subject-specific Competencies: Concepts and Theories assessed
- Method-specific Competencies: Analytical Competencies assessed
- Social Competencies: Communication fostered
- Personal Competencies: Self-direction and Self-management fostered

Plant Pathology I

Abstract
Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems.

Objective
Students will understand: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems as a basis for implementing disease management strategies in agroecosystems.
Course description: Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems. Topics under the first theme will include pathogen life cycles, disease cycles, and an overview of plant pathogenic nematodes, viruses, bacteria, and fungi. Topics under the second theme will include plant defense strategies, host range, passive and active defenses, and chemical and structural defenses. Topics under the third theme will include the disease triangle and cultural control strategies.

Lecture Topics and Tentative Schedule

Week 1  The nature of plant diseases, symbiosis, parasites, mutualism, biotrophs and necrotrophs, disease cycles and pathogen life cycles.

Week 2  Nematode attack strategies and types of damage. Viral pathogens, classification, reproduction and transmission, attack strategies and types of damage. Examples TMV, BYDV. Bacterial pathogens and phytoplasmas, classification, reproduction and transmission.

Week 3  Bacterial attack strategies and symptoms. Example bacterial diseases: fire blight, Agrobacterium crown gall, soft rots. Fungal and oomycete pathogens, classification, growth and reproduction, sexual and asexual spores, transmission.

Week 4  Fungal and oomycete life cycles, disease cycles, infection processes, colonization, phytotoxins and mycotoxins. Attack strategies of fungal necrotrphs and biotrophs. Symptoms and signs of fungal infection. Example fungal diseases: potato late blight.

Week 5  Example fungal diseases: wheat stem rust, grape powdery mildew, wheat septoria tritici blotch. Plant defense mechanisms, host range and non-host resistance. Passive structural and chemical defenses, preformed chemical defenses. Active structural defense, histological and cellular (papillae).

Week 6  Active chemical defense, hypersensitive response, pathogenesis-related (PR) proteins, phytoalexins and disease resistance. Pisatin and pisatin demethylase. Local and systemic acquired resistance (LAR, SAR), induced systemic resistance (ISR), signal molecules, defense activaters (Bion). Pathogen effects on food quality. Positive and negative transformations.


Week 8  Epidemiology: Disease pyramid, environmental effects on epidemic development, plant effects on development of epidemics, including resistance, physiology, density, uniformity.

Week 9  Disease assessment: incidence and severity measures, keys, diagrams, scales, measurement errors. Correlations between incidence and severity. Molecular detection and diagnosis of pathogens. Host indexing, serology, monoclonal and polyclonal antibodies, ELISA.

Week 10  Molecular detection and diagnosis of pathogens: PCR, rDNA and loop-mediated isothermal amplification. Strategies for minimizing disease risks: calculating disease thresholds, disease forecasting systems.


Week 12  Physical control methods. Cultural control methods: avoidance, tillage practices, crop sanitation.

Week 13  Cultural control methods: fertilizers, crop rotations.

Week 14  Open lecture.

Lecture notes

Detailed lecture notes (~160 pages) will be available for purchase at the cost of reproduction at the start of the semester.

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies assessed

Major in Environmental Systems Policy

Theoretical Foundations for Environmental Policy

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<tr>
<td>701-1563-00L</td>
<td>Climate Policy</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>A. Patt, S. Hanger-Kopp</td>
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Abstract

This course provides an in-depth of analysis both of the theoretical underpinnings to different approaches to climate policy at the international and national levels, and how these different approaches have played out in practice. Students will learn how legislative frameworks have developed over the last 25 years, and also be able to appraise those frameworks critically.

Objective

The goal is to give students a glimpse into the enormous complexity of this policy area, an understanding of some of the many debates that are currently raging (of which the debate about whether climate change is actually real is probably the least complicated or interesting). We want to give students the ability to evaluate policy arguments made by politicians, experts, and academics with a critical eye, informed by a knowledge of history, an understanding of the theoretical underpinnings, and the results of empirical testing of different strategies. A student taking this course ought to be able to step into an NGO or government agency involved in climate policy analysis or political advocacy, and immediately be able to make an informed and creative contribution. Moreover, by experiencing the depth of this policy area, students should be able to appreciate the complexity inherent in all policy areas.
Content

Climate change is one of the defining challenges of our time, touching all aspects of the environment and of society. There is broad recognition (although with some dissent) that governments ought to do something about it: making sure that emissions of greenhouse gases (GHGs) stop within the next 20 to 30 years; helping people to adapt to the consequences of the climate change to which we have already committed ourselves; and, most controversially, perhaps taking measures to actively remove GHG’s from the atmosphere, or to alter the radiation balance of the Earth through solar engineering.

It’s a complicated set of problems, especially the first of these, known as mitigation. Fundamentally this is because it means doing something that humanity has never really tried before at a planetary scale: deliberately altering the ways the we produce, convert, and consume energy, which is at the heart of modern society. Modern society – the entire anthropocene – grew up on fossil fuels, and the huge benefits they offered in terms of energy that was inexpensive, easy to transport and store, and very dense in terms of its energy content per unit mass or volume. How to manage a society of over 7 billion people, at anything like today’s living standards, without the benefits of that energy, is a question for which there is no easy answer. There are also other challenges outside of energy. How do we build houses, office buildings, and infrastructure networks without cement, a substance that releases large amounts of CO2 as it hardens? How do we reverse the pace of deforestation, particularly in developing countries? How do we eliminate the GHG emissions from agriculture: the methane from cows’ bellies and rice paddies, together with the chemicals that enter the atmosphere from the application of fertilizer?

These are all tough questions at a technical level, but even tougher when you consider that governments typically need to employ indirect methods to get these things to happen. Arguably a government could simply pass a law that forbids people from using fossil fuels. But politically this is simply unrealistic, at least while so many people depend on fossil fuels in their daily lives. What is to be done? For this, one needs to turn to various ideas about how government can and should influence society. On the one hand are ideas suggesting that government ought to play a very limited role, relative to private actors, and should step in only to correct “market failures,” with interventions designed specifically around that failure. On the other hand are ideas suggesting that government (meaning all of us, working together through a democratic process) is the appropriate decision-making body for core decisions on where society can and should go. These issues come to the fore in climate policy discussions and debates.

Literature

There will be reading assignments for select classes. All of these will be posted in PDF format on a course Moodle. In addition, there will be one book and one report to be read over the course of the semester. They are:

- Ministry of the Future, by Kim Stanley Robinson

Competencies

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<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
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<tr>
<td>701-1651-00L</td>
<td>Environmental Governance</td>
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<tr>
<td>Abstract</td>
<td>O</td>
<td>6 credits</td>
<td>3G</td>
<td>E. Lieberherr</td>
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<tr>
<td>Objective</td>
<td>To analyze the evolution as well as the key elements of environmental governance.</td>
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<tr>
<td>Content</td>
<td>To be able to identify the main challenges and opportunities for environmental governance and to critically discuss them with reference to various practical policy examples.</td>
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<td>Improvements in environmental quality and sustainable management of natural resources cannot be achieved through technical solutions alone. The quality of the environment and the achievement of sustainable development strongly depend on human behavior and specifically the human uses of nature. To influence human behavior, we rely on public policies and other societal rules, which aim to steer the way humans use natural resources and their effects on the environment. Such steering can take place through government intervention alone. However, this often also involves governance, which includes the interplay between governmental and non-governmental actors, the use of diverse tools such as emission standards or financial incentives to steer actors’ behavior and can occur at the local, regional, national or international level.</td>
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<td>In this course, we will address both the practical aspects of as well as the scientific debate on environmental governance. The course gives future environmental experts a strong basis to position themselves in the governance debate, which does not preclude government but rather involves a spectrum from government to governance.</td>
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<td>Key questions that this course seeks to answer: What are the core characteristics of environmental challenges from a policy perspective? What are key elements of ‘environmental governance’ and how legitimate and effective are these approaches in addressing persistent environmental challenges?</td>
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<td>Furthermore, we encourage the development of soft skills by engaging students in activities such as moderating discussions in class, presenting own proposals, giving regular peer feedback, as well as critically reflecting on various relevant publications in the environmental governance domain.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture slides, a script and additional course material will be provided on Moodle. A detailed course schedule will be made available at the beginning of the semester.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>During the lecture we will work with Moodle. We ask that all students register themselves on this platform before the lecture.</td>
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<td>We recommend that students have (a) three-years BSc education of a (technical) university; (b) successfully completed Bachelor introductory course to environmental policy (Entwicklungen nationaler Umweltpolitik (or equivalent)); and (c) familiarity with key issues in environmental policy and some fundamental knowledge of one social science or humanities discipline (political science, economics, sociology, history, psychology, philosophy)</td>
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</table>
This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and assessed T. Bernauer assessed L. P. Fesenfeld assessed. Climate change, access to energy and other societal challenges are directly linked to the way we use and create energy. Both the 2015-2016 United Nations Paris climate change agreement and the UN Sustainable Development Goals make a fast and extensive transition of the energy system necessary.

- To gain an overview of the history of the transition of large technical systems
- To recognize current challenges in the energy system to understand the theoretical frameworks and concepts for studying transitions
- To gain knowledge on the role of policy and politics in energy transitions

Objective

Content

The course addresses environmental issues as policy problems and explores how the environment is regulated, controlled, and contested by a range of actors and institutions. The course focuses on the spatial dimension of environmental change and uses key concepts from geography. Course participants will develop a theoretically as well as practically informed understanding of recent issues and debates in contemporary geographies of environmental governance.

This course provides an overview of dominant and emerging trends in the theory and practice of environmental governance. The course addresses environmental issues as policy problems and explores how the environment is regulated, controlled, and contested by a range of actors and institutions. The course focuses on the spatial dimension of environmental change and uses key concepts from geography (scale, region, network) to advance regional environmental governance thinking.

The lectures are complemented by seminar classes to work on case studies in smaller groups of students.

The grade will be determined by a final exam.

Lecture notes Slides and reading material will be made available via moodle.ethz.ch (only for registered students).

Literature A reading list will be provided via moodle.ethz.ch at the beginning of the semester.

Prerequisites / notice This course is particularly suited for students of the following programmes: MA Comparative International Studies; MSc Energy Science & Technology; MSc Environmental Sciences; MSc Management, Technology & Economics; MSc Science, Technology & Policy; ETH & UZH PhD programmes.

This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined.

860-0023-00L International Environmental Politics

- To gain an overview of important questions pertaining to international environmental politics from a social sciences viewpoint;
- To learn how to identify interesting/innovative questions in this policy area and how to address them in a conceptually and methodologically meaningful and insightful way;
- To gain an overview of important global and regional environmental problems and how they or could be solved.

Objective

Content

This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined, for example international efforts to reduce air pollution, manage international water resources, mitigate and adapt to global warming, protect the stratospheric ozone layer, address biodiversity challenges, deal with plastic waste, and prevent pollution of the oceans.

Lecture notes Reading materials and slides will be available via Moodle.

Literature Reading materials and slides will be available via Moodle.

701-1590-00L Geographies of Environmental Governance (University of Zurich)

- To gain an overview of dominant and emerging trends in the theory and practice of environmental governance. The course addresses environmental issues as policy problems and explores how the environment is regulated, controlled, and contested by a range of actors and institutions. The course focuses on the spatial dimension of environmental change and uses key concepts from geography.

Objective

Content

The course provides an overview of dominant and emerging trends in the theory and practice of environmental governance. The course addresses environmental issues as policy problems and explores how the environment is regulated, controlled, and contested by a range of actors and institutions. The course focuses on the spatial dimension of environmental change and uses key concepts from geography (scale, region, network) to advance regional environmental governance thinking.

The lectures are complemented by seminar classes to work on case studies in smaller groups of students.

The grade will be determined by a final exam.

Lecture notes Slides and reading material will be made available via moodle.ethz.ch (only for registered students).

Literature A reading list will be provided via moodle.ethz.ch at the beginning of the semester.

Prerequisites / notice This course is particularly suited for students of the following programmes: MA Comparative International Studies; MSc Energy Science & Technology; MSc Environmental Sciences; MSc Management, Technology & Economics; MSc Science, Technology & Policy; ETH & UZH PhD programmes.
The course is open to all ETH students and visiting students from other universities. Participation does not require previous coursework in the social sciences or environmental policy. This course will take place on campus (ETH Main Building, HG F.3). There will be no live-streaming, and the course is NOT in hybrid (on-campus plus online) format. However, the lecture will be recorded and the recordings will be made available via the Moodle platform for this course a few days after the respective lecture for students who are unable to attend in person. All electronic correspondence will take place via the ETH myStudies system and Moodle, so please make sure you are properly registered there with a functioning email address/account.

Credits and Exam
After passing a written test at the end of the course (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test). Visiting students (e.g., from the University of Zurich, exchange students) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory. Students who obtain a grade of < 4.0 for the test will have a second chance (see table below). Students who did not participate in the test on 18 December 2023 will not have access to the repeat test unless they submit compelling and documented (e.g., medical, other exam in parallel at ETH) reasons for why they were unable to participate in the first test. It covers all contents of the lectures and the reading assignments. Visiting students (e.g., from the University of Zurich or other universities) are subject to the same conditions. Registration for the course in the myStudies system of ETH is compulsory. No separate registration for the exam is required, registration for the course as such covers everything. The exam will take place on campus, either in the F3 lecture hall or in a computer room. That is, you must be present in person at ETH Zurich on the exam date/time.

### Modeling and Statistical Analysis

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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>701-1453-00L</td>
<td>Ecological Assessment and Evaluation</td>
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<td>3G</td>
<td>F. Knaus</td>
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</table>

**Objective**

Students will be able to:

1. critically consider biological data books and local, regional, and national inventories;
2. evaluate the validity of ecological criteria used in decision making processes;
3. critically appraise the handling of ecological data and criteria used in the process of evaluation
4. perform an ecological evaluation project from the field survey up to the decision making and planning.

**Lecture notes**

Powerpoint slides are available on the moodle page. Additional documents are handed out as copies.

**Literature**

Basic literature and references are listed on the webpage.

**Prerequisites / notice**

The course structure changes between lecture parts, seminars and discussions. The didactic atmosphere is intended as working group.

Suggested prerequisites for attending this course are skills and knowledge equivalent to those taught in the following ETH courses:

- Pflanzen- und Vegetationsökologie
- Systematische Botanik
- Raum- und Regionalentwicklung
- Naturschutz und Naturschutzbiologie

**Competencies**

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<th>Competencies</th>
<th>Concepts and Theories</th>
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<td>Techniques and Technologies</td>
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<td>Analytical Competencies</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<td>Social Competencies</td>
<td>Communication</td>
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<td></td>
<td>Cooperation and Teamwork</td>
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<td>Negotiation</td>
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<tr>
<td>Person Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Self-direction and Self-management</td>
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<tr>
<td>701-1565-00L</td>
<td>Quantitative Policy Analysis and Modeling</td>
<td>O</td>
<td>6</td>
<td>4G</td>
<td>A. Patt, L. Booth, C. Moretti, T. Tröndle</td>
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</table>

**Abstract**

The lectures will introduce students to the principles of quantitative policy analysis, namely the methods to predict and evaluate the social, economic, and environmental effects of alternative strategies to achieve public objectives. A series of individual assignments, and one group project, will give students an opportunity for students to apply those methods to a set of case studies.

**Objective**

The objectives of this course are to develop the following key skills necessary for policy analysts:

- Identifying the critical quantitative factors that are of importance to policy makers in a range of decision-making situations.
- Developing conceptual models of the types of processes and relationships governing these quantitative factors, including stock-flow dynamics, feedback loops, optimization, sources and effects of uncertainty, and agent coordination problems.
- Develop and program numerical models to simulate the processes and relationships, in order to identify policy problems and the effects of policy interventions.
- Communicate the findings from these simulations and associated analysis in a manner that makes transparent their theoretical foundation, the level and sources of uncertainty, and ultimately their applicability to the policy problem.

The course will proceed through a series of policy analysis and modeling exercises, involving real-world or hypothetical problems. The specific examples around which work will be done will concern the environment, energy, health, and natural hazards management.
The students are able to

**Competencies**

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<tr>
<th>Subject-specific Competencies</th>
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<td>Techniques and Technologies</td>
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**Method-specific Competencies**

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<th>Analytical Competencies</th>
<th>Decision-making</th>
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<tr>
<td>Media and Digital Technologies</td>
<td>Problem-solving</td>
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<td>Project Management</td>
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**Social Competencies**

| Communication | fostered |

**Personal Competencies**

| Creative Thinking | assessed |
| Critical Thinking | assessed |
| Self-awareness and Self-reflection | fostered |
| Self-direction and Self-management | fostered |

**701-3001-00L Environmental Systems Data Science: Data Processing**

**Abstract**

Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

**Objective**

The students are able to

- frame a data science problem and build a hypothesis
- describe the steps of a typical data science project workflow
- conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
- critically think about the limits and implications of a method
- visualise data and results throughout the workflow
- access online resources to keep up with the latest data science methodology and deepen their understanding

**Content**

- The data science workflow
- Access and handle (large) datasets
- Prepare and clean data
- Analysis: data exploratory steps
- Analysis: machine learning and computational methods
- Evaluate results and analyse uncertainty
- Visualisation and communication

**Prerequisites / notice**

252-0840-02L Anwendungsnahes Programmieren mit Python
401-0624-00L Mathematik IV: Statistik
401-6215-00L Using R for Data Analysis and Graphics (Part I)
401-6217-00L Using R for Data Analysis and Graphics (Part II)
701-0105-00L Mathematik VI: Angewandte Statistik für Umwelt- und Umweltwissenschaften

**701-3003-00L Environmental Systems Data Science: Machine Learning**

**Abstract**

Students are introduced to advanced data science where environmental data are analyzed using state of the art machine learning methods. Starting from known statistical approaches, they learn the principle of more advanced machine learning methods with practical application. The course enables students to plan their own data science project in their specialization and to apply machine learning methods.

**Objective**

The students are able to

- select an appropriate model related to a research question and dataset
- describe the steps from data preparation to running and evaluating models
- prepare data for running machine learning with dependent and independent variable
- build and validate regressions and neural network models
- understand convolution and deep learning models
- access online resources to keep up with the latest data science methodology and deepen their understanding

**Content**

- The data science workflow
- Data preparation for running and validating machine learning models
- Get to know machine learning approaches including regression, random forest and neural network
- Model complexity and hyperparameters
- Model parameterization and loss
- Model evaluations and uncertainty
- Deep learning with convolutions

**Literature**

Building on existing data science resources

**Prerequisites / notice**

Math IV, VI (Statistics); R, Python; ESDS I

**101-0491-00L Agent Based Modeling in Transportation**

**Abstract**

This course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based simulation models' current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in groups.

**Objective**

At the end of the course, the students should:

- have an understanding of agent-based modeling
- have an understanding of MATSim
- have an understanding of the process needed to set up an agent-based study
- have practical experience of using MATSim to perform transportation studies

**Content**

This course provides an introduction to agent-based models for transportation policy analysis. Four essential topics are covered:

1) Introduction of agent-based modeling and its comparison to the traditional state of practice modeling
2) Introduction of MATSim, an open-source agent-based model, developed at ETH Zurich and TU Berlin, and its various parts
3) Setting up an agent-based model simulation, where different statistical methods used in the process will be introduced and explained.
4) Conducting a transport policy study. The case study will be performed in groups and will include a paper-like report.

During the course, outside lecturers will give several lectures on using MATSim in practice (i.e., SBB).
This course provides an in-depth analysis both of the theoretical underpinnings to different approaches to climate policy at the international and national levels, and how these different approaches have played out in practice. Students will learn how legislative frameworks have developed over the last 25 years, and also be able to appraise those frameworks critically.

We start with a comparison of different modeling approaches, to highlight the problems and challenges of system modeling. The subsequent lectures then introduce different one- and two-dimensional nonlinear models with applications in economics, such as models of supply and demand, business cycles, growth and competition. Emphasis is on the formal analysis of these models using methods from applied mathematics and tools for solving coupled differential equations.

Weekly self-study tasks are used to apply the concepts introduced in the lectures. We practice how to solve nonlinear models formally and numerically and how to interpret the results.

For those without object-oriented programming experience, a crash course 101-0491-10 Basics of Java and Best Practices for Scientific Computing before the start of HS is recommended.

There are no strict preconditions regarding which lectures the students should have previously attended. However, experience with at least one high-level programming language (Java, R, Python, or other) is recommended.

Additional relevant readings, primarily scientific articles, will be recommended throughout the course.

More details during the first lecture.

There are no strict preconditions regarding which lectures the students should have previously attended. However, experience with at least one high-level programming language (Java, R, Python, or other) is recommended.

Additional relevant readings, primarily scientific articles, will be recommended throughout the course.

More details during the first lecture.

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Problem-solving

- **Method-specific Competencies**
  - Techniques and Technologies
  - Analytical Competencies
  - Problem-solving
  - Project Management

- **Social Competencies**
  - Cooperation and Teamwork

- **Personal Competencies**
  - Critical Thinking

### Literature

- **Agent-based modeling in general**

- **MATSim**

### Prerequisites / notice

- Lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.

- Students should be familiar with nonlinear differential equations and should have basic programming skills. All necessary details to solve nonlinear models will be provided in the course. The course will not build on mathematical proofs, optimization, statistics, efficient numerical computation and other specialized skills.

### Content

- System theory sees the economy as a complex adaptive system.

### Methods

- We practice how to solve nonlinear models formally and numerically and how to interpret the results.

### Objective

- What does this mean for economic modeling?

### Objectives

- Understand the importance of different modeling approaches
- Formalize and solve one- and two-dimensional nonlinear models
- Identify critical conditions for stability and dynamic transitions
- Analyze macroeconomic models of business cycles, supply and demand
- Apply formal concepts to model economic growth and competition

### Systems

- System dynamics rooted general system theory and cybernetics, and nonlinear dynamics using applied mathematics.

- We focus on two sources of complexity: (a) nonlinear dynamics, which is captured in this course, “Economic Dynamics and Complexity” and (b) collective interactions, which is captured in the course “Agent-Based Modeling of Economic Systems” (in Spring).

- Our approach to economic dynamics combines insights from different disciplines: macroeconomics studying business cycles and growth, system dynamics rooted general system theory and cybernetics, and nonlinear dynamics using applied mathematics.

- We study the role of bifurcations and control parameters for dynamic stability. Feedback cycles and coupled dynamics are reasons for limited predictability, instability and chaos.

- We start with a comparison of different modeling approaches, to highlight the problems and challenges of system modeling.

- The subsequent lectures then introduce different one- and two-dimensional nonlinear models with applications in economics, such as models of supply and demand, business cycles, growth and competition.

- Emphasis is on the formal analysis of these models using methods from applied mathematics and tools for solving coupled differential equations.

- We focus on two sources of complexity: (a) nonlinear dynamics, which is captured in this course, “Economic Dynamics and Complexity” and (b) collective interactions, which is captured in the course “Agent-Based Modeling of Economic Systems” (in Spring).

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Problem-solving

- **Method-specific Competencies**
  - Techniques and Technologies
  - Analytical Competencies
  - Problem-solving
  - Project Management

- **Social Competencies**
  - Cooperation and Teamwork

- **Personal Competencies**
  - Critical Thinking

### Policy Engagement

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<th>Lecturers</th>
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<tr>
<td>701-1563-00L</td>
<td>Climate Policy</td>
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<td>4G</td>
<td>A. Patt, S. Hanger-Kopp</td>
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This course provides an in-depth analysis both of the theoretical underpinnings to different approaches to climate policy at the international and national levels, and how these different approaches have played out in practice. Students will learn how legislative frameworks have developed over the last 25 years, and also be able to appraise those frameworks critically.

The goal is to give students a glimpse into the enormous complexity of this policy area, an understanding of some of the many debates that are currently raging (of which the debate about whether climate change is actually real is probably the least complicated or interesting). We want to give students the ability to evaluate policy arguments made by politicians, experts, and academics with a critical eye, informed by a knowledge of history, an understanding of the theoretical underpinnings, and the results of empirical testing of different strategies. A student taking this course ought to be able to step into an NGO or government agency involved in climate policy analysis or political advocacy, and immediately be able to make an informed and creative contribution. Moreover, by experiencing the depth of this policy area, students should be able to appreciate the complexity inherent in all policy areas.
Content

Climate change is one of the defining challenges of our time, touching all aspects of the environment and of society. There is broad recognition (although with some dissent) that governments ought to do something about it: making sure that emissions of greenhouse gases (GHGs) stop within the next 20 to 30 years; helping people to adapt to the consequences of the climate change to which we have already committed ourselves; and, most controversially, perhaps taking measures to actively remove GHG's from the atmosphere, or to alter the radiation balance of the Earth through solar engineering.

It’s a complicated set of problems, especially the first of these, known as mitigation. Fundamentally this is because it means doing something that humanity has never really tried before at a planetary scale: deliberately altering the ways the we produce, convert, and consume energy, which is at the heart of modern society. Modern society – the entire anthropocene – grew up on fossil fuels, and the huge benefits they offered in terms of energy that was inexpensive, easy to transport and store, and very dense in terms of its energy content per unit mass or volume. How to manage a society of over 7 billion people, at anything like today’s living standards, without the benefits of that energy, is a question for which there is no easy answer. There are also other challenges outside of energy. How do we build houses, office buildings, and infrastructure networks without cement, a substance that releases large amounts of CO2 as it hardens? How do we reverse the pace of deforestation, particularly in developing countries? How do we eliminate the GHG emissions from agriculture: the methane from cows’ bellies and rice paddies, together with the chemicals that enter the atmosphere from the application of fertilizer?

These are all tough questions at a technical level, but even tougher when you consider that governments typically need to employ indirect methods to get these things to happen. Arguably a government could simply pass a law that forbids people from using fossil fuels. But politically this is simply unrealistic, at least while so many people depend on fossil fuels in their daily lives. What is to be done? For this, one needs to turn to various ideas about how government can and should influence society. On the one hand are ideas suggesting that government ought to play a very limited role, relative to private actors, and should step in only to correct “market failures,” with interventions designed specifically around that failure. On the other hand are ideas suggesting that government (meaning all of us, working together through a democratic process) is the appropriate decision-making body for core decisions on where society can and should go. These issues come to the fore in climate policy discussions and debates.

Literature

There will be reading assignments for select classes. All of these will be posted in PDF format on a course Moodle. In addition, there will be one books and one report to be read over the course of the semester. They are:

- Ministry of the Future, by Kim Stanley Robinson
- Ten Principles for Policy Making in the Energy Transition, by Laura Diaz Anadon et al.

Competencies

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<th>Competencies</th>
<th>Concepts and Theories</th>
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<th>Decision-making</th>
<th>Problem-solving</th>
<th>Communication</th>
<th>Negotiation</th>
<th>Creative Thinking</th>
<th>Critical Thinking</th>
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<tbody>
<tr>
<td>Subject-specific Competencies</td>
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<td>Method-specific Competencies</td>
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<td>Social Competencies</td>
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751-2107-00L Agrarian and Environmental Values: Tensions, Synergies, Practices and Policies

Limited to 20 students.

Abstract

In politics, society, and science, it can seem that the values and practices of agricultural production and environmental protection are in conflict. This tension is often described as “protection versus use” of natural resources. We will explore ways to move beyond the apparent conflict. We will apply this learning to field trips and transdisciplinary projects.

Objective

Students are able to:
- Define different kinds and categories of values.
- Relate value concepts to their own studies, life, and experiences through reflective journaling.
- Infer the underlying values in a text or policy about agri-environmental topics.
- Collaboratively develop a transdisciplinary project for an agri-environmental case study from the field trips.

Content

The course consists of interactive seminars alongside fieldtrips to farms that have found innovative solutions to balancing protection and production.

Seminars will cover topics such as the relationship between values and behavior and how people perceive value trade-offs. We will also discuss environmental ethics, environmental valuation and its critiques, the interplay of facts and values in agri-environmental decision-making, cultural ecosystem services, and relational values.

This class requires active participation. Learning is based on in-class activities, group work and fieldtrips.
Literature will draw from political ecology, value theory and environmental values, as well as case studies and primary texts, such as the following (not all will be required reading; we will read 1 or 2 papers or book chapters each week).


Environmental Values, by O'Neill, Holland and Light, 2008

IPBES Values Assessment 2023


Competencies

Subject-specific Competencies

Concepts and Theories

Methods and Technologies

Analytical Competencies

Decision-making

Problem-solving

Project Management

Social Competencies

Communication

Cooperation and Teamwork

Customer Orientation

Leadership and Responsibility

Sensitivity to Diversity

Personal Competencies

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

Electives

<table>
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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1590-00L</td>
<td>Geographies of Environmental Governance (University of Zurich)</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: 07SMGEO837
Spatial development as a discipline deals with the development, (trans)formation, and arrangement of our urban environment. The course focuses on the spatial dimension of environmental change and uses key concepts from geography.

Course participants will develop a theoretically as well as practically informed understanding of recent issues and debates in contemporary geographies of environmental governance. The course provides an overview of dominant and emerging trends in the theory and practice of environmental governance. The course addresses environmental issues as policy problems and explores how the environment is regulated, controlled, and contested by a range of actors and institutions. The course focuses on the spatial dimension of environmental change and uses key concepts from geography (scale, region, network) to advance regional environmental governance thinking. The lectures are complemented by seminar classes to work on case studies in smaller groups of students.

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A course will be set up on Moodle for the provision of lectures and documents, to upload group deliverables and to ask questions in a discussion Forum. All documents provided are exclusively available for use within this course. The exercises provide a framework for practical application of the learned theoretical concepts of spatial planning to real-life situations. The course focuses on both theoretical concepts and practice-oriented approaches to gain knowledge and be equipped to address current issues in spatial planning and development. This is mirrored in the course’s structure made of both of lectures and exercises. The course focuses on both theoretical concepts and practice-oriented approaches to gain knowledge and be equipped to address current issues in spatial planning and development. This is mirrored in the course’s structure made of both of lectures and exercises.

You as students will...
... assess present and future core challenges of spatial planning and development.
... discuss the role of spatial planning and development in shaping our living environment.
... differentiate the levels, scales and tasks of spatial planning instruments and processes.
... reflect on theoretical concepts and practical examples of decision-making of spatial tasks.
... identify and apply spatially relevant principles and systems for action-oriented planning and decision-making.
... acquire theoretical, methodological, practical know-how to examine, clarify, and solve tasks on spatial development

The course consists of a mixture of theoretical lectures and exercises or practical sessions. The exercises provide a framework for practical application of the learned theoretical concepts of spatial planning to real-life situations. The course focuses on both theoretical concepts and practice-oriented approaches to gain knowledge and be equipped to address current issues in spatial planning and development. This is mirrored in the course’s structure made of both of lectures and exercises. The course focuses on both theoretical concepts and practice-oriented approaches to gain knowledge and be equipped to address current issues in spatial planning and development. This is mirrored in the course’s structure made of both of lectures and exercises.

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Lecture notes
A course will be set up on Moodle for the provision of lectures and documents, to upload group deliverables and to ask questions in a discussion Forum. All documents provided are exclusively available for use within this course. A course will be set up on Moodle for the provision of lectures and documents, to upload group deliverables and to ask questions in a discussion Forum. All documents provided are exclusively available for use within this course.

### Competencies

- **Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies
  - Analytical Competencies
  - Decision-making
  - Problem-solving
  - Project Management
  - Cooperation and Teamwork
  - Creative Thinking
  - Critical Thinking
  - Self-direction and Self-management

- **Method-specific Competencies**
  - assessed
  - assessed
  - assessed
  - assessed
  - fostered
  - fostered
  - assessed
  - assessed
  - fostered

- **Social Competencies**
  - fostered

- **Personal Competencies**
  - fostered

### Major in Forest and Landscape Management

#### Natural Science Foundations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1613-01L</td>
<td>Landscape Patterns and Processes</td>
<td>W</td>
<td>5</td>
<td>3G</td>
<td>L. Pellissier, N. Bauer, S. Gradinaru, D. Karger</td>
</tr>
</tbody>
</table>

- **Abstract**
  - This course introduces landscapes as socially perceived, spatially and temporally dynamic entities that are shaped by natural and societal factors. Concepts and qualitative and quantitative methods to study landscapes from an ecological and societal perspective are presented. The course consists of a mixture of theoretical lectures and exercises or practical sessions.
Objective

Students will learn:
- The use of spatial data and analyses for quantifying patterns and processes in landscapes
- Concepts and methods to quantify functional connectivity in landscapes and seascapes.
- The use of remote sensing (satellites images, drones) to extract information about landscape structure and change, with a focus on land-use.
- The use of landscape genetics and its application to biodiversity conservation.
- To computationally optimize land-use planning problems.
- Concepts and methods in scenario-based land-use change modelling.
- Concepts of social preference of landscapes and related measurement methods.
- The role of landscape features in influencing human well-being.
- Approaches of actively influencing attitudes and behavior toward landscapes as well as their scientific evaluation.

Content

Thematic topics
1. Ecological quantification of landscape patterns:
   - Landscape resources and green infrastructure (e.g., ecological conservation areas).
   - Landscape and seascape connectivity.
   - Landscape genetics and conservation applications.
   - Concepts of spatial quantitative methods: least cost paths, resistance surfaces, Circuitscape, land-use change models, various statistical methods.
   - Image processing from remote sensing from satellites and drones.
   - Modelling future land-use.
   - Spatial optimization and trade-offs relative to biodiversity, agriculture and energy production.

2. Social perception and of landscapes:
   - Theories on landscape preference and place identity.
   - Role of landscapes for recreation, health and well-being
   - Methods of investigating the human-landscape relationship and evaluating interventions

Lecture notes

Handouts will be available in the course and for download

Prerequisites / notice

Basic Landscape Ecology courses at Bachelor level

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Creative Thinking
- Critical Thinking

ECTS

Mountain Hydrology W 5 credits 3G M. Brunner, K. Meusburger Di Bella

Abstract

This course presents a process-based view of the hydrology of mountain streams. Students learn how to integrate process knowledge, data, and models to understand how landscapes regulate the fluxes of water, sediment, nutrients, and pollutants in streams, and to anticipate how streams will respond to changes in land use, water use, and climate.

Objective

Main learning objective: Describe the main elements and processes and their interlinkages of the water cycle in mountain catchments and analyze their characteristics and changes.

Objective 1: Identify and describe the important components of the water cycle and their influencing factors and discuss how changes in these influencing factors may affect different parts of the hydrological cycle.

Objective 2: Analyse, visualize, and interpret climate and hydrological time series data.

Objective 3: Explain how hydrological data are collected, how hydrological models work, how they are calibrated, and how they are evaluated.

Content

Streams are integrated monitors of the health and functioning of their surrounding landscapes. Streams integrate the fluxes of water, solutes, and sediment from their contributing catchment area; thus they reflect the spatially integrated hydrological, ecophysiological, biogeochemical, and geomorphological processes in the surrounding landscape. At a practical level, there is a significant public interest in managing upland landscapes to provide a reliable supply of high-quality surface water and to minimize the risk of catastrophic flooding and debris flows, but the scientific background for such management advice is still evolving.

Using a combination of lectures, field exercises, and data analysis, we explore the processes controlling the delivery of water, solutes, and sediment to streams, and how those processes are affected by changes in land cover, land use, and climate. We review the connections between process understanding and predictive modeling in these complex environmental systems. Practical problems to be considered include the effects of land use and climate on streamflow and water quality, illustrated with data from experimental watersheds in North America and Europe.

Lecture notes

Handouts will be available through moodle.

Literature

Recommended and required reading will be specified at the first class session (with possible modifications as the semester proceeds).

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Problem-solving

Social Competencies
- Cooperation and Teamwork

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection

ECTS

Foundations of Ecosystem Management W 5 credits 3G J. Ghazoul, A. Giger Dray

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2495 of 2653
Abstract This course introduces the broad variety of conflicts that arise in projects focusing on sustainable management of natural resources. It explores case studies of ecosystem management approaches and considers their practicability, their achievements and possible barriers to their uptake.

Objective Students should be able to
a) propose appropriate and realistic solutions to ecosystem management problems that integrate ecological, economic and social dimensions across relevant temporal and spatial scales.
b) identify important stakeholders, their needs and interests, and the main conflicts that exist among them in the context of land and resource management.

Content Traditional management systems focus on extraction of natural resources, and their manipulation and governance. However, traditional management has frequently resulted in catastrophic failures such as, for example, the collapse of fish stocks and biodiversity loss. These failures have stimulated the development of alternative ecosystem management approaches that emphasise the functionality of human-dominated systems. Inherent to such approaches are system-wide perspectives and a focus on ecological processes and services, multiple spatial and temporal scales, as well as the need to incorporate diverse stakeholder interests in decision making. Thus, ecosystem management is the science and practice of managing natural resources, biodiversity and ecological processes, to meet multiple demands of society. It can be local, regional or global in scope, and addresses critical issues in developed and developing countries relating to economic and environmental security and sustainability.

This course provides an introduction to ecosystem management, and in particular the importance of integrating ecology into management systems to meet multiple societal demands. The course explores the extent to which human-managed terrestrial systems depend on underlying ecological processes, and the consequences of degradation of these processes for human welfare and environmental well-being. Building upon a theoretical foundation, the course will tackle issues in resource ecology and management, notably forests, agriculture and wild resources within the broader context of sustainability, biodiversity conservation and poverty alleviation or economic development. Case studies from tropical and temperate regions will be used to explore these issues. Dealing with ecological and economic uncertainty, and how this affects decision making, will be discussed. Strategies for conservation and management of terrestrial ecosystems will give consideration to landscape ecology, protected area systems, and community management, paying particular attention to alternative livelihood options and marketing strategies of common pool resources.

Lecture notes No Script


Competencies

Subject-specific Competencies
Concepts and Theories assessed
Decision-making assessed
Problem-solving assessed
Project Management assessed

Method-specific Competencies
Communication fostered
Cooperation and Teamwork assessed
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence assessed
Sensitivity to Diversity fostered
Negotiation assessed

Social Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

Personal Competencies

701-1635-00L Multifunctional Forest Management W 5 credits 2G M. Lévesque, M. Mayer

Abstract Forests provide a variety of ecosystem goods and services. Multifunctional forest management attempts to control natural processes in a sustainable and near-natural way so that various requirements from the society can be met. Adaptivity to changing conditions (global changes), handling of conflicting goals and the development of alternative management strategies are of central importance.

Objective At the end of this course participants will be able:
- To describe forest management and silvicultural measures for enhancing forest resilience to climate change, increased disturbances, and invasive species, and evaluate their feasibility and effectiveness in various situations;
- To concisely describe silvicultural options for the management of multifunctional forests and critically evaluate their feasibility and suitability;
- To explain the various social expectations towards forest ecosystem services and their implications for multifunctional forest management and critically analyse conflicts and synergies resulting from different forest ecosystem services;
- To carry out research on a given topic, identify relevant literature and present the results in a structured presentation and discuss the implications for forest management.

Content The course will cover important topics for the sustainable management of multifunctional forests and present silvicultural strategies to fulfill a variety of forest ecosystem goods and services. Current and future challenges of forest management will be presented. The course is structured into the following sub-topics:
1) Forest management under climate change and increasing disturbances.
2) Invasive alien species: Implications for forest management.
3) Non-native tree species: Risks, opportunities and management options.
4) Silvicultural and management options in multifunctional forests.
5) Challenges and silvicultural strategies for wood production.
6) Forest management and biodiversity in temperate forests.

Lecture notes No class notes or text books

Literature Lecture presentations are available for download

Literature will be provided for the group presentations.
Prerequisites / notice

Course language is English. Prerequisites: Sufficient English language skills

In addition to the lectures, students need to attend 4 all-day field excursions.

Excursion topics: Forest management and climate change, Nature-based silvicultural concepts; Soil protection and forest management; Continuous cover forestry.

Participation at all 4 full-day excursions is a prerequisite for the credits.

Excursions are held in English, German and French (some German and French knowledge is good to have).

Additional field excursions focusing on silvicultural systems and multifunctional forest management will be offered during the spring semester in the optional course "Selected Topics of Multifunctional Forest Management". 9 all-day field trips will provide the possibility to consolidate theoretical knowledge, to apply it to real examples in the field, to discuss with forest practitioners and further consolidate what has been taught in this course. The additional course is an important part of the formation of the Major in Forest and Landscape and is highly recommended.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: fostered

Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed

Decision Making, Policy and Planning

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<th>Number</th>
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<tr>
<td>701-1651-00L</td>
<td>Environmental Governance</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>E. Lieberherr</td>
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Abstract
The course addresses environmental policies, focusing on new steering approaches, which are generally summarized as environmental governance. The course also provides students with tools to analyze environmental policy processes and assesses the key features of environmental governance by examining various practical environmental policy examples.

Objective
To understand how an environmental problem may (not) become a policy and explain political processes, using basic concepts and techniques from political science.

To analyze the evolution as well as the key elements of environmental governance.

To be able to identify the main challenges and opportunities for environmental governance and to critically discuss them with reference to various practical policy examples.

Content
Improvements in environmental quality and sustainable management of natural resources cannot be achieved through technical solutions alone. The quality of the environment and the achievement of sustainable development strongly depend on human behavior and specifically the human uses of nature. To influence human behavior, we rely on public policies and other societal rules, which aim to steer the way humans use natural resources and their effects on the environment. Such steering can take place through government intervention alone. However, this often also involves governance, which includes the interplay between governmental and non-governmental actors, the use of diverse tools such as emission standards or financial incentives to steer actors' behavior and can occur at the local, regional, national or international level.

In this course, we will address both the practical aspects of as well as the scientific debate on environmental governance. The course gives future environmental experts a strong basis to position themselves in the governance debate, which does not preclude government but rather involves a spectrum from government to governance.

Key questions that this course seeks to answer: What are the core characteristics of environmental challenges from a policy perspective? What are key elements of 'environmental governance' and how legitimate and effective are these approaches in addressing persistent environmental challenges?

Furthermore, we encourage the development of soft skills by engaging students in activities such as moderating discussions in class, presenting own proposals, giving regular peer feedback, as well as critically reflecting on various relevant publications in the environmental governance domain.

Lecture notes
Lecture slides, a script and additional course material will be provided on Moodle.

Prerequisites / notice
A detailed course schedule will be made available at the beginning of the semester.

During the lecture we will work with Moodle. We ask that all students register themselves on this platform before the lecture.

We recommend that students have (a) three-years BSc education of a (technical) university; (b) successfully completed Bachelor introductory course to environmental policy (Entwicklungen nationaler Umweltpolitik (or equivalent)) and (c) familiarity with key issues in environmental policy and some fundamental knowledge of one social science or humanities discipline (political science, economics, sociology, history, psychology, philosophy)
### Competencies

**Subject-specific Competencies**
- Concepts and Theories

**Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

**Social Competencies**
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Personal Competencies**
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

### Methods and Tools

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<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
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<tr>
<td>701-1673-00L</td>
<td><strong>Environmental Measurement Laboratory</strong></td>
<td>W</td>
<td>5</td>
<td>4G</td>
<td>P. U. Lehmann Grunder, A. Carminati</td>
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</table>

### Abstract

This course covers and integrates knowledge from the disciplines of landscape level forest management planning, ecology, and forest economics. Students will apply knowledge and methods acquired throughout their studies to real world case studies, and will learn to make predictions about the development of forest ecosystems, prescribe realistic management solutions, and assess the economic consequence.

### Objective

After participating in this course, students will be able to:
- Identify and integrate environmental, social and economic objectives for managing a forest.
- Design landscape level forest management concepts to meet these objectives.
- Identify criteria and indicators appropriate for assessing and monitoring the success of alternative forest management approaches in achieving their objectives.
- Apply standard procedures for cashflow-based evaluations to review the economic sustainability of different forest management scenarios.
- Develop forest-based business proposals including income from traditional timber harvesting operations and complementary sources.
- Prepare, write and defend a comprehensive landscape level forest management plan.

Additionally, students will practice and enhance soft skills – such as providing constructive feedback to peers – or by learning to effectively work in diverse teams.

### Content

- **Introduction to Business Planning and Financial evaluation in forestry.**

  Faustmann and the Land expectation value.
  Calculating internal rates of return.
  Choice experiments and valuing forest attributes.
  Payments for ecosystem services.

- **Economics of risk, uncertainties and natural disturbances.**

  Economics of forest property rights and certification.

- **Literature.**

  https://eth.swisscovery.slsp.ch/permalink/41SLSP_ETH/ish64/alma990046045590205503

### Data

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2498 of 2653
Content

Week 1: Plant-Soil interactions – short introduction before sensor demonstration and installation in forest lab; Scholander pressure bomb (suction in leaves); LiCOR soil chamber

Weeks 2 to 6 - Experimental Methods for Soil Health Assessment

- Week 2: Lecture on soil health and soil indicators; defining measurable soil health indicators for case studies for different soil threats and climate regions
- Week 3: Short lecture on sampling, sensors and data logging; preparing sensors and data loggers in the lab; measurements on water content and temperature in the lab
- Week 4: Short introduction on field installation; sensor installation at field site Hönggerberg
- Week 5: Lecture on geophysical methods on subsurface characterization: basic principles of ERT, GPR, and EM; planning of field experiment to assess soil health
- Week 6: Short introduction on data analysis; field sampling and conducting field experiment to assess soil health

Week 7: Analysis of experimental data and soil health assessment; poster presentation and discussion

Week 8: Lecture on plant soil relationship; connecting information below and above ground – data analysis

Weeks 9 and 10: Forest characterization/ inventory: Principles of LiDAR; structures and features of the tree crowns, size/volume of the leaf area tree positions and diameters at breast height

Weeks 11 and 12: Eddy covariance methods -Principles for field measurement of water vapor, carbon dioxide, and energy exchange between terrestrial surfaces and the atmosphere; Analysis of measured time series to determine evaporation rate and CO2-fluxes

Week 13: Swiss Soil Monitoring networks – Monitoring of soil water content and potential; climate change and droughts

Week 14: Global data – Global modeling and data interpretation; SoilGrids and OpenLandMap; exercises on Budyko analysis

Literature

Lecture material will be online for registered students using moodle

Prerequisites / notice

The details of the schedule will be optimized based on the number of students; some blocks of the course will be offered as well to students of Environmental Engineering

Competencies

Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Decision-making
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork

Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

Electives

Natural Science Foundations

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
701-1343-00L | Soil-Plant Water Relations | W | 3 credits | 2V | A. Carminati

Abstract

Water limitation is a primary constraint on plant growth and terrestrial fluxes worldwide. In this course, the principles of water flow in soil and plants are discussed, with particular attention on the effect of drought on root water uptake, transpiration and plant growth. Strategies of plants to tolerate drought are discussed in relation to both agricultural and ecological implications.

Objective

The students are able to: explain and compare systematically the drivers of water stress to plants; to solve the equations of water flow in soil and plants and to calculate plant water status for varying soil and climatic conditions and plant traits; to critically review and present one research question in soil-plant water relations; to openly debate on the current trends in soil and plant water research and climate change ecology.

Content

Part 1 - Lectures
- Week 1: Introduction.
- Week 2: Soil water relations; Principles of soil water retention and soil water flow; Soil hydraulic properties.
- Week 3: Root water uptake; soil hydraulic constraints on transpiration
- Week 4: Rhizosphere processes and properties; root-soil contact; root hairs; mycorrhiza; rhizodeposition.
- Week 5: Water flow in roots and xylem; root anatomy, architecture and plasticity; cavitation.
- Week 6: Transpiration; Vapor Pressure Deficit; Photosynthesis; Stomatal regulation.
- Week 7: Soil-plant-atmospheric continuum; Below- and above-ground feedbacks; Soil and atmospheric drivers of transpiration losses.

Part 2 - Seminar
- Week 8: Plant response to drought and consequences for agriculture and forests. Open questions and introduction to seminar topics.
- Week 9: Class work - preparation of the presentations/Debate
- Week 10: Class work - preparation of the presentations/Debate
- Week 11: Seminar/Debate (presentations)
- Week 12: Seminar/Debate (presentations)
- Week 13: Seminar/Debate (presentations)
- Week 14: Feedback, Summary, Conclusion

Literature

Lecture notes; selection of articles

Prerequisites / notice

Vadose Zone Hydrology/Environmental Soil Physics (recommended but not required)
The course provides a comprehensive overview on concepts and applications of tree genetics and complements basic knowledge of biology, dendrology, forest ecology and forest management in the frame of forest and landscape management topics. It introduces concepts of evolution and genetic methods as foundations, explains the most important processes and drivers of gene flow and adaptation, including coevolutionary aspects of associated organisms, and shows relevant topics of the management of genetic resources from reproduction to conservation and monitoring. Theories and their application into practice are illustrated on behalf of case studies on forest tree species. Two full-day excursions illustrate the contents with exemplary objects, actors and applications in Switzerland.

Lecture notes: Script: modular slide script (parts by each lecturer).
Textbook: collection of accompanying or background articles according to detailed contents (to be defined).

Literature:

Prerequisites / notice: No mandatory prerequisites. Basic knowledge of genetics is advantageous and recommended.

Competencies
- Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: fostered
  - Problem-solving: assessed
- Social Competencies
  - Communication: fostered
  - Cooperation and Teamwork: fostered
- Personal Competencies
  - Adaptability and Flexibility: fostered
  - Critical Thinking: assessed
  - Self-awareness and Self-reflection: fostered
  - Self-direction and Self-management: fostered

701-1620-00L Tree Genetics – Concepts and Applications
- W 3 credits 2G
- A. Rudow, F. Gugerli, C. Sperisen, K. Streit

Abstract
Trees are important elements and drivers of ecosystem processes in forests and landscapes. Tree species diversity and intraspecific genetic diversity are relevant factors for continuous adaptation, required for a sustainable maintenance of forest products and services. Sustainable forest and landscape management under climate change has to take forest genetic resources into consideration.

Objective
The educational goals of the course are:
To know basic concepts of evolution and molecular and quantitative methods of genetics.
To understand the most relevant processes of gene flow, adaptation and species interactions, on the basis of ecological theories and case studies on forest tree species.
To know management principles and instruments for the promotion and the conservation of forest genetic resources, with a view on application in practice.

Content
The course provides an introduction to the applicability of stable isotopes to ecological research questions. Topics will focus on carbon (13C), nitrogen (15N), oxygen (18O) and hydrogen (2H) at natural isotope abundance and tracer levels. Lectures will be supplemented by intensive laboratory sessions, short presentations by students and computer exercises.

This course will provide an introduction to the applicability of stable isotopes to ecological research questions. Topics will focus on carbon (13C), nitrogen (15N), oxygen (18O) and hydrogen (2H) at natural isotope abundance and tracer levels. Lectures will be supplemented by intensive laboratory sessions, short presentations by students and computer exercises.

Lecture notes
Handouts will be available on the webpage of the course.

Prerequisites / notice
This course is based on fundamental knowledge about plant ecophysiology, soil science, and ecology in general. Course will be taught in English.
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Method-specific Competencies
Analytical Competencies assessed
Problem-solving fostered
Project Management assessed
Social Competencies
Communication assessed
Cooperation and Teamwork fostered
Personal Competencies
Creative Thinking assessed
Self-direction and Self-management assessed

Decision Making, Policy and Planning

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
751-2107-00L | Agrarian and Environmental Values: Tensions, Synergies, Practices and Policies | W | 5 credits | 3G | M. Chapman, J. Jacobi

Limited to 20 students.

Abstract
In politics, society, and science, it can seem that the values and practices of agricultural production and environmental protection are in conflict. This tension is often described as “protection versus use” of natural resources. We will explore ways to move beyond the apparent conflict. We will apply this learning to field trips and transdisciplinary projects.

Objective
Students are able to:

- Define different kinds and categories of values.
- Relate value concepts to their own studies, life, and experiences through reflective journaling.
- Infer the underlying values in a text or policy about agri-environmental topics.
- Collaboratively develop a transdisciplinary project for an agri-environmental case study from the field trips.

Content
The course consists of interactive seminars alongside fieldtrips to farms that have found innovative solutions to balancing protection and production.

Seminars will cover topics such as the relationship between values and behavior and how people perceive value trade-offs. We will also discuss environmental ethics, environmental valuation and its critiques, the interplay of facts and values in agri-environmental decision-making, cultural ecosystem services, and relational values.

This class requires active participation. Learning is based on in-class activities, group work and fieldtrips.
Literature will draw from political ecology, value theory and environmental values, as well as case studies and primary texts, such as the following (not all will be required reading; we will read 1 or 2 papers or book chapters each week).


Competencies

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Ecosystem Management

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<tbody>
<tr>
<td>701-1453-00L</td>
<td>Ecological Assessment and Evaluation</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td>F. Knaus</td>
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</tbody>
</table>

The course provides methods and tools for ecological evaluations dealing with nature conservation or landscape planning. It covers census methods, ecological criteria, indicators, indices and critically appraises objectivity and accuracy of the available methods, tools and procedures. Birds and plants are used as main example guiding through different case studies.
Objective
Students will be able to:
1) critically consider biological data books and local, regional, and national inventories;
2) evaluate the validity of ecological criteria used in decision making processes;
3) critically appraise the handling of ecological data and criteria used in the process of evaluation
4) perform an ecological evaluation project from the field survey up to the decision making and planning.

Lecture notes
Powerpoint slides are available on the moodle page. Additional documents are handed out as copies.

Literature
Basic literature and references are listed on the webpage.

Prerequisites / notice
The course structure changes between lecture parts, seminars and discussions. The didactic atmosphere is intended as working group.

Suggested prerequisites for attending this course are skills and knowledge equivalent to those taught in the following ETH courses:
- Pflanzen- und Vegetationsökologie
- Systematische Botanik
- Raum- und Regionalentwicklung
- Naturschutz und Naturschutzbiologie

Competencies

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<td>Critical Thinking</td>
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<td>Self-direction and Self-management</td>
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701-1645-00L Forest Operations W 3 credits 2G H. Griess, J. Schweier

Abstract
The discipline of Forest operations is constantly challenged to find solutions for unique problems. Each forest site requires specific technological approaches and machinery based on given management goals and ecological and environmental circumstances. Various terrain types and soil conditions, harvesting costs and taking care of the workforce by creating safe working conditions are some of the a

Objective
In this course, students will learn to use a wide variety of approaches grounded in the natural sciences, engineering and technology to develop solutions tailored to unique challenges from the field of forest operations.

After participating in this course students will have acquired foundational knowledge of a wide variety of core elements in the field of forest operations:
• The course will provide students with the ability to describe and differentiate site and stand conditions from an engineering perspective.
• Students will gain an overview and good working knowledge of current technology used in forest operations in Switzerland and around the world.
• Students will acquire the ability to assess the strength and weaknesses of the most commonly used equipment and analyze their suitability for a given set of environmental, economic and social factors.
• Students will be able to combine different types of technology to create an optimal harvesting system for a given task, and assess a given system for its task specific suitability.
• Participants will be able to assess the sustainability and potential short- and long-term impacts of harvesting systems under ecological, economic and social constraints.
Content

Introduction
  • Historic overview
  • Scope of operation
  • Site and stand characteristics

Timber harvesting
  • Logging methods
  • Felling methods
    • Motor-Manual felling methods
      o Falling and processing
  • Forest machine structure and function
  • Harvester Technology
    o Felling heads
    o Carriers for felling heads
  • Bunching
  • Mechanical processing
  • Loading equipment
  • Operating techniques

Primary Transport Systems
  • Ground based
    o Common features
    o Skidder
    o Forwarder
    o Loader Forwarder
  • Cable yarding
    o Common features
    o Wire rope
    o Cable yarding systems
    o Operating techniques
  • Aerial
    o Common features
    o Operating techniques

Winch-Assisted Harvesting Operations
  • Harvesting
  • Primary transport

Loading Equipment

Secondary transport
  • Truck configurations
  • Soil compaction and contamination
  • Riparian areas

Forest Operations management
  • Ergonomics
  • Work Safety
  • Economic Aspects
  • Environmental impact assessment
  • Equipment selection

Forest operations across the globe
  • New Zealand
  • North America
    o British Columbia, Canada
    o South-eastern U.S.A

Specialized equipment for small scale forest operations

Overview into the future of forest operations

Literature
Published on Moodle
Prerequisites / notice
701-1544-00 Forest Access and Transportation

Methods and Tools

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<tr>
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<tbody>
<tr>
<td>701-1411-00L</td>
<td>Environmental DNA - Concepts and Applications for Biodiversity Monitoring at the Landscape Scale</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td>L. Pellissier, C. P. Albouy, K. Deiner, A. Frossard</td>
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</tbody>
</table>

Abstract

Environmental DNA (eDNA) allows the detection of organisms from traces of their DNA sampled from water, air or soil. Sampling eDNA instead of organisms makes monitoring fast, non-invasive, scalable and inexpensive. In this lecture, students will learn about eDNA and how it can be sampled, sequenced and analysed for biodiversity discovery and monitoring.

Objective

At the end of this course, participants should be able to:
- describe what eDNA is and how to harness the information in eDNA to turn it into a survey method for biodiversity
- describe the eDNA analytical steps, from the sampling, laboratory, data analysis and interpretation.
- summarise the common software and analytical tools for analysing eDNA data and be able to interpret the results.
- apply eDNA methods to design programs for monitoring in conservation and restoration through case studies.

Additionally, participants should be able to:
- provide constructive feedback to peers and learn from feedback,
- integrate concepts within and among disciplines of science.
The course is consisting of two pillars:

Pillar 1: Theoretical background. The first pillar offers general theoretical knowledge about the nature of eDNA and its use in biodiversity science. It is structured into theoretical blocks with video content about sampling design, laboratory and data processing, which offer fundamental knowledge to solve the practical case studies of pillar 2.

Pillar 2: Data application on applied Case Studies. Each theory block will be associated with an exercise in which students are challenged to apply their knowledge from the theory. Students will collaborate on planning eDNA sampling design, visit the laboratory, run eDNA analysis (in R) following the best guidelines and interpret the results of analyses. These exercises will happen in person in the classroom.

**701-1677-00L Quantitative Vegetation Dynamics: Models from Tree to Globe**

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<tbody>
<tr>
<td>- Students will be able to understand the fundamental properties of dynamic vegetation models using vegetation models as case studies.</td>
<td>- Models of individuals and vegetation dynamics from the individual tree to the landscape. - Models of ecosystems and global vegetation patterns.</td>
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<td>- Students will be able to work with such model types on their own.</td>
<td>- Develop DGVMs as components of Earth System Models.</td>
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<tr>
<td>- Students will appreciate the methodological basis for impact assessments of future climate change and other environmental changes on ecosystems.</td>
<td>- Understand the basic assumptions of the various model types, which dictate the applicability and limitations of the respective model types.</td>
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</table>

**Prerequisites / notice**

- Basic understanding of genetics and molecular analyses.
- Basic knowledge of R and Geographic Information Systems (GIS).
- The analytic part of the lecture will rely on skills from "Environmental Systems Data Science".

**Lecture notes**

Handouts will be available in the course and for download.

**Literature**

Will be indicated at the beginning of the course.

<table>
<thead>
<tr>
<th>Lecture notes</th>
<th>Literature</th>
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<tr>
<td>Lecture notes (in English) will be handed out in the class.</td>
<td>Literature lists will be handed out in the class.</td>
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**701-1682-00L Dendroecology**

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<th>Objective</th>
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<tr>
<td>- The students will understand, how wood is configured and how tree-ring structures are formed.</td>
<td>- Overview and history of dendrochronology.</td>
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<td>- Are able to identify and describe different tree-ring structures.</td>
<td>- Principles of dendrochronology.</td>
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<td>- Understand the theoretical and practical aspects of the dating of tree rings.</td>
<td>- Formation and structure of wood and tree rings.</td>
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<td>- Know the effects of different abiotic and biotic environmental influences (climate, site, competition, insects, fire, physical-mechanical influences) on trees and tree rings.</td>
<td>- Wood anatomy and intra-seasonal tree-ring growth.</td>
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<td>- Discover a tool for understanding and reconstructing global change processes.</td>
<td>- Continuous and discontinuous tree-ring characteristics.</td>
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<td>- Learn software to date, standardize and analyze tree rings.</td>
<td>- Sampling and measuring of tree rings.</td>
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<tr>
<td>- Get hands-on experience based on the demonstration of wood (increment cores, stem discs, wedges), sampling in the field, and measuring and dating of tree rings in the tree-ring lab.</td>
<td>- Crossdating methods (visual, skeleton plots, quantitative).</td>
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<td>- Solve R-based exercises (R tutorial will be provided) and answer questions in Moodle.</td>
<td>- Detrending and standardization of tree-ring series.</td>
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<td>- Work out an independent research question related to a dendroecological topic and write a short literature review based on scientific papers.</td>
<td>- Development of tree-ring chronologies.</td>
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<td>- Appreciate the methodological basis for impact assessments of future climate change and other environmental changes on ecosystems.</td>
<td>- Water transport in trees.</td>
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**Prerequisites / notice**

- Basic knowledge of R and Geographic Information Systems (GIS).
- Basic understanding of genetics and molecular analyses.
- Work on scientific papers.

**Lecture notes**

The lecture notes and further documents (papers, software) can be downloaded from Moodle (https://moodle-app2.let.ethz.ch) following registration for the course.

**Literature**

The literature lists will be handed out in the class.
701-1776-00L Geographic Data Processing with Python and ArcGIS

Abstract
The course communicates the basics of the Python programming language and provides a general introduction to the ArcGIS Pro Python scripting framework. It also introduces several Python libraries (pandas, numpy, scpy, statsmodels, geopandas, rasterio) that greatly extend the capabilities of spatial data analysis and modelling.

Objective
Students will learn the basics of geographic data processing using the Python programming language and ArcGIS Pro (arcpy). They will be able to implement their own geoprocessing scripts for spatial data analysis and modelling. Students will be able to integrate open source libraries into their Python scripts and know how to apply the libraries to geospatial datasets.

Content
The course covers basic Python language concepts such as data types, control structures and functions. These concepts are then used to gain a deeper understanding of ArcGIS Pro’s geoprocessing framework (arcpy). This includes vector data processing functions as well as geoprocessing functions for raster data analysis. It also introduces the use of key Python libraries in conjunction with geospatial datasets.

Literature

Prerequisites / notice
Basic knowledge of ArcGIS is assumed.

701-3001-00L Environmental Systems Data Science: Data Processing

Abstract
Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

Objective
The students are able to
- frame a data science problem and build a hypothesis
- describe the steps of a typical data science project workflow
- conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
- critically think about the limits and implications of a method
- visualise data and results throughout the workflow
- access online resources to keep up with the latest data science methodology and deepen their understanding

Content
- The data science workflow
- Access and handle (large) datasets
- Prepare and clean data
- Analysis: data exploratory steps
- Analysis: machine learning and computational methods
- Evaluate results and analyse uncertainty
- Visualisation and communication

Prerequisites / notice
252-0840-02L Anwendungsnahe Programmieren mit Python
401-0624-00L Mathematik IV: Statistik
401-6215-00L Using R for Data Analysis and Graphics (Part I)
401-6217-00L Using R for Data Analysis and Graphics (Part II)
701-0105-00L Mathematik VI: Angewandte Statistik für Umwelt Naturwissenschaften

701-3003-00L Environmental Systems Data Science: Machine Learning

Abstract
Students are introduced to advanced data science where environmental data are analyzed using state of the art machine learning methods. Starting from known statistical approaches, they learn the principle of more advanced machine learning methods with practical application. The course enables students to plan their own data science project in their specialization and to apply machine learning method

Objective
The students are able to
- select an appropriate model related to a research question and dataset
- describe the steps from data preparation to running and evaluating models
- prepare data for running machine learning with dependent and independent variable
- build and validate regressions and neural network models
- understand convolution and deep learning models
- access online resources to keep up with the latest data science methodology and deepen their understanding
• The data science workflow
• Data preparation for running and validating machine learning models
• Get to know machine learning approaches including regression, random forest and neural network
• Model complexity and hyperparameters
• Model parameterization and loss
• Model evaluations and uncertainty
• Deep learning with convolutions

Literature
Building on existing data science resources

Prerequisites / notice
Math IV, VI (Statistics); R, Python; ESDS I

401-0627-00L Smoothing and Nonparametric Regression with Examples

Abstract
Starting with an overview of selected results from parametric inference, kernel smoothing will be introduced along with some asymptotic theory, optimal bandwidth selection, data driven algorithms and some special topics. Selected numerical examples will be used for motivation. The presented methods will also be applicable elsewhere.

Objective
The students will learn about methods of kernel smoothing and application of concepts to data. The aim will be to build sufficient interest in the topic and intuition as well as the ability to implement the methods to various different datasets.

Content
Rough Outline:
- Parametric estimation methods: selection of important results
  o Method of Least squares: regression & diagnostics
- Nonparametric curve estimation
  o Density estimation, Kernel regression, Local polynomials, Bandwidth selection, various theoretical results related to consistency
  o Selection of special topics (as time permits, we will discuss some of the following): rapid change points, mode estimation, partial linear models, probability and quantile curve estimation, etc.
- Applications: potential areas of applications will be discussed such as, change assessment, trend and surface estimation and others.

Lecture notes
Summaries or outlines of some of the lecture material may be communicated to registered students by Email at irregular intervals.

Note: These summaries/outlines will tend to be brief, likely to be incomplete & may have typos. Only in-class lessons will contain complete information.

Literature
References:
- Statistical Inference, by S.D. Silvey, Chapman & Hall.
- Density Estimation, by B.W. Silverman, Chapman and Hall.
- Nonparametric Simple Regression, by J. Fox, Sage Publications.

Additional references will be given out in the lectures.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed

Social Competencies
Communication fostered

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

Colloquium

Number Title Type ECTS Hours Lecturers
701-1691-00L Colloquium Forest and Landscape Management Z 0 credits 1.5K H. Bugmann

Abstract
This course is geared towards outreach and dissemination of research results to Swiss forest practitioners.

Objective
Exchange platform between forest science and forest practitioners, geared towards Swiss stakeholders

Literature
wird angegeben, so weit sinnvoll

Competencies

Subject-specific Competencies
Concepts and Theories fostered
Techniques and Technologies fostered

Method-specific Competencies
Analytical Competencies fostered
Decision-making fostered
Media and Digital Technologies fostered
Problem-solving fostered

Social Competencies
Communication fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking fostered

Major in Human Health, Nutrition and Environment

Public Health
The module Public Health is compulsory for all students in the major Human Health, Nutrition and Environment.

### Applied Biostatistics

**Number**: 401-0629-00L  
**Title**: Applied Biostatistics  
**Type**: W  
**ECTS**: 4  
**Hours**: 3G  
**Lecturers**: M. Tanadini

**Abstract**  
This course covers the main methods used in Biostatistics. It starts by revising Linear Models (Regression, Anova), then moves to Generalised Linear Models (logistic regression and methods for count data) and finally introduces more advanced topics (Linear Mixed-Effects Models and Generalised Additive Models). The course strongly focuses on applied aspects of data analysis.

**Objective**  
After this course students:
- revised Linear Models
- revised or got introduced to Generalised Linear Models
- got introduced to Linear Mixed-Effects Models
- are able to select among these methods to solve an applied problem in Biostatistics
- can perform the data analysis using the statistical software R
- can interpret the results of such an analysis and draw valid "biological" conclusions

**Content**  
This course is structured into three parts. The first part focuses on Linear and Generalised Linear Models. The second part introduces more advanced methodologies such as Linear Mixed-Effects Models and Generalised Additive Models. Both, part one and two will include the following topics: exploratory data analysis, model fitting, model "selection", residual diagnostics, model validation and results interpretation. Analyses will be carried out using the statistical software R. Finally, in the third part of the course students will be analysing real-world datasets to put into practice the knowledge and skills acquired during the first two parts.

**Prerequisites / notice**  
The statistical software R will be used in the exercises. If you are unfamiliar with R, it is highly recommend to view the online R course "etutoR".

### Epidemiology and Prevention

**Number**: 752-6105-00L  
**Title**: Epidemiology and Prevention  
**Type**: W  
**ECTS**: 3  
**Hours**: 2V  
**Lecturers**: M. Puhan, R. Heusser

**Abstract**  
The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.

**Objective**  
The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware of how epidemiological facts are used in prevention, practice, and politics.

**Content**  
The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

### Public Health Concepts

**Number**: 752-6151-00L  
**Title**: Public Health Concepts  
**Type**: W  
**ECTS**: 3  
**Hours**: 2V  
**Lecturers**: R. Heusser

**Abstract**  
The module "public health concepts" offers an introduction to key principles of public health. Students get acquainted with the concepts and methods of epidemiology. Students also learn to use epidemiological data for prevention and health promotion purposes. Public health concepts and intervention strategies are presented, using examples from infectious and chronic diseases.

**Objective**  
At the end of this module students are able:
- to interpret the results of epidemiological studies
- to critically assess scientific literature
- to know the definition, dimensions and determinants of health
- to plan public health interventions and health promotion projects
- to draw a bridge from evidence to policies and politics

**Content**  
Concepts of descriptive and analytical epidemiology, study designs, measures of effect, confounding and bias, screening, surveillance, definition of health and health promotion, health dimensions and health determinants, prevention strategies, public health interventions, public health action cycle, epidemiology and prevention of infectious and chronic diseases (HIV, COVID-19, Obesity, Iodine/PH nutrition).

**Lecture notes**  
Handouts are provided to students in the classroom.

### Nutrition and Health

### Food and Consumer Behaviour

**Number**: 752-2122-00L  
**Title**: Food and Consumer Behaviour  
**Type**: W  
**ECTS**: 2  
**Hours**: 2V  
**Lecturers**: M. Siegrist, F. Michel

**Abstract**  
This course focuses on food consumer behavior, consumer's decision-making processes and consumer's attitudes towards food products.

**Objective**  
Students will be able...
- to describe heuristics that influence consumer behavior in the food domain
- to explain the consumer led food product development
- to summarise how consumers perceive the environmental impact and the healthiness of foods
- to assess the cultural, the environmental and and the food policy impact on consumer behavior
- to explain psychological factors influencing eating behavior

**Competencies**  
Subject-specific Competencies  
- Concepts and Theories  
- Techniques and Technologies  
Method-specific Competencies  
- Analytical Competencies  
- Decision-making  
Social Competencies  
- Communication  
- Customer Orientation  
- Sensitivity to Diversity

**Nutrition and Chronic Disease

**Number**: 752-6101-00L  
**Title**: Nutrition and Chronic Disease  
**Type**: W  
**ECTS**: 3  
**Hours**: 2V  
**Lecturers**: F. von Meyenn, M. Andersson

**Objective**  
This course introduces concepts and intervention strategies are presented, using examples from infectious and chronic diseases.
Abstract
To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Objective
To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic disease, as well as the progression of complications of the chronic diseases.

Content
The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Lecture notes
There is no script. Powerpoint presentations will be made available on-line to students.

Prerequisites / notice
No compulsory prerequisites, but prior completion of the courses “Introduction to Nutritional Science” and “Advanced Topics in Nutritional Science” is strongly advised.

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<tr>
<td>376-1353-00L</td>
<td>Nanostructured Materials Safety</td>
<td>W</td>
<td>2</td>
<td>1V</td>
<td>P. Wick, T. Bürki-Thurnherr</td>
</tr>
</tbody>
</table>

**Environment and Health**

**Infectious Diseases**

**Ecological Parasitology**

Does not take place this semester. Does not take place this semester.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0263-01L</td>
<td>Seminar in Evolutionary Ecology of Infectious Diseases</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>R. R. Regös, S. Bonhoeffer</td>
</tr>
</tbody>
</table>

**Economic Overviews**

No compulsory prerequisites, but prior completion of the courses “Introduction to Nutritional Science” and “Advanced Topics in Nutritional Science” is strongly advised.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1471-00L</td>
<td>Ecological Parasitology</td>
<td>W</td>
<td>3</td>
<td>1V+1P</td>
<td>F. Feijen, J. Jokela, C. Vorburger</td>
</tr>
</tbody>
</table>

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2509 of 2653
Abstract

The course will not take place fall semester 2024.

Course focuses on the ecology and evolution of macroparasites and their hosts. Through lectures and practical work, students learn about diversity and natural history of parasites, adaptations of parasites, ecology of host-parasite interactions, applied parasitology, and human macroparasites in the modern world.

Objective

1. Identify common macroparasites in invertebrates.
2. Understand ecological and evolutionary processes in host-parasite interactions.
3. Conduct parasitological research

Content

Lectures:
1. Diversity and natural history of parasites (i.e. systematic groups and life-cycles).
2. Adaptations of parasites (e.g. evolution of life-cycles, host manipulation).
3. Ecology of host-parasite interactions (e.g. parasite communities, effects of environmental changes).
4. Ecology and evolution of parasitoids and their applications in biocontrol
5. Human macroparasites (schistosomiasis, malaria).

Practical exercises:
1. Examination of parasites in molluscs (identification and examination of host exploitation strategies).
2. Examination of parasites in amphipods (identification and examination of effects on hosts).
3. Examination of parasitoids of aphids.

Prerequisites / notice

The three practicals will take place at the 03.10.2023, the 17.10.2023 and the 07.11.2023 at Eawag Dübendorf from 08:15 - 12:00. Note that each practical takes 2 hours longer than the weekly lecture.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Methods-specific Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
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<tr>
<td>Techniques and Technologies</td>
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<tr>
<td>Decision-making</td>
<td>Decision-making</td>
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<tr>
<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Project Management</td>
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<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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<tr>
<td>Adaptability and Flexibility</td>
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<tr>
<td>Critical Thinking</td>
<td>Critical Thinking</td>
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<tr>
<td>Integrity and Work Ethics</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
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<tr>
<td>Self-direction and Self-management</td>
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</tbody>
</table>

701-1703-00L Evolutionary Medicine for Infectious Diseases

Abstract

This course explores infectious disease from both the host and pathogen perspective. Through short lectures, reading and active discussion, students will identify areas where evolutionary thinking can improve our understanding of infectious diseases and, ultimately, our ability to treat them effectively.

Objective

Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses.

Content

We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (~ 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

Literature

The focus is on primary literature, but for some parts the following text books provide good background information:

Schmid Hempel 2011 Evolutionary Parasitology
Stearns & Medzhitov 2016 Evolutionary Medicine

Prerequisites / notice

A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

Competencies

<table>
<thead>
<tr>
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<tr>
<td>Concepts and Theories</td>
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551-0223-00L Immunology III

Abstract

This course provides a detailed understanding of
- development of T and B cells
- the dynamics of an immune response during acute and chronic infection
- mechanisms of immunopathology
- modern vaccination strategies

Key experimental results will be shown to help understanding how immunological text book knowledge has evolved.
Objective
Obtain a detailed understanding of
- the development, activation, and differentiation of different types of T cells and their effectormechanisms during immune responses,
- Recognition of pathogenic microorganisms by the host cells and molecular events thereafter,
- events and signals for maturation of naïve B cells to antibody producing plasma cells and memory B cells.
- Optimization of B cell responses by intelligent design of new vaccines

Content
- Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg)
- NK T cells and responses to lipid antigens
- Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17
- Overview of cytokines and their effector function
- Co-stimulation (signals 1-3)
- Dendritic cells
- Evolution of the "Danger" concept
- Cells expressing Pattern Recognition Receptors and their downstream signals
- T cell function and dysfunction in acute and chronic viral infections

Literature
Documents of the lectures are available for download at: https://moodle-app2.let.ethz.ch/course/view.php?id=2581&notifyeditingon=1

Prerequisites / notice
Immunology I and II recommended but not compulsory

752-4009-00L Molecular Biology of Foodborne Pathogens W 3 credits 2V M. Loessner, A. Harms, M. Schuppler, E. Slack

Abstract
The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Objective
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content
Molecular biology of infectious foodborne pathogens (Listeria, E. coli, Campylobacter, Salmonella, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Prerequisites / notice
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without a break!

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving
Social Competencies
- Communication
Personal Competencies
- Creative Thinking
- Critical Thinking

Semester Paper and Seminar
The compulsory course 701-1701-00L Human Health, Nutrition and Environment: Term Paper is offered in the autumn semester only.

Number Title Type ECTS Hours Lecturers

Abstract
Writing of a review paper of scientific quality on a topic in the domain of Human Health, Nutrition and Environment based on critical evaluation of scientific literature.

Objective
- Acquisition of knowledge in the field of the review paper
- Assessment of original literature as well as synthesis and analysis of the findings
- Practising of academic writing in English
- Giving an oral presentation with discussion on the topic of the review paper

Content
Topics are offered in the domains of the major 'Human Health, Nutrition and Environment' covering 'Public Health', "Infectious Diseases", 'Nutrition and Health' and 'Environment and Health'.

Lecture notes
Guidelines will be handed out in the beginning.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
Method-specific Competencies
- Analytical Competencies
- Media and Digital Technologies
Social Competencies
- Communication
- Cooperation and Teamwork
Personal Competencies
- Critical Thinking
- Integrity and Work Ethics
- Self-direction and Self-management

Electives

Number Title Type ECTS Hours Lecturers
701-3001-00L Environmental Systems Data Science: Data Processing W 2 credits 2G L. Pellissier, C. P. Albouy, M. Volpi
Abstract
Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

Objective
The students are able to
- frame a data science problem and build a hypothesis
- describe the steps of a typical data science project workflow
- conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
- critically think about the limits and implications of a method
- visualise data and results throughout the workflow
- access online resources to keep up with the latest data science methodology and deepen their understanding

Content
- The data science workflow
- Access and handle (large) datasets
- Prepare and clean data
- Analysis: data exploratory steps
- Analysis: machine learning and computational methods
- Evaluate results and analyse uncertainty
- Visualisation and communication

Prerequisites / notice
252-0640-02L Anwendungsnahes Programmieren mit Python
401-0624-00L Mathematik IV: Statistik
401-6215-00L Using R for Data Analysis and Graphics (Part I)
401-6217-00L Using R for Data Analysis and Graphics (Part II)
701-0105-00L Mathematik VI: Angewandte Statistik für Umweltwissenschaften

701-3003-00L Environmental Systems Data Science: Machine Learning
Abstract
Students are introduced to advanced data science where environmental data are analyzed using state of the art machine learning methods. Starting from known statistical approaches, they learn the principle of more advanced machine learning methods with practical application. The course enables students to plan their own data science project in their specialization and to apply machine learning mod

Objective
The students are able to
- select an appropriate model related to a research question and dataset
- describe the steps from data preparation to running and evaluating models
- prepare data for running machine learning with dependent and independent variable
- build and validate regressions and neural network models
- understand convolution and deep learning models
- access online resources to keep up with the latest data science methodology and deepen their understanding

Content
- The data science workflow
- Data preparation for running and validating machine learning models
- Get to know machine learning approaches including regression, random forest and neural network
- Model complexity and hyperparameters
- Model parameterization and loss
- Model evaluations and uncertainty
- Deep learning with convolutions

Literature
Building on existing data science resources

Prerequisites / notice
Math IV, VI (Statistics); R, Python; ESDS I

Minors
Minor in Sustainable Energy Use

Number Title Type ECTS Hours Lecturers
701-0967-00L Project Development in Renewable Energies W 2 credits 2G R. Rechsteiner, A. Appenzeller

Abstract
The focus is on the implementation of projects:
- photovoltaics
- wind energy
- hydropower
You will learn about new business models, including storage and sector coupling, discuss framework conditions, economic efficiency, security of supply, market organization and business risks. Guidance from experts with many years of political and project experience.

Objective
You will receive a practice-oriented introduction to the regulatory and economic requirements for renewable energy projects.
You will be familiar with the options for integrating fluctuating energy production in an environment of volatile prices.
You will be familiar with the opportunities and risks and strategies for economic security.

Content
Detailed program
https://www.rechsteiner-basel.ch/lehrmittel?no_cache=1#c273
Lecture notes
PPT presentation will be distributed (in German)
Future climate change can only be kept within reasonable bounds when CO2 emissions are drastically reduced. In this course, we will discuss portfolio and risk management in the electrical power business, Pan-European power market and trading, futures and forward contracts, hedging, options and derivatives, performance indicators for the risk management, modelling of physical assets, cross-border trading, ancillary services, balancing power market, Swiss market model.

From the large number of carbon sequestration/mitigation options, a few options will be selected and then investigated in detail by the students. The results of this research will then be presented to the other students, the involved faculty, and discussed in detail by the whole group.

The goal of this course is to investigate, as a group, a particular set of carbon mitigation/sequestration options and to evaluate their potential, their cost, and their consequences. Presentations from guest speakers from industry and the public sector, and final presentations by the students.

For group exercise and presentation reasons the number of participants is limited at 30 students. For exercises students build learning and presentational groups. Credit points are based on group performance.

Exam: No final exam. Pass/No-Pass is assigned based on the quality of the presentation and ensuing discussion.

For group exercise and presentation reasons the number of participants is limited at 30 students. For exercises students build learning and presentational groups. Credit points are based on group performance.
Objective

Content
1. Pan-European power market and trading
   1.1. Power trading
   1.2. Development of the European power markets
   1.3. Energy economics
   1.4. Spot and OTC trading
   1.5. European energy exchange EEX

2. Market model
   2.1. Market place and organisation
   2.2. Balance groups / balancing energy
   2.3. Ancillary services
   2.4. Market for ancillary services
   2.5. Cross-border trading
   2.6. Capacity auctions

3. Portfolio and Risk management
   3.1. Portfolio management 1 (introduction)
   3.2. Forward and futures contracts
   3.3. Risk management 1 (m2m, VaR, hpfc, volatility, cVaR)
   3.4. Risk management 2 (PaR)
   3.5. Contract valuation (HPFC)
   3.6. Portfolio management 2

4. Energy & Finance I
   4.1. Options 1 basics
   4.2. Options 2 hedging with options
   4.3. Introduction to derivatives (swaps, cap, floor, collar)
   4.4. Financial modelling of physical assets
   4.5. Trading and hydro power
   4.6. Incentive regulation

Lecture notes
Handouts of the lecture

Prerequisites / notice
Case studies and ML exercise for Power Market can give bonus points for the exam. Guest speakers for specific topics.

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management assessed

Method-specific Competencies
- Communication fostered
- Cooperation and Teamwork fostered

Social Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered

Personal Competencies

Minor in Physical Glaciology

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>101-0289-00L</td>
<td>Applied Glaciology</td>
<td>W</td>
<td>4 credits</td>
<td>2G</td>
<td>D. Farinotti, A. Bauder, M. Werder</td>
</tr>
</tbody>
</table>

Abstract
The course transmits fundamental knowledge for treating applied glaciological problems. Topics include climate-glacier interactions, glacier ice flow, glacier hydrology, ice avalanches, and lake ice.

Objective
The objectives of the courses are to:
- learn about fundamental glaciological processes, including glacier mass balance, ice dynamics, and glacier-related hazards;
- apply the above knowledge to some case studies inspired by contract-works performed at ETH's Glaciology section;
- generate the own computer code to solve the above case studies, and interpret the results;
- understand, both in class and in the field, the practical relevance of glaciology, with a focus on the Swiss applications.

Content
The course will develop along the following outline:
- How glaciology became a scientific discipline
- Glaciology and hydropower
- Glacier mechanics and ice flow
- Gravitational glacier instabilities
- Glacier hydrology and glacier lake outbursts
- Lake ice and ice bearing capacity
- Field excursion to Jungfraujoch
- Discussion of the exercises performed during the semester

Lecture notes
Digital lecture handouts will be distributed prior to each class.

Literature
Links to relevant literature will be provided during the classes.

Prerequisites / notice
Completed BSc studies. Basic knowledge in computer scripting in any language (e.g. Python, R, Julia, Matlab, IDL, ...) will be advantageous for solving the exercises. The exercises will be performed in groups. A minimal level of fitness is required for the field excursion.
## Seminar in Glaciology

**Code:** 651-1581-00L  
**Credit:** 3 credits  
**Semester:** W  
**Module:** A. Bauder, M. Jacquemart

**Abstract:**
Introduction to classic and modern literature of research in Glaciology. Active participation is expected and participants are mentored by PhD students of Glaciology.

**Objective:**
In-depth knowledge of selected topics of research in Glaciology. Introduction to different types of scientific presentation. Improve ability of the discussion of scientific topics.

**Content:**
- Selected topics of scientific research in Glaciology
- Copies/pdf of scientific papers will be distributed during the course (moodle interface)

**Prerequisites / notice:**
Active participation is expected with presence at the sessions. Only a limited number of participants can be accepted. One of the following courses should be taken as preparation:
- 651-3561-00L Kryosphäre
- 101-0289-00L Applied Glaciology
- 651-4101-00L Physics of Glaciers

## 651-4077-00L Quantification and Modeling of the Cryosphere: Dynamic Processes (University of Zurich)

**W 3 credits 1V**  
**University lecturers**

**Abstract:**
This course introduces quantitative approaches and models to processes of the cryosphere in high mountain areas. The main focus are dynamic and thermal processes related to glaciers and permafrost. During the course, simple simple mathematical and numerical models will be used to investigate ground temperature profiles as well as glacier evolution and dynamics in relation to climate.

**Objective:**
This course combines lectures providing the background on the physical processes and methods with computer practicals in which quantitative methods are applied to glaciers and permafrost processes. These lectures and practicals run as 2-hour blocks per week and are combined with group and individual excercises. Topics indicative for the content of this course are:

- Heat flow processes in the ground and in glaciers, and their solution with numerical models.
- Glacier dynamics and evolution in relation to climate change.
- Simple and reduced mathematical models for glaciers flow.
- Numerical models for glacier dynamics.

**Content:**
For the modeling and project parts of the course, programs written in the Python programming language are used. Prior Python or programming knowledge is not necessary, and introductory tutorials are given.

The course starts with lectures introducing the basic concepts of the different topics. The main focus lies on extensive computer practicals in which the related quantitative methods and models are applied and explored. Extensive group work on a topic of choice, using the quantitative models, will give a deep understanding how computer models are used in applied science.

## 651-4101-00L Physics of Glaciers

**W 3 credits 3G**  
**Module:** M. Lüthi, F. T. Walter, M. Werder

**Abstract:**
Understanding glaciers and ice sheets with simple physical concepts. Topics include the reaction of glaciers to the climate, flow of glacier ice, temperature in glaciers and ice sheets, glacier hydrology, glacier seismology, basal motion and calving glaciers. A special focus is the current development of the ice sheets of Greenland and Antarctica.
Objective
After the course the students are able understand and interpret measurements of ice flow, subglacial water pressure and ice temperature. They will have an understanding of glaciology-related physical concepts sufficient to understand most of the contemporary literature on the topic. The students will be well equipped to work on glacier-related problems by numerical modeling, remote sensing, and field work.

Content
The dynamics of glaciers and polar ice sheets is the key requisite to understand their history and their future evolution. We will take a closer look at ice deformation, basal motion, heat flow and glacier hydraulics. The specific dynamics of tide water and calving glaciers is investigated, as is the reaction of glaciers to changes in mass balance (and therefore climate).

Lecture notes
Will be provided on Moodle

Literature
A list of relevant literature is available on Moodle

Prerequisites / notice
High-school mathematics and physics knowledge required.

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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>701-0565-00L</td>
<td>Principles of Natural Hazard Management</td>
<td>W</td>
<td>3</td>
<td>4G</td>
<td>A. Ringenbach</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course provides an overview of the main natural hazards and their importance in a national and international context. The probability, risk and implications of various natural hazards will be discussed, along with potential management options. The course consists of introductory lectures and exercises, seminars with guest lectures by experts and a field trip.</td>
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<tr>
<td>Objective</td>
<td>By the end of the course, students will be able to:</td>
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<td>• explain the main natural hazards, their processes and their importance in different contexts.</td>
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<td>• describe the likelihood, risk, and consequences of natural hazards and their management options.</td>
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<td>• identify and discuss the development of natural hazards in the context of climate change.</td>
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<tr>
<td>Literature</td>
<td>will be distributed and available on Moodle</td>
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Competencies
Subject-specific Competencies: Concepts and Theories assessed
Method-specific Competencies: Analytical Competencies assessed,
Media and Digital Technologies assessed, Problem-solving assessed
Social Competencies: Communication fostered, Cooperation and Teamwork fostered, Self-presentation and Social Influence fostered
Personal Competencies: Creative Thinking assessed, Critical Thinking assessed, Integrity and Work Ethics fostered

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<tr>
<td>101-1250-00L</td>
<td>Transport Processes in Torrents</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>I. Schalko</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course focuses on the various transport processes in torrents. This includes discharge, bedload, debris flow, and large wood. Differences between transport processes in rivers versus torrents will be discussed. Special focus will be put on the (1) analysis of the interaction between the transport processes (cascading processes) and the (2) design of countermeasures.</td>
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<tr>
<td>Objective</td>
<td>At the end of the course, the students will be able to:</td>
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<td></td>
<td>(1) Describe the different transport processes in torrents, such as flow discharge or bedload transport,</td>
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<td></td>
<td>(2) discuss how cascading processes affect the resulting natural hazard, and</td>
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<td></td>
<td>(3) derive solutions for a sustainable hazard management.</td>
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<tr>
<td>Content</td>
<td>The first part of the lecture introduces the different transport processes in torrents such as discharge, bedload, debris flow, and large wood. This will include methods to determine and calculate the discharge, characterize debris flow, and quantify wood load.</td>
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<td></td>
<td>In the second part of the lecture, special focus will be put on the cascading effects (what happens if multiple transport processes occur at once) and their implications on the resulting natural hazards. The last part of the lecture focuses on the design of countermeasures such as check dams and will include examples from selected catchments in Switzerland.</td>
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<tr>
<td>Literature</td>
<td>Two field trips are planned to illustrate the transport processes and existing countermeasures.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture slides can be downloaded via Moodle.</td>
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<tr>
<td>Literature</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Recommended lectures:</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Hydrology (102-0293-AAL), Hydraulics I (101-0203-01L), Hydraulic Engineering (101-0206-00L), River Engineering (101-0258-00L)</td>
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</tbody>
</table>
This introductory course starts from a description of the behavior and phenomena of soils and rocks under near surface loading conditions. Analytical Competencies:

- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies:

- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

Social Competencies:

- Communication
- Cooperation and Teamwork

Personal Competencies:

- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-direction and Self-management

Hydrology

W 3 credits 2G  P. Burlando

Objective

Know the main features of engineering hydrology. Apply methods to estimate hydrological variables for dimensioning hydraulic structures and managing water resources.

Content

The hydrological cycle: global water resources, water balance, space and time scales of hydrological processes.

Precipitation: mechanisms of precipitation formation, precipitation measurements, variability of precipitation in space and time, precipitation regimes, point/basin precipitation, isohyetal method, Thiessen polygons, storm rainfall, design hyetograph.

Interception: measurement and estimation.

Evaporation and evapotranspiration: processes, measurement and estimation, potential and actual evapotranspiration, energy balance method, empirical methods.

Infiltration: measurement, Horton's equation, empirical and conceptual models, phi-index and percentage method, SCS-CN method.

Surface runoff and subsurface flow: Hortonian and Dunnian surface runoff, streamflow measurement, streamflow regimes, annual hydrograph, flood hydrograph analysis - baseflow separation, flow duration curve.

Basin characteristics: morphology, topographic and phreatic divide, hypsometric curve, slope, drainage density.

Rainfall-runoff models (R-R): rationale, linear model of rainfall-runoff transformation, concept of the instantaneous unit hydrograph (IUH), linear reservoir, Nash model.

Flood estimation methods: flood frequency analysis, deterministic methods, probabilistic methods (e.g. statistical regionalisation, indirect R-R methods for flood estimation, rational method).

Erosion and sediment transport: watershed scale erosion, soil erosion by water, estimation of surface erosion, sediment transport.

Snow (and ice) hydrology: snow characteristic variables and measurements, estimation of snowmelt processes by the energy budget equation and conceptual melt models (temperature index method and degree-day method), snowmelt runoff.

Lecture notes

The lecture notes as well as the lecture presentations and handouts may be downloaded from the website of the Chair of Hydrology and Water Resources Management.

Literature


Prerequisites / notice

Knowledge of statistics is a prerequisite. The required theoretical background, which is needed for understanding part of the lectures and performing part of the assignments, may be summarised as follows:

- Elementary data processing: hydrological measurements and data, data visualisation (graphical representation and numerical parameters), Frequency analysis: hydrological data as random variables, return period, frequency factor, probability paper, probability distribution fitting, parametric and non-parametric tests, parameter estimation.

Introduction to Engineering Geology

W 4 credits 2G+1U  J. Aaron, L. de Palézieux dit Falconnet

Objective

Understanding the basic geotechnical and geomechanical properties and processes of rocks and soils. Understanding the interaction of rock and soil masses with technical systems. Understanding the fundamentals of geological hazards.

Content


Lecture notes

Written course documentation available on moodle.
Literature


Prequisites / notice

Lectures held by Prof. J. Aaron will be conducted in English. The lecture slides for these lectures will be available in both German and English. All other lecture material will be provided in German. The exam is held in German.

Students registering for the course confirm having read and accepted the terms and conditions for excursions and field courses of D-EAPS: https://www.ethz.ch/content/dam/ethz/special-interest/erdw/department/dokumente/studium/exkursionen/AGB_ERDW_Exkursionen_en.pdf

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Personal Competencies
Critical Thinking fostered

Competencies

651-4088-03L Physical Geography III (Geomorphology and Glaciology) (University of Zürich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: GEO231

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

Abstract

Das Modul bietet eine kurze Einführung in einige Komponenten und Prozesse des hydrologischen Kreislaufs. Dabei werden einzelne Wasserspeicher (Schnee-, Boden und Grundwasser) und Flüsse zwischen den Speichern (Verdunstung, Niederschlag und Abfluss) betrachtet. Übungen ergänzen die Vorlesung.

 Minor in Forest Engineering and Wood Products

To successfully complete this minor, KPs must be earned for the two required courses:

- 701-1645-00 Forest Operations (autumn semester) and
- 701-1544-00 Forest Access and Transportation (spring semester)

Number

<table>
<thead>
<tr>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1645-00L</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>H. Griess, J. Schweier</td>
</tr>
</tbody>
</table>

Abstract

The discipline of Forest operations is constantly challenged to find solutions for unique problems. Each forest site requires specific technological approaches and machinery based on given management goals and ecological and environmental circumstances. Various terrain types and soil conditions, harvesting costs and taking care of the workforce by creating safe working conditions are some of the aspects.

Objective

In this course, students will learn to use a wide variety of approaches grounded in the natural sciences, engineering and technology to develop solutions tailored to unique challenges from the field of forest operations.

The course is aimed at students who either plan an academic or professional career in the field of forest operations, or who will work at the interface between forest operations and the various related disciplines, such as forest ecosystem management and forestry in the wider sense.

After participating in this course students will have acquired foundational knowledge of a wide variety of core elements in the field of forest operations:

- The course will provide students with the ability to describe and differentiate site and stand conditions from an engineering perspective.
- Students will gain an overview and good working knowledge of current technology used in forest operations in Switzerland and around the world.
- Students will acquire the ability to assess the strength and weaknesses of the most commonly used equipment and analyze their suitability for a given set of environmental, economic and social factors.
- Students will be able to combine different types of technology to create an optimal harvesting system for a given task, and assess a given system for its task specific suitability.
- Participants will be able to assess the sustainability and potential short- and long-term impacts of harvesting systems under ecological, economic and social constraints.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2518 of 2653
Content

Introduction
• Historic overview
• Scope of operation
• Site and stand characteristics

Timber harvesting
• Logging methods
• Felling methods
• Motor-Manual felling methods
  o Falling and processing
• Forest machine structure and function
• Harvester Technology
  o Felling heads
  o Carriers for felling heads
• Bunching
• Mechanical processing
• Loading equipment
• Operating techniques

Primary Transport Systems
• Ground based
  o Common features
  o Skidder
  o Forwarder
  o Loader Forwarder
• Cable yarding
  o Common features
  o Wire rope
  o Cable yarding systems
  o Operating techniques
• Aerial
  o Common features
  o Operating techniques

Winch-Assisted Harvesting Operations
• Harvesting
• Primary transport

Loading Equipment

Secondary transport
• Truck configurations
• Soil compaction and contamination
• Riparian areas

Forest Operations management
• Ergonomics
• Work Safety
• Economic Aspects
• Environmental impact assessment
• Equipment selection

Forest operations across the globe
• New Zealand
• North America
  o British Columbia, Canada
  o South-eastern U.S.A

Specialized equipment for small scale forest operations

Outlook into the future of forest operations

Literature

Prerequisites / notice

Published on Moodle

701-1544-00 Forest Access and Transportation

101-0637-10L Wood Structure and Function W 3 credits 2G I. Burgert, G. von Arx

Abstract
The course Wood structure and function conveys basic knowledge on the microstructure of softwoods and hardwoods as well as general and species-specific relationships between growth processes, wood properties and wood function in the living tree.

Objective
Learning target is a basic understanding of the anatomy of wood and the related impact of endogenous and exogenous factors. The students can learn how to distinguish common central European wood species at the macroscopic and microscopic level. A deeper insight will be given by wood identification exercises for softwood species. Further, the students will gain insight into the relationships between tree growth and wood properties with a specific focus on the wood function in the living tree.

Content
In an introduction to wood anatomy, the general structural features of softwoods and hardwoods will be explained and factors of diversity and variability will be discussed. A specific focus is laid on common central European tree species with relevance in the wood sector, which will be studied in macro- and microstructural investigations. In the following, relationships between wood structure, properties and function in the living tree will be in the focus of the lectures. Topics covered are water transport, trends in wood anatomy within trees, environmental impact on wood anatomy, wood defects and their causes, tools to study wood properties over time, secondary changes in wood, and tree biomechanics.

101-0637-20L Wood processing W 3 credits 2G I. Burgert, S. Koch, M. Schubert

Abstract
The course Wood Processing conveys knowledge on the technological properties of wood and wood-based materials as well as on industrial processes for the fabrication of a vast variety of wood products and covers new developments in the field of digital technologies.

Objective
The learning target is a fundamental understanding of the dominating wood processing chains, which are applied to fabricate common wood products. Students will be introduced to the economic relevance of the renewable resource wood and are trained in its technological properties. The students will learn to identify the relationships between wood species and their properties as well as the suitable wood machining processes to fabricate targeted wood products. Finally, the digital transformation process, which will affect all sectors of the wood industry with an impact on the entire value chain and business models will be covered. It will be illustrated how production processes can become more flexible, efficient and less resource-demanding.
The general introduction shows the economic relevance of the resource wood in a global, European, and Swiss context and reflects aspects of sustainability in wood production. In terms of bulk wood products, a specific focus is laid on sawn timber production and drying processes. Concerning wood veneer production, steaming, veneer cutting, and assembly to veneer lumber products are presented. Further, the common technologies for the production of particle boards and fibre boards will be discussed. Topics related to wood gluing and wood protection as well as potentials and limitations in the application of wood and wood-based products are covered. In a further part, the lecture deals with the most important digital technologies, e.g., Internet of Things, artificial intelligence, and their impact on the wood industry based on illustrative examples.

### Minor in Agricultural Plant Production and Environment

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1343-00L</td>
<td>Soil-Plant Water Relations</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>A. Carminati</td>
</tr>
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</table>

**Abstract**

Water limitation is a primary constraint on plant growth and terrestrial fluxes worldwide. In this course, the principles of water flow in soil and plants are discussed, with particular attention on the effect of drought on root water uptake, transpiration and plant growth. Strategies of plants to tolerate drought are discussed in relation to both agricultural and ecological implications.

**Objective**

The students are able to: explain and compare systematically the drivers of water stress to plants; to solve the equations of water flow in soil and plants and to calculate plant water status for varying soil and climatic conditions and plant traits; to critically review and present one research question in soil-plant water relations; to openly debate on the current trends in soil and plant water research and climate change ecology.

**Content**

*Part 1 - Lectures*

- Week 1: Introduction.
- Week 2: Soil water relations; Principles of soil water retention and soil water flow; Soil hydraulic properties.
- Week 3: Root water uptake; soil hydraulic constraints on transpiration
- Week 4: Rhizosphere processes and properties; root-soil contact; root hairs; mycorrhiza; rhizodeposition.
- Week 5: Water flow in roots and xylem; root anatomy, architecture and plasticity; cavitation.
- Week 6: Transpiration; Vapor Pressure Deficit; Photosynthesis; Stomatal regulation.
- Week 7: Soil-plant-atmospheric continuum; Below- and above-ground feedbacks; Soil and atmospheric drivers of transpiration losses.

*Part 2 - Seminar*

- Week 8: Plant response to drought and consequences for agriculture and forests. Open questions and introduction to seminar topics.
- Week 9: Class work - preparation of the presentations/Debate
- Week 10: Class work - preparation of the presentations/Debate
- Week 11: Seminar/Debate (presentations)
- Week 12: Seminar/Debate (presentations)
- Week 13: Seminar/Debate (presentations)
- Week 14: Feedback, Summary, Conclusion

**Literature**

Lecture notes; selection of articles

**Prerequisites / notice**

Vadose Zone Hydrology/Environmental Soil Physics (recommended but not required)

### Competencies

**Subject-specific Competencies**

- Concepts and Theories
- Analytical Competencies
- Media and Digital Technologies

**Method-specific Competencies**

- Problem-solving
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity

**Social Competencies**

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

**Personal Competencies**

Number of participants limited to 25

A motivational application is required:

- presenting yourself and your studies
- stating what topic in the field of Political Ecology that you are interested in
- suggesting one paper to enrich the literature list for the course

Questions regarding the application to johanna.jacobi@usys.ethz.ch.

**Abstract**

In this seminar, students are introduced to the multi-disciplinary field of political ecology to investigate human-environment relationships in food and agricultural systems.

**Objective**

- Being able to provide an overview of the multi-disciplinary field of political ecology for investigating the relationships of humans to our environment
- Learn to identify how power and interest influence social-ecological systems and to distinguish symptoms from systemic root causes
- Become enabled to analyse complex and sometimes distant human-ecology relationships choosing from a broad range of methods

**Content**

We will review common narratives in agri-food systems informed by a range of different theories and assisted by different analytical tools. For this purpose, we will start from different concepts of nature, power and interests, explore different ontologies and epistemologies through a set of topics such as hunger, obesity, agrobiodiversity and seeds, forests and deforestation, climate change and food production. Students will explain one concept in each course to the groups and practice their argumentative and writing skills in a final essay, applying the acquired tools to a topic of their choice. While specific inputs from external lecturers broaden our perspective, enough time for critical discussion and reflection will be granted.
Lecture notes
20.9.2024 Introduction to political ecology
27.9.2024 Ontologies and epistemologies
4.10.2024 Green revolution, industrial agriculture, and agroecology
11.10.2024 Don't blame the rain: Water management in agriculture
18.10.2024 Climate justice and food systems
25.10.2024 Conservation: Protecting what from what?
1.11.2024 Deforestation: Root causes and alternatives
8.11.2024 Pandemics, syndemics and the food system
15.11.2024 Technology and the politics of knowledge
22.1.2024 Land-sharing, land-sparing
29.11.2024 Feminist (political) agroecology
6.12.2024 Food: Commons or commodity?
13.12.2024 Alternatives to sustainable development
20.12.2024 Final session (The Hunger Banquet)

Literature
Literaturelist provided on Moodle when the course starts.

https://moodle-app2.let.ethz.ch/course/view.php?id=20544

Competencies

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Concepts and Theories</td>
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<td>Adaptable and Flexibility</td>
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<td>Decision-making</td>
<td>Leadership and Responsibility</td>
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<td>Self-direction and Self-management</td>
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Assessed: assessed, foster: fostered

751-2107-00L Agrarian and Environmental Values: Tensions, Synergies, Practices and Policies

Limited to 20 students.

Abstract
In politics, society, and science, it can seem that the values and practices of agricultural production and environmental protection are in conflict. This tension is often described as "protection versus use" of natural resources. We will explore ways to move beyond the apparent conflict. We will apply this learning to field trips and transdisciplinary projects.

Objective
Students are able to:
- Define different kinds and categories of values.
- Relate value concepts to their own studies, life, and experiences through reflective journaling.
- Infer the underlying values in a text or policy about agri-environmental topics.
- Collaboratively develop a transdisciplinary project for an agri-environmental case study from the field trips.

Content
The course consists of interactive seminars alongside fieldtrips to farms that have found innovative solutions to balancing protection and production.

Seminars will cover topics such as the relationship between values and behavior and how people perceive value trade-offs. We will also discuss environmental ethics, environmental valuation and its critiques, the interplay of facts and values in agri-environmental decision-making, cultural ecosystem services, and relational values.

This class requires active participation. Learning is based on in-class activities, group work and fieldtrips.
Literature

Literature will draw from political ecology, value theory and environmental values, as well as case studies and primary texts, such as the following (not all will be required reading; we will read 1 or 2 papers or book chapters each week).


Environmental Values, by O’Neill, Holland and Light, 2008
IPBES Values Assessment 2023


751-3700-00L

Plant Ecophysiology

W 2 credits 2V

N. Buchmann, A. Walter

Abstract

The general theme of this course is the effect of environmental factors (such as light, temperature, relative humidity, CO2 concentrations, etc.) on plant physiology: water uptake and transport, transpiration, CO2 gas exchange of plants (photosynthesis, respiration), growth and C allocation, yield and production, stress physiology. Working with measurement data and Jupyter Notebooks is included.

Objective

The students will understand the impact of environmental factors on plant physiology and will learn the theoretical basis and terminology of plant ecophysiology that is necessary to analyze yield potentials in agriculture. The students will learn about classical and latest studies in plant ecophysiology. Students will check and implement their knowledge and understanding of ecophysiology using measurement data.

Competencies

Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies

- Analytical Competencies: fostered
- Decision-making: fostered
- Problem-solving: assessed
- Project Management: assessed

Social Competencies

- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Sensitivity to Diversity: fostered

Personal Competencies

- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: fostered

Data: 15.06.2024 12:39  Autumn Semester 2024  Page 2522 of 2653
## Content

This class conveys current topics and methods of agroecological and food systems research through selected case studies from ongoing research of the Sustainable Agroecosystems group. Students will be encouraged to develop critical thinking competencies, through individual and group work, on major agricultural and food system challenges and paths towards agricultural and food system transformation.

### Lecture notes

Handouts stehen online.

### Literature


### Prerequisites / notice

This course is based on basics of plant identification and plant physiology. It is the basis for the courses Plant Production, Part Forage Production and Grassland Systems.

### Competencies

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</table>

### Objective

(1) Systematically analyse and discuss case studies from ongoing agroecological and food system research.

(2) Learn and experiment on methods for field and laboratory investigations in agroecology.

(3) Engage with positive and empowering frameworks that motivate critical reflection and action on the types of transformative responses needed to adapt and thrive within agricultural and food systems.

(4) Reflect critically on agricultural and food system transformation tools and methods from the perspective a food system stakeholder.

(5) Identify and describe institutions in the context of sustainable agricultural development (for Bachelor and Master thesis and internships).

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### Prerequisites

Basic knowledge of plant ecophysiology, terrestrial ecology and management of agro- and forest ecosystems. Course will be taught in English.

### Lecture notes

None

### Prerequisites / notice

None

### Competencies

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### Objective

Students will be able to understand and evaluate experimental design and data interpretation of on-going studies, be able to critically analyze published research results, practice to present and discuss results in the public, and gain a broad knowledge of recent research and current topics in agro- and forest ecosystem sciences.

### Competencies

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### Objective

Research results in agro- and forest ecosystem sciences will be presented by experienced researchers as well as by doctoral and graduate students. Citation classics as well as recent research results will be discussed. Topics will range from plant ecophysiology, biodiversity and biogeochemistry to management aspects in agro- and forest ecosystems.

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### Objective

Research results in agro- and forest ecosystem sciences will be presented by experienced researchers as well as by doctoral and graduate students. Citation classics as well as recent research results will be discussed. Topics will range from plant ecophysiology, biodiversity and biogeochemistry to management aspects in agro- and forest ecosystems.
Subject-specific Competencies

The course will address a wide range of agricultural and food system challenges (e.g. food security, climate crisis, soil degradation, etc.) in both temperate and tropical contexts. In class we will address topics like building food system resilience through innovative measures, improving soil fertility management or understanding the effects of agroforestry systems.

Case studies from the on-going research in the Sustainable Agroecosystems Group (sae.ethz.ch) will be presented, covering different scales (e.g. food value-chains, farm dynamics and soil management). The class is complemented by practical group work and contains the CSA Meh Als Gnuess in Zürich on Measuring and monitoring Agroecological performance.

Students will gain an overview on institutions and actors' roles in the field of sustainable agricultural development. Throughout the group work, students will learn to engage directly with various stakeholders, monitor agroecological transition and communicate their research to a wider audience. Ultimately, this class should provide an overview on methods, tools, innovations and platforms that support a sustainable food transformation.

Literature


Prerequisites / notice

Prior participation in the lecture Nachhaltige Agrarökosysteme I (Sustainable Agroecosystems I) 751-5000-00G (spring term) recommended.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Analytical Competencies: assessed
- Decision-making: fostered
- Problem-solving: assessed
- Project Management: fostered

Method-specific Competencies
- Social Competencies: Communication: fostered
- Cooperation and Teamwork: assessed
- Self-presentation and Social Influence: fostered
- Personal Competencies: Sensitivity to Diversity: fostered
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

Method-specific Competencies
- Analytical Competencies: assessed

Literature


Minor in Environmental, Resource and Food Economics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>363-0537-00L</td>
<td>Resource and Environmental Economics</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>A. Miftakhova, A. Minabutdinov</td>
</tr>
</tbody>
</table>

Abstract

The course covers all interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of environmental externalities; the economics of non-renewable resources, renewable resources, environmental cost-benefit analysis, sustainability concepts, and international resource and environmental problems.

Objective

A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness.

Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

Content

The course covers all interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of environmental externalities; the economics of non-renewable resources, renewable resources, environmental cost-benefit analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power.

When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

Literature


Competencies

- Subject-specific Competencies: Concepts and Theories: assessed
- Analytical Competencies: assessed
- Techniques and Technologies: assessed

Minor in Environmental, Resource and Food Economics

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<tr>
<td>751-0423-00L</td>
<td>Risk Analysis and Risk Management in Agriculture</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>R. Finger</td>
</tr>
</tbody>
</table>

Abstract

Agricultural production is exposed to various risks and risk management is indispensable. This course introduces modern concepts on farmers' decision making under risk and risk management. We present innovative insights, empirical example from European agriculture. You gain hands-on experience using R.

Objective

- to develop a better understanding of decision making under uncertainty and risk;
- gain hands-on experience in risk analysis and management using R;
- to develop an understanding for different sources of risk in agricultural production;
- to understand the crucial role of subjective perceptions and preferences for risk management decisions;
- to get an overview on risk management in the agricultural sector, with a particular focus on insurance solutions.
Content
- Quantification and measurement of risk
- Risk preferences, Expected Utility Theory, Cumulative Prospect Theory
- Production and input use decisions under risk
- Portfolio Theory and Farm Diversification
- Forwards, Futures, Crop Insurance
- Weather Index Insurance and Satellite Imagery
- Empirical Applications using R

Lecture notes
Handouts will be distributed in the lecture and available on the moodle.

Prerequisites / notice
knowledge of basic concepts of probability theory and microeconomics

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity

Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Integral and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

751-0903-00L Microeconomics of the Agriculture and Food Sector
W 3 credits 2V L. Zachmann

Abstract
In dieser Vorlesung werden ökonomische Charakteristika des Agrar- und Lebensmittelsektors herausgearbeitet und anderen Sektoren gegenübergestellt. Fokus ist dabei Lebensmittelindustrie in der Schweiz und in der EU. Es werden mikroökonomische Zusammenhänge, insbesondere zur Preis- und Mengenbildung in verschiedenen Wettbewerbsmodellen, am Fallbeispiel des Agrar- und Ernährungssektor vermittelt.

Objective

Content
- Der Agrar- und Lebensmittelsektor in der EU und der Schweiz
- Preiselastizitäten von Angebot und Nachfrage im Ernährungssektor
- Gewinnmaximierung
- Grundlagen der Spieltheorie
- Monopol / Monopolistischer Wettbewerb
- Oligopol (Stackelberg, Cournot, Bertrand)
- Monopson
- Produktdifferenzierung
- Preisdiskriminierung
- Kartelle

Literature

Prerequisites / notice
Empfohlene Vorkenntnisse:
- Grundkenntnisse der Ökonomie/Agrarökonomie
- Vorlesung Einführung in die Mikroökonomie

Competencies
Subject-specific Competencies
- Concepts and Theories

Method-specific Competencies
- Decision-making

Social Competencies
- Negotiation

Personal Competencies
- Critical Thinking

751-1311-00L Introduction to Agricultural Management
W 2 credits 2V R. Finger

Abstract
Vermittlung von betriebswirtschaftlichen Grundlagenwissen und Analyse- und Planungsinstrumenten mit Anwendung auf Unternehmen der Agrar- und Ernährungswirtschaft

Objective
Teilnehmer des Kurses sollen am Ende der Vorlesung i) grundlegende Unternehmensentscheide strukturieren und analysieren können, ii) verschiedene Analyse- und Planungsinstrumente auf Fragestellungen der Produktionsplanung, Investition und Finanzierung an Beispielen anwenden zu können, iii) verschiedene Werkzeuge zur unternehmerischen Entscheidungsunterstützung anwenden können und iv) die Spezifik von Unternehmen in der Agrar- und Ernährungswirtschaft kennen.

Content
Die Vorlesung geht auf folgende Inhalte, mit spezifischen Anwendungen im Agrar- und Ernährungssektor ein:
- Grundlagen und Ziele unternehmerischen Entscheidens
- Kosten und Leistungsrechnung
- Produktionsstheorie
- Produktionsprogrammplanung
- Investitionsplanung und Finanzierung
- Entscheidungen unter Unsicherheit und Risikomanagement

Lecture notes
Vorlesungsunterlagen werden im Laufe des Semesters zur Verfügung gestellt

Literature
## Competencies

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### 751-1573-00L Dynamic Simulation in Agricultural and Regional Economics

**W** 3 credits 2V B. Kopainsky

#### Abstract
In this class, students learn the basics of system dynamics and its application to agricultural and regional economic questions. In the second half of the class, students develop their own simulation model, with which they evaluate potential interventions for improving the economic as well as the ecological sustainability of food systems.

#### Objective
- Students learn the basic theory and practice of dynamic simulation
- Students can develop, analyze and extend a dynamic simulation model and interpret its results.
- By applying the developed simulation model, students gain insights into food system issues. They also learn to recognize the benefits and pitfalls of dynamic simulation, both from a theoretical and an applied perspective.

#### Lecture notes
slides (will be provided during the class)

#### Literature
articles and papers (will be provided during the class)

### 751-2103-00L Socioeconomics of Agriculture

**W** 2 credits 2V S. Mann

#### Abstract
The main part of this lecture will examine constellations where hierarchies, markets or cooperation have been observed and described in the agricultural sector. On a more aggregated level, different agricultural systems will be evaluated in terms of main socioeconomic parameters like social capital or perceptions.

#### Objective
Students should be able to describe the dynamics of hierarchies, markets and cooperation in an agricultural context.

#### Content
- Introduction to Sociology
- Introduction to Socioeconomics
- Agricultural Administration: Path dependencies and efficiency issues
- Power in the Chain
- The farming family
- Occupational Choices
- Market Segregation
- The issue of meat demand
- Common Resource Management in Alpine Farming
- Agricultural Cooperatives
- Societal perceptions of agriculture
- Perceptions of farming from within
- Varieties of agricultural systems and policies

#### Lecture notes

#### Literature
see script

#### Prerequisites / notice
Basic economic knowledge is expected.

### 751-2105-00L Political Ecology of Food and Agriculture

**W** 3 credits 2G J. Jacobi

#### Number of participants limited to 25

#### A motivational application is required:
- presenting yourself and your studies
- stating what topic in the field of Political Ecology that you are interested in
- suggesting one paper to enrich the literature list for the course

#### Questions regarding the application to
johanna.jacobi@usys.ethz.ch.

#### Abstract
In this seminar, students are introduced to the multi-disciplinary field of political ecology to investigate human-environment relationships in food and agricultural systems.

#### Objective
- Being able to provide an overview of the multi-disciplinary field of political ecology for investigating the relationships of humans to our environment
- Learn to identify how power and interest influence social-ecological systems and to distinguish symptoms from systemic root causes
- Become enabled to analyse complex and sometimes distant human-ecology relationships choosing from a broad range of methods

#### Content
We will review common narratives in agri-food systems informed by a range of different theories and assisted by different analytical tools.

For this purpose, we will start from different concepts of nature, power and interests, explore different ontologies and epistemologies through a set of topics such as hunger, obesity, agrobiodiversity and seeds, forests and deforestation, climate change and food production.

Students will explain one concept in each course to the groups and practice their argumentative and writing skills in a final essay, applying the acquired tools to a topic of their choice. While specific inputs from external lecturers broaden our perspective, enough time for critical discussion and reflection will be granted.
751-2903-00L Evaluation of Agricultural Policies

Abstract
In this course, students get an overview of agricultural policy evaluations and their societal and political relevance. They learn to understand and apply the principles of scientific based evaluations of agricultural policies. 

Objective
The course has four major learning objectives: 1) Students know the conceptual background of evaluations and can relate concepts in agricultural economics to the evaluation of policies. 2) They know the basics of how to design and implement a policy evaluation study. 3) Students can transfer their methodological knowledge from other agricultural economics courses to the context of agricultural policy evaluations (econometrics, modelling etc.). They make hands-on experiences of methodological challenges. 4) They can critically assess the science-policy interface of policy evaluations.

Content
The course consists of two blocks: First, students will learn the basics of how to design, implement and interpret agricultural policy evaluations. In this block, the conceptual embedding, the design and methodological tools as well as case studies are presented. Secondly, the students make hands-on experience using econometric and modelling tools in the context of agricultural policy evaluations. They apply their theoretical and empirical knowledge to Swiss case studies.
The course will be run as a book reading club. The first session will provide a short introduction as to how to explore a particular text (that is not a scientific paper) to identify the key points for discussion.

Thereafter, in each week a text (typically a chapter from a book or a paper) considered to be seminal or foundational will be assigned by a course lecturer. The course will introduce the selected text with a brief background of the historical and cultural context in which it was written, with some additional biographical information about the author. He/she will also briefly explain the justification for selecting the particular text.

The students will read the text, with two to four students (depending on class size) being assigned to present it at the next session. Presentation of the text requires the students to prepare by, for example:

- identifying the key points made within the text
- identifying issues of particular personal interest and resonance
- considering the impact of the text at the time of publication, and its importance now
- evaluating the text from the perspective of our current societal and environmental position

Such preparation would be supported by a mid-week tutorial discussion (about 1 hour) with the assigning lecturer.

These students will then present the text (for about 15 minutes) to the rest of the class during the scheduled class session, with the lecturer facilitating the subsequent class discussion (about 45 minutes). Towards the end of the session the presenting students will summarise the emerging points (5 minutes) and the lecturer will finish with a brief discussion of how valuable and interesting the text was (10 minutes). In the remaining 15 minutes the next text will be presented by the assigning lecturer for the following week.

The specific texts selected for discussion will vary, but examples include:

- Leopold (1949) A Sand County Almanach
- Carson (1962) Silent Spring
- Jared Diamond (2005) Collapse

Discussions might also encompass films or other forms of media and communication about nature.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Media and Digital Technologies</th>
<th>Communication</th>
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Social Competencies

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<th>Cooperation and Teamwork</th>
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<th>Sensitivity to Diversity</th>
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Personal Competencies

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401-0624-00L Mathematik IV: Statistik
401-6215-00L Using R for Data Analysis and Graphics (Part I)
401-6217-00L Using R for Data Analysis and Graphics (Part II)
701-0105-00L Mathematik VI: Angewandte Statistik für Umweltwissenschaften
After the course, students will be able to critically examine and select appropriate robotic solutions for agricultural applications.

Analytical Competencies

Subject-specific Competencies

• The data science workflow
• Data preparation for running and validating machine learning models
• Get to know machine learning approaches including regression, random forest and neural network
• Model complexity and hyperparameters
• Model parameterization and loss
• Model evaluations and uncertainty
• Deep learning with convolutions

Literature

Building on existing data science resources

Prerequisites / notice

Math IV, VI (Statistics); R, Python; ESDS I

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<tr>
<td>701-1001-00L</td>
<td>Professional Internship</td>
<td>O</td>
<td>30 credits</td>
<td></td>
<td>J. Schlosser</td>
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</tbody>
</table>

**Course Catalogue of ETH Zurich**

**Professional Internship**

In the internship outside of ETH Zürich, the students in Environmental Sciences learn about how environmental issues are handled professionally through their own practical work and by applying the knowledge they acquired. They will analyse complex environmental problems on scientific, technical and social levels and develop solutions in conjunction with social actors.
During the internship, students will learn how to professionally handle environmental issues from the technical-scientific, planning, administrative, and/or advisory perspective through their own practical experiences. They should apply the knowledge acquired from their studies. Furthermore, students will deepen their understanding in terms of development and implementation of environmental-friendly solutions in an everyday work-routine. Through this experience, they will develop important professional competence. Moreover, the internship will show them possible professional fields and establish valuable contacts for starting their careers in the future.

Job positions for environmental scientists are available in the following areas: environmental consulting firms, engineering and planning offices, clean-tech companies, industrial and service companies, federal administration, administration of cantons and municipalities, organizations and associations as well as companies operating in education, higher education, and media in relation to environmental and sustainable themes. Generally, the internship is performed outside of universities, colleges and research institutes.

Further support is provided by the company catalogue with companies in Switzerland and abroad that offer internships according to possibilities or where professional internships have taken place so far: https://www.usys.ethz.ch/pa-internship-envsc

Additional information is posted on the following webpage: https://www.usys.ethz.ch/en/studies/environmental-sciences/master/thesis.html

The students look for a placement themselves. In order for an internship to be recognised as compulsory professional internship, an internship agreement must be approved in advance by the Internship Coordinator.

Further information and support online https://moodle-app2.let.ethz.ch/course/view.php?id=15228

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▶ Master’s Thesis

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<tr>
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<td>30 credits</td>
<td>64D</td>
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Only students who fulfill the following criteria are allowed to begin with their Master’s thesis:
- a) The signed request for the Bachelor’s Degree Certificate has been submitted or processed.
- b) At least 32 CP of coursework related to the major have been acquired.
- c) All additional requirements (as stated in the admissions decision), including any assessment repetitions, are fulfilled.

Additional information is posted on the following webpage: https://www.usys.ethz.ch/en/studies/environmental-sciences/master/thesis.html

Abstract

The study programme is completed by a Master’s thesis. The Master’s thesis is an independent, scientific work. A topic within the field of specialization is chosen. It lasts 6 months.

Objective

This component is designed to enable the students to explore how the course content can be applied to an actual scientific problem. The thesis also provides an opportunity for the students to exercise initiative and to demonstrate that they are capable of working independently and in a scientifically structured manner.

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Objective
Upon successful completion of the course, you will be able to:
- Describe the basic microeconomic and macroeconomic problems and theories.
- Make economic arguments to a given topic.
- Evaluate economic measures.

Content
Households, firms, supply and demand: How are household preferences and consumption behavior formed? How does a household react to price changes? How are goods prices formed? At what prices are firms willing to offer goods? How do we make economic decisions?
Markets: What is "perfect competition" and how does a competitive market work? Are monopolies always a bad thing? How can governments influence the market?
Market failure: What happens when prices give wrong signals?
Labor market: How do supply and demand work in the labor market? What influences unemployment?
National Accounts: How big is the Swiss economy?
Foreign trade: Why do countries trade with each other? What are the consequences for the domestic market?
Money and inflation: What exactly is money? How does money creation work, and what happens when there is too much (or too little) money on the market?

Students will be asked to apply these concepts to issues in their own field of study and to current issues in society.

Literature

Competencies
Subject-specific Competencies
- Concepts and Theories
  - assessed

Personal Competencies
- Self-direction and Self-management
  - assessed

406-0062-AAL Physics I
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enroll for this course unit.

Abstract
Introduction to the concepts and tools in physics: mechanics of point-like and rigid bodies, elasticity theory, elements of hydrostatics and hydrodynamics, periodic motion and mechanical waves.

Objective
Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve the latter.

The student should acquire an overview over the basic concepts in mechanics.

Content

Chapters:
1, 2, 3, 4, 5, 6 (without: 6-5, 6-6, 6-8), 7, 8 (without 8-9), 9, 10 (without 10-10), 11 (without 11-7), 13 (without 13-13, 13-14), 14 (without 14-6).

Literature
see "Content"

Friedhelm Kuypers
Physik für Ingenieure und Naturwissenschaftler
Band 1: Mechanik und Thermodynamik
Wiley-VCH Verlag, 2002
4th edition 2022

Competencies
Subject-specific Competencies
- Concepts and Theories
  - assessed

Method-specific Competencies
- Analytical Competencies
  - fostered

Personal Competencies
- Self-direction and Self-management
  - fostered

406-0063-AAL Physics II
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enroll for this course unit.

Abstract
Introduction to the "way of thinking" and the methodology in Physics. The Chapters treated are Magnetism, Refraction and Diffraction of Waves, Elements of Quantum Mechanics with applications to Spectroscopy, Thermodynamics, Phase Transitions, Transport Phenomena.

Objective
Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve the latter.

The student should acquire an overview over the basic concepts used in the theory of heat and electricity.

Content

Chapters:

Literature
see "Content"

Friedhelm Kuypers
Physik für Ingenieure und Naturwissenschaftler
Band 2: Elektrizität, Optik, Wellen
Verlag Wiley-VCH, 2003
4th edition 2022

Competencies
Subject-specific Competencies
- Concepts and Theories
  - assessed

Method-specific Competencies
- Analytical Competencies
  - fostered

Personal Competencies
- Self-direction and Self-management
  - fostered

406-0064-AAL Physics I and II
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enroll for this course unit.

Abstract
Introduction to the concepts and tools in physics: mechanics of point-like and rigid bodies, elasticity theory, elements of hydrostatics and hydrodynamics, periodic motion and mechanical waves.

Objective
Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve the latter.

The student should acquire an overview over the basic concepts used in the theory of heat and electricity.

Content

Chapters:
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Objective
Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve the latter. The student should acquire an overview over the basic concepts used in mechanics, in the theory of heat and electricity.

Content
Book:

Chapters:
1, 2, 3, 4, 5, 6 (without: 6-5, 6-6, 6-8), 7, 8 (without 8-9), 9, 10 (without 10-10), 11 (without 11-7), 13 (without 13-13, 13-14), 14 (without 14-6), 15 (without 15-3, 15-5, 15-7, 15-9, 15-10, 15-11), 17 (without 17-5, 17-10), 18 (without 18-5, 18-6, 18-7), 19, 20 (without 20-7, 20-8, 20-9, 20-10, 20-11), 21 (without 21-12), 23, 25 (without 25-9, 25-10), 26 (without 26-4, 26-5, 26-7), 27, 28 (without 28-4, 28-5, 28-8, 28-9, 28-10), 29 (without 29-5, 29-8), 32 (without 32-8), 33 (without 33-4, 33-5, 33-9, 33-10), 34 (without 34-4, 34-5, 34-7), 35 (without 35-2, 35-3, 35-9, 35-11, 35-12, 35-13).

Literature
see "Content"

Friedhelm Kuypers
Physik für Ingenieure und Naturwissenschaftler
Band 1: Mechanik und Thermodynamik

Friedhelm Kuypers
Physik für Ingenieure und Naturwissenschaftler
Band 2: Elektrizität, Optik, Wellen

Competencies

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406-0251-AAL Mathematics I
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
This course covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems - notably through ordinary differential equations.

Objective
Mathematics is of ever increasing importance to the Natural Sciences and Engineering. The key is the so-called mathematical modelling cycle, i.e. the translation of problems from outside of mathematics into mathematics, the study of the mathematical problems (often with the help of high level mathematical software packages) and the interpretation of the results in the original environment.

The goal of Mathematics I and II is to provide the mathematical foundations relevant for this paradigm. Differential equations are by far the most important tool for modelling and are therefore a main focus of these courses.

Content
1. Linear Algebra and Complex Numbers: systems of linear equations, Gauss-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, complex roots, fundamental theorem of algebra.


3. Ordinary Differential Equations: separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

Literature
- Bretscher, O.: Linear Algebra with Applications (Pearson Prentice Hall).

Prerequisites
familiarity with the basic notions from Calculus, in particular those of function, derivative and integral.

Schedule and location of the assistance hours (Mathe-Lab) may be found on the Moodle webpages for the parallel courses in German:
- 401-0251-00L Mathematik I in the Fall semester and
- 401-0252-00L Mathematik II in the Spring semester.

Competencies

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406-0252-AAL Mathematics II
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
Continuation of the topics of Mathematics I, with main focus on multivariable calculus.
Objective

Mathematics is of ever increasing importance to the Natural Sciences and Engineering. The key is the so-called mathematical modelling cycle, i.e. the translation of problems from outside of mathematics into mathematics, the study of the mathematical problems (often with the help of high level mathematical software packages) and the interpretation of the results in the original environment.

The goal of Mathematics I and II is to provide the mathematical foundations relevant for this paradigm. Differential equations are by far the most important tool for modelling and are therefore a main focus of these courses.

Content

- **Multivariable Differential Calculus:**
  - functions of several variables, partial differentiation, curves and surfaces in space, scalar and vector fields, gradient, curl and divergence.

- **Multivariable Integral Calculus:**
  - multiple integrals, line and surface integrals, work and flux, Green, Gauss and Stokes theorems, applications.

- **Introduction to Partial Differential Equations:**
  - separation of variables, heat equation, wave equation, Laplace equation.

Lecture notes

See literature

Literature


Prerequisites / notice

**Prerequisites:**
- familiarity with the basic notions from Calculus, in particular those of function, derivative and integral.

**Schedule and location of the assistance hours (Mathe-Lab) may be found on the Moodle webpages for the parallel courses in German:**
- 401-0251-00L Mathematik I in the Fall semester and
- 401-0252-00L Mathematik II in the Spring semester.

Competencies

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**406-0253-AAL**

**Mathematics I & II**

Enrolment ONLY for MSC students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Mathematics I covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems, notably through linear algebra and calculus, with an emphasis on ordinary differential equations.

The main focus of Mathematics II is multivariable calculus.

Objective

Mathematics is of ever increasing importance to the Natural Sciences and Engineering. The key is the so-called mathematical modelling cycle, i.e. the translation of problems from outside of mathematics into mathematics, the study of the mathematical problems (often with the help of high level mathematical software packages) and the interpretation of the results in the original environment.

Content

1. **Linear Algebra and Complex Numbers:**
   - systems of linear equations, Gauss-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex roots, fundamental theorem of algebra.

2. **Single-Variable Calculus:**
   - review of differentiation, linearisation, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

3. **Ordinary Differential Equations:**
   - separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

4. **Multivariable Differential Calculus:**
   - functions of several variables, partial differentiation, curves and surfaces in space, scalar and vector fields, gradient, curl and divergence.

5. **Multivariable Integral Calculus:**
   - multiple integrals, line and surface integrals, work and flow, Green, Gauss and Stokes theorems, applications.

6. **Introduction to Partial Differential Equations:**
   - separation of variables, heat equation, wave equation, Laplace equation.

Lecture notes

See literature

Literature

- Bretscher, O.: Linear Algebra with Applications, Pearson Prentice Hall.

Prerequisites / notice

**Prerequisites:**
- familiarity with the basic notions from Calculus, in particular those of function, derivative and integral.

Schedule and location of the assistance hours (Mathe-Lab) may be found on the Moodle webpages for the parallel courses in German:
- 401-0251-00L Mathematik I in the Fall semester and
- 401-0252-00L Mathematik II in the Spring semester.

Competencies

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**406-0503-AAL**

**Stochastics (Probability and Statistics)**

Enrolment ONLY for MSC students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.
Objective
The objective of this course is to build a solid foundation in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

Content
From "Statistics for research" (online)
Ch 1: The Role of Statistics
Ch 2: Populations, Samples, and Probability Distributions
Ch 3: Binomial Distributions
Ch 6: Sampling Distribution of Averages
Ch 7: Normal Distributions
Ch 8: Student's t Distribution
Ch 9: Distributions of Two Variables

From "Introductory Statistics with R (online)"
Ch 1: Basics
Ch 2: The R Environment
Ch 3: Probability and distributions
Ch 4: Descriptive statistics and tables
Ch 5: One- and two-sample tests
Ch 6: Regression and correlation

Literature
- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
  From within the ETH, this book is freely available online under: http://onlinelibrary.wiley.com/book/10.1002/0471477435
  From within the ETH, this book is freely available online under: http://www.springerlink.com/content/m1757b/

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Media and Digital Technologies assessed
Problem-solving assessed

Personal Competencies
Self-direction and Self-management assessed

529-2001-AAL
Chemistry I and II
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
General Chemistry I and II: Chemical bond and molecular structure, chemical thermodynamics, chemical equilibrium, kinetics, acids and bases, electrochemistry

Objective
Introduction to general and inorganic chemistry. Basics of the composition and the change of the material world. Introduction to the thermodynamically controlled physico-chemical processes. Macroscopic phenomena and their explanation through atomic and molecular properties. Using the theories to solve qualitatively and quantitatively chemical and ecologically relevant problems.

Content
1. Stoichiometry
2. Atoms and Elements (Quantenmechanical Model of the Atom)
3. Chemical Bonding
4. Thermodynamics
5. Chemical Kinetics
6. Chemical Equilibrium (Acids and Bases, Solubility Equilibria)
7. Electrochemistry

Lecture notes
Nivaldo J. Tro
Chemistry - A molecular Approach (Pearson), Chapter 1-18

Literature
Housecroft and Constable, CHEMISTRY
Oxtoby, Gillis, Nachtrieb, MODERN CHEMISTRY

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics fostered
Self-awareness and Self-reflection fostered
Self-direction and Self-management fostered

529-0234-AAL
Chemistry I
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
Chemistry I: Chemical bonding and molecular structure, chemical thermodynamics and kinetics, chemical equilibrium.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.
Acquiring the basics for describing the structure, composition and transformations of the material world. Introduction to thermodynamically determined chemical-physical processes. Use modeling to show how macroscopic phenomena can be understood in terms of atomic and molecular properties. Applications of theory to qualitatively and quantitatively solve simple chemical and environmental problems.

**Objective**

**Content**

1. Stoichiometry
2. Atomic structure
4. Basics of chemical thermodynamics
   - System and environment. Description of the state and changes of state of chemical systems.
5. First law of thermodynamics
   - Internal energy, heat and work. Enthalpy and enthalpy of reaction. Standard thermodynamic conditions.
6. Second law of thermodynamics
   - Entropy. Entropy changes in the system and in the universe. Reaction entropy due to heat of reaction and due to changes in matter.
7. Gibbs energy and chemical potential.
   - Combination of the first and second law of thermodynamics. Reaction Gibbs energy.
8. Chemical equilibrium
   - Mass action law, reaction quotient and equilibrium constant. Equilibrium in phase transitions.
9. Acids and bases
10. Dissolution and precipitation
    - Heterogeneous equilibrium. Dissolution process and solubility constant. Speciation diagrams. The carbon dioxide-carbonate equilibrium in the environment.

**Literature**


**Competencies**

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies
- Decision-making
- Problem-solving

**Personal Competencies**

- Creative Thinking
- Critical Thinking

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**529-2002-AAL**

**Chemistry II**

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract

Erweitern der allgemeinen Grundlagen und Erarbeiten einer Basis, um Prozesse in komplexeren Umweltsystemen (Wasser / Luft / Boden) in ihrem zeitlichen und quantitativen Ablauf verstehen und beurteilen zu können.

**Objective**

1. Redoxreactions

2. Inorganic Chemistry
   - Rules for nomenclature of inorganic compounds. Systematic description of the groups of elements in the periodical system and the most important compounds of these elements. Formation of compounds as a consequence of the electronoc structure of the elements.

3. Introduction to organic chemistry
   - Description of the most important classes of compounds and of the functional groups. Principal reactivity of these functional groups. Stereochemistry.

   Recton mechanisms: SN1- and SN2-reactions, electrophilic aromatic subtitutions, eliminations (E1 and E2), addition reactions (C=C and C=O double bonds). Chemistry of carbynyl and carboxyl groups.
   - Rules for nomenclature of inorganic compounds. Systematic description of the groups of elements in the periodical system and the most important compounds of these elements. Formation of compounds as a consequence of the electronoc structure of the elements.

3. Introduction to organic chemistry
   - Description of the most important classes of compounds and of the functional groups. Principal reactivity of these functional groups. Stereochemistry.

   Recton mechanisms: SN1- and SN2-reactions, electrophilic aromatic subtitutions, eliminations (E1 and E2), addition reactions (C=C and C=O double bonds). Chemistry of carbynyl and carboxyl groups.

**Lecture notes**


**Competencies**

**Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Method-specific Competencies**

- Analytical Competencies
- Decision-making
- Problem-solving

**Personal Competencies**

- Creative Thinking
- Critical Thinking

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**551-0001-AAL**

**General Biology I**

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

**Competencies**

**Personal Competencies**

- Self-awareness and Self-reflection
- Self-direction and Self-management

U. Sauer, O. Y. Martin, A. Widmer
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Organismic biology to teach the basic principles of classical and molecular genetics, evolutionary biology and phylogeny.

Objective
The understanding of basic principles of biology (inheritance, evolution and phylogeny) and an overview of the diversity of life.

Content
The first semester focuses on the organismal biology aspects of genetics, evolution and diversity of life in the Campbell chapters 12-34.

Week 1-7 by Alex Widmer, Chapters 12-25
12 Cell biology Mitosis
13 Genetics Sexual life cycles and meiosis
14 Genetics Mendelian genetics
15 Genetics Linkage and chromosomes
20 Genetics Evolution of genomes
21 Evolution How evolution works
22 Evolution Phylogenetic reconstructions
23 Evolution Microevolution
24 Evolution Species and speciation
25 Evolution Macroevolution

Week 8-14 by Oliver Martin, Chapters 26-34
26 Diversity of Life Introduction to viruses
27 Diversity of Life Prokaryotes
28 Diversity of Life Origin & evolution of eukaryotes
29 Diversity of Life Nonvascular & seedless vascular plants
30 Diversity of Life Seed plants
31 Diversity of Life Introduction to fungi
32 Diversity of Life Overview of animal diversity
33 Diversity of Life Introduction to invertebrates
34 Diversity of Life Origin & evolution of vertebrates

Lecture notes
No script

Literature

Prerequisites / notice
This is a virtual self-study lecture for non-german speakers of the "Allgemeine Biology I (551-0001-00L) lecture. The exam will be written jointly with the participants of this lecture.

Example exam questions will be discussed during the lectures, and old exam questions are kept by the various student organisations. If necessary, please contact Prof. Uwe Sauer (sauer@ethz.ch) for details regarding the exam.

551-0003-AAL

General Biology I+II
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

General Biology I: Organismic biology to teach the basic principles of classical and molecular genetics, evolutionary biology and phylogeny.

General Biology II: Molecular biology approach to teach the basic principles of biochemistry, cell biology, cgenetics, evolutionary biology and form and function of vascular plants.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
General Biology I: Organismic biology to teach the basic principles of classical and molecular genetics, evolutionary biology and phylogeny.

Objective
General Biology II: Molecular biology approach to teach the basic principles of biochemistry, cell biology, cgenetics, evolutionary biology and form and function of vascular plants.

General Biology I: The understanding of basic principles of biology (inheritance, evolution and phylogeny) and an overview of the diversity of life.

General Biology II: The understanding basic concepts of biology: the hierarchy of the structural levels of biological organisation, with particular emphasis on the cell and its molecular functions, the fundamentals of metabolism and molecular genetics, as well as form and function of vascular plants.
Content

General Biology I focuses on the organismal biology aspects of genetics, evolution and diversity of life in the Campbell chapters 12-34.

Week 1-7 by Alex Widmer, Chapters 12-25
12 Cell biology Mitosis
13 Genetics Sexual life cycles and meiosis
14 Genetics Mendelian genetics
15 Genetics Linkage and chromosomes
20 Genetics Evolution of genomes
21 Evolution How evolution works
22 Evolution Phylogentic reconstructions
23 Evolution Microevolution
24 Evolution Species and speciation
25 Evolution Macroevoeulation

Week 8-14 by Oliver Martin, Chapters 26-34
26 Diversity of Life Introduction to viruses
27 Diversity of Life Prokaryotes
28 Diversity of Life Origin & evolution of eukaryotes
29 Diversity of Life Nonvascular&seedless vascular plants
30 Diversity of Life Seed plants
31 Diversity of Life Introduction to fungi
32 Diversity of Life Overview of animal diversity
33 Diversity of Life Introduction to invertebrates
34 Diversity of Life Origin & evolution of vertebrates

General Biology II: The structure and function of biomacromolecules; basics of metabolism; tour of the cell; membrane structure and function; basic energetics of cellular processes; respiration, photosynthesis; cell cycle, from gene to protein; structure and growth of vascular plants, resource acquisition and transport, soil and plant nutrition.

Specifically the following Campbell chapters will be covered:
3 Biochemistry Chemistry of water
4 Biochemistry Carbon: the basis of molecular diversity
5 Biochemistry Biological macromolecules and lipids
7 Cell biology Cell structure and function
8 Cell biology Cell membranes
10 Cell biology Respiration: introduction to metabolism
10 Cell biology Cell respiration
11 Cell biology Photosynthetic processes
16 Genetics Nucleic acids and inheritance
17 Genetics Expression of genes
18 Genetics Control of gene expression
19 Genetics DNA Technology
35 Plant structure & function Plant Structure and Growth
36 Plant structure & function Transport in vascular plants
37 Plant structure & function Plant nutrition
38 Plant structure & function Reproduction of flowering plants
39 Plant structure & function Plants signal and behavior

Lecture notes
No script

Literature

Prerequisites / notice
Basic general and organic chemistry

This is a virtual self-study lecture for non-German speakers of the "Allgemeine Biology I (551-0001-00L) and "Allgemeine Biology II (551-0002-00L) lectures. The exam will be written jointly with the participants of this lecture.

701-0023-AAL Atmosphere
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

E- 6R 3 credits

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective
Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

Content
Understanding of basic physical and chemical processes in the atmosphere. Understanding of mechanisms of and interactions between: weather - climate, atmosphere - ocean - continents, troposphere - stratosphere. Understanding of environmentally relevant structures and processes on vastly differing scales. Basis for the modelling of complex interrelations in the atmosphere.

Lecture notes
Written information will be supplied.

Literature

701-0071-AAL Mathematics III: Systems Analysis
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

E- 9R 4 credits

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective
The objective of the systems analysis course is to deepen and illustrate the mathematical concepts on the basis of a series of very concrete examples. Topics covered include: linear box models with one or several variables, non-linear box models with one or several variables, time-discrete models, and continuous models in time and space.

Learning and applying of concepts (models) and quantitative methods to address concrete problems of environmental relevance.

Understanding and applying the systems-analytic approach, i.e., Recognizing the core of the problem - simplification - quantitative approach - prediction.
Introduction to principles of models; one-dimensional linear box models; multi-dimensional linear box models; nonlinear box models; models in space and time


701-0106-AAL Mathematics V: Applied Deepening of Mathematics I - III Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
Selected mathematical topics are presented for later use in more specialised lectures. Part of the topics were already discussed in the lectures Mathematics I-III. Here, they should be shortly recapitulated and most importantly applied to practical problems. If necessary, new mathematical concepts and methods will be introduced in order to solve challenging and inspiring problems from practice.

Objective
The aim of this lecture is to prepare the students for the more specialised lectures. They should become more familiar with the mathematical background, the mathematical concepts and most of all with their application and interpretation.

Content
Practical examples from the following areas will be discussed: ordinary differential equations; eigenvalue problems from linear algebra; systems of linear and nonlinear differential equations; partial differential equations (diffusion, transport, waves).

701-0243-AAL Biology III: Essentials of Ecology Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
This course assigns reading for students needing further background for understanding ecological processes. Central problems in ecology, including population growth and regulation, the dynamics of species interactions, the influence of spatial structure, the controls over species invasions, and community responses to environmental change will be explored from basic and applied perspectives.

Objective
Students will understand how ecological processes operate in natural communities. They will appreciate how mathematical theory, field experimentation, and observational studies combine to generate a predictive science of ecological processes.

Upon completing the course, students will be able to:
Understand the factors determining the outcome of species interactions in communities, and how this information informs management.
Apply theoretical knowledge on species interactions to predict the potential outcomes of novel species introductions.
Understand the role of spatial structure in mediating population dynamics and persistence, species interactions, and patterns of species diversity.
Use population and community models to predict the stability of interactions between predators and prey and between different competitors.
Understand the conceptual basis of predictions concerning how ecological communities will respond to climate change.

Content
Readings from a text book will focus on understanding central processes in community ecology. Topics will include demographic and spatial structure, consumer resource interactions, food webs, competition, invasion, and the maintenance of species diversity. Each of these more conceptual topics will be discussed in concert with their applications to the conservation and management of species and communities in a changing world.

Competencies
Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies fostered
Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Problem-solving assessed
Personal Competencies
Integrity and Work Ethics assessed
Self-direction and Self-management assessed

701-0401-AAL Hydrosphere Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
In this self-study course, students learn about relevant processes that control the water cycle on earth. Energy and mass exchange, mixing and transport processes are described and the coupling of the hydrosphere with the atmosphere and the solid Earth are discussed.

Objective
Qualitative and quantitative understanding on how physical (and geochemical) processes control the natural dynamics in groundwater, lakes ans oceans and constrain the exchange of mass and energy.
Topics of the course.
- Physical properties of water (i.e. density and equation of state)
- Exchange at boundaries
- Mixing and transport processes in open waters
- Turbulence and mixing
- Mixing and exchange processes in rivers
- Groundwater and its dynamics
- Ground water as part of the terrestrial water cycle
- Aquifers and their properties
- Hydrochemistry and tracer
- Ground water use
Case studies
- 1. Water as resource
- 2. Water and climate

Lecture notes
In addition to the self-learning literature handouts are distributed.

Literature
Textbooks for self-studying.

Surface water:
Chapter 4: Imboden, D.M., and Wüest, A. 'Mixing Mechanisms in Lakes'
Chapter 6.4: Air-Water Partitioning
Chapter 19.2: Bottleneck Boundaries

Ground water:
Chapters 1 - 6, 8, 10, 11.

Optional additional readers.

701-0473-AAL  Weather Systems
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
The students learn about the dynamical features of the Earth's atmosphere. They interpret satellite imagery and learn about basic concepts in dynamical meteorology. The global circulation is briefly discussed, before introducing the Eulerian and the Lagrangian perspective, which are used to study air streams in extratropical cyclones and to investigate basic aspects in mountain meteorology.

Objective
The students are able to
- explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- to discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
- to explain how mountains influence the atmospheric flow on different scales
- basic understanding of the role of moist adiabatic processes for weather systems and why stable water isotopes are useful in this context

Content
Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

Lecture notes
Lecture notes and slides

Literature
Atmospheric Science, An Introductory Survey
John M. Wallace and Peter V. Hobbs, Academic Press

Competencies
Subject-specific Competencies
Method-specific Competencies
Social Competencies

701-0475-AAL  Atmospheric Physics
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
This course is a self-study course for MSc students, who like to learn something about Atmospheric Physics but for cannot follow the course Atmosphärenphysik, because that is taught in German. However, the slides and the textbook of the course Atmosphärenphysik, and they form the basis also for this course.

Objective
See entry under LV 701-0475-00L Atmosphärenphysik

Content
See entry under LV 701-0475-00L Atmosphärenphysik

Lecture notes
Powerpoint slides and script from LV 701-0475-00L Atmosphärenphysik will be made available

Literature
Lohmann, U., Lüboud, F. and Mahrt, F., An Introduction to Clouds:
From the Microscale to Climate, Cambridge Univ. Press, 391 pp., 2016.
pdf-files of the revised book will be provided as well.

Competencies
Subject-specific Competencies
Method-specific Competencies
Social Competencies

701-0501-AAL  Pedosphere

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Content
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Lecture notes
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Literature
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Competencies
Subject-specific Competencies
Method-specific Competencies
Social Competencies

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Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to the formation and properties of soils as a function of parent rock, landscape position, climate, and soil organisms. Complex relationships between soil forming processes, physical and chemical soil properties, soil biota, and ecological soil properties.

Objective
Understanding of soils as integral parts of ecosystems, development and distribution of soils as a function of environmental factors, and processes leading to soil degradation.

Content
Definition of the pedosphere, soil functions, rocks as parent materials, minerals and weathering, soil organisms, soil organic matter, physical soil properties and functions, chemical soil properties and functions, soil formation, principles of soil classification, global soil regions, soil fertility, land use and soil degradation.

Literature

Prerequisites / notice
Prerequisites: Basic knowledge in chemistry, biology and geology.

Competencies

<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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<tr>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Problem-solving</td>
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</table>

701-0721-AAL Psychology
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
This self-study course is an introductory course in psychology. This course will emphasize cognitive psychology and the psychological experiment.

Objective
Knowledge of key concepts and exemplary theories of psychology and their relation to "daily" psychology. Comprehension of relation between theory and experiment in psychology.

Goals: Learning how psychologists are thinking, a side change from the ETH natural science perspective to psychological thinking.

Domains of psychology:
- Psychology fields
- Concept definitions of psychology
- Theories of psychology
- Methods of psychology
- Results of psychology

Capability:
Be able to define a psychological research question
Basics understanding of role of psychology

Comprehension:
Psychology as a science of experience and behavior of the human

Content
Einführung in die psychologische Forschung und Modellbildung unter besonderer Berücksichtigung der kognitiven Psychologie und des psychologischen Experimenten. Themen sind u.a.: Wahrnehmung; Lernen und Entwicklung; Denken und Problemlösen; Kognitive Sozialpsychologie; Risiko und Entscheidung.

Literature

Prerequisites / notice
Determine with Prof. Dr. Michael Siegrist the chapters in "Zimbardo" which are compulsory reading

Read the two Psychology chapters (6 + 7) from the book of Prof. Roland W. Scholz

752-4001-AAL Microbiology
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
Self-study course in microbiology.

Objective
Teaching of basic knowledge in microbiology.

Content
This is a self-study course for students with microbiology as an admission requirement. The goal of the course is that students acquire basics in microbiology, including bacterial cell biology, genetics, growth and physiology, metabolism, phylogeny and microbial diversity, and applications of microbiology.

Literature
This self-study course is based on the book 'Brock, Biology of Microorganisms'.

Environmental Sciences Master - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
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<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2540 of 2653
<table>
<thead>
<tr>
<th>Key for Hours</th>
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<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>151-0125-00L</td>
<td>Hydrodynamics and Cavitation</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>O. Supponen</td>
</tr>
</tbody>
</table>

**Abstract**

This course builds on the foundations of fluid dynamics to describe hydrodynamic flows and provides an introduction to cavitation.

**Objective**

The main learning objectives of this course are:
1. Identify and describe dominant effects in liquid fluid flows through physical modelling.
2. Identify and predict the onset of hydrodynamic instabilities.
3. Describe acoustic wave behaviour in liquids.
4. Explain tension, nucleation and phase-change in liquids.
5. Predict the behaviour of a gas bubble subject to changes in surrounding liquid pressure.
6. Describe hydrodynamic cavitation and its consequences in physical terms.
7. Recognise experimental techniques and industrial and medical applications for cavitation.
8. Read and evaluate research papers on recent research on cavitation and bubble dynamics and communicate the content orally to a multidisciplinary audience.

**Content**

The course gives an overview on the following topics: basics of hydrodynamics, capillarity, hydrodynamic instabilities, liquid fragmentation. Acoustics in liquids, tension in liquids, phase change. Cavitation and bubble dynamics: single bubbles (nucleation, dynamics, collapse), bubble clouds and cavitating flows. Industrial applications and measurement techniques.

**Lecture notes**

Class notes and handouts

**Literature**

Literature will be provided in the course material.

**Prerequisites / notice**

Fluid dynamics I & II or equivalent

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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>151-0209-00L</td>
<td>Renewable Energy Technologies</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>A. Bardow, E. Casati</td>
</tr>
</tbody>
</table>

**Abstract**

The first part of the course covers the engineering aspects of the prominent renewable energy technologies: solar (PV and thermal), wind, hydro, geothermal and bioenergy. We further discuss energy storage, renewable transport and renewable heating & cooling. Finally, we introduce the key concepts of the economics of renewable energy and its integration in the energy system.

**Objective**

Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization.

**Lecture notes**

Lecture Notes containing copies of the presented slides.

**Prerequisites / notice**

Prerequisite: strong background on the fundamentals of engineering thermodynamics, equivalent to the material taught in the courses Thermodynamics I, II, and III of D-MAVT.

**Competencies**

<table>
<thead>
<tr>
<th>Competencies</th>
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<th>assessed</th>
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<tbody>
<tr>
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<td>Techniques and Technologies</td>
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<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td></td>
<td>Decision-making</td>
<td>fostered</td>
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<td></td>
<td>Problem-solving</td>
<td>fostered</td>
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<tr>
<td>Social Competencies</td>
<td>Communication</td>
<td>fostered</td>
</tr>
<tr>
<td>Personal Competencies</td>
<td>Cooperation and Teamwork</td>
<td>fostered</td>
</tr>
</tbody>
</table>

**Prerequisites / notice**

Thermodynamics I, II, and III of D-MAVT.

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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0213-00L</td>
<td>Fluid Dynamics with the Lattice Boltzmann Method</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>I. Karlin</td>
</tr>
</tbody>
</table>

**Abstract**

The course provides an introduction to theoretical foundations and practical usage of the Lattice Boltzmann Method for fluid dynamics simulations.

**Objective**

Methods like molecular dynamics, DSMC, lattice Boltzmann etc are being increasingly used by engineers all over and these methods require knowledge of kinetic theory and statistical mechanics which are traditionally not taught at engineering departments. The goal of this course is to give an introduction to ideas of kinetic theory and non-equilibrium thermodynamics with a focus on developing simulation algorithms and their realizations.

During the course, students will be able to develop a lattice Boltzmann code on their own. Practical issues about implementation and performance on parallel machines will be demonstrated hands on.

Central element of the course is the completion of a lattice Boltzmann code (using the framework specifically designed for this course).

The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.

Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.
Content
The course builds upon three parts:
I. Elementary kinetic theory and lattice Boltzmann simulations introduced on simple examples.
II. Theoretical basis of statistical mechanics and kinetic equations.
III. Lattice Boltzmann method for real-world applications.

The content of the course includes:

1. Background: Elements of statistical mechanics and kinetic theory:
   Particle's distribution function, Liouville equation, entropy, ensembles, Kinetic theory; Boltzmann equation for rarefied gas, H-theorem, hydrodynamic limit and derivation of Navier-Stokes equations, Chapman-Enskog method, Grad method, boundary conditions; mean-field interactions, Vlasov equation.
   Kinetic models: BGK model, generalized BGK model for mixtures, chemical reactions and other fluids.

2. Basics of the Lattice Boltzmann Method and Simulations:
   Minimal kinetic models: lattice Boltzmann method for single-component fluid, discretization of velocity space, time-space discretization, boundary conditions, forcing, thermal models, mixtures.

3. Hands on:
   Development of the basic lattice Boltzmann code and its validation on standard benchmarks (Taylor-Green vortex, lid-driven cavity flow etc).

4. Practical issues of LBM for fluid dynamics simulations:
   Lattice Boltzmann simulations of turbulent flows; numerical stability and accuracy.

5. Microflow:
   Rarefaction effects in moderately dilute gases; Boundary conditions, exact solutions to Couette and Poiseuille flows; micro-channel simulations.

6. Advanced lattice Boltzmann methods:
   Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

7. Introduction to lattice Boltzmann methods:
   Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

Lecture notes
Lecture notes on the theoretical parts of the course will be made available.
Selected original and review papers are provided for some of the lectures on advanced topics.
Handouts and basic code framework for implementation of the lattice Boltzmann models will be provided.

Prerequisites / notice
The course addresses mainly graduate students (MSc/Ph D) but BSc students can also attend.

151-0293-00L
Combustion and Reactive Processes in Energy and Materials Technology
4 credits 2V+1U+2A
N. Noiray, F. Ernst, C. E. Frouzakis

Abstract
This course will provide an introduction to the fundamentals and the applications of combustion in energy conversion and nanoparticles synthesis. The content is highly relevant for technologies which cannot be electrified such as long distance aviation and shipping, and which will more and more rely on carbon-neutral synthetic fuels.

Objective
The main learning objectives of this course are: 1. Understand the thermodynamic, fluid-dynamic and chemical kinetics fundamentals of combustion processes. 2. Predict relevant parameters for combustion systems, such as laminar and turbulent flame speeds, adiabatic flame temperature or quenching distance. 3. Understand the causal relations of relevant combustion parameters such as the pressure influence on the laminar flame speed. 4. Analyze the challenges of developing sustainable combustion technologies based on carbon-neutral synthetic fuels.

Content

Lecture notes
No script available. Instead, material will be provided in lecture slides and the following text book (which can be downloaded for free) will be followed:

Teaching language, assignments and lecture slides in English

Literature


151-0509-00L
Acoustics in Fluid Media: From Robotics to Additive Manufacturing
4 credits 3G
D. Ahmed

Abstract
The course will provide you with the fundamentals of the new and exciting field of ultrasound-based microrobots to treat various diseases. Furthermore, we will explore how ultrasound can be used in additive manufacturing for tissue constructs and robotics.

Objective
The course is designed to equip students with skills in the design and development of ultrasound-based manipulation devices and microrobots for applications in medicine and additive manufacturing.

Content
Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices

Lecture notes

Literature

Prerequisites / notice
Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.
Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: fostered
- Negotiation: fostered

Personal Competencies
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-direction and Self-management: assessed

151-0905-00L  Medical Technology Innovation - From Concept to Clinics
W 4 credits 3G  I. Herrmann

Abstract
Project-oriented learning on how to develop technological solutions to address unmet clinical needs.

Objective
After completing the course, you will be able to effectively collaborate with medical doctors in order to identify important unmet clinical needs. You will be able to ideate and develop appropriate engineering solutions and implementation strategies for real-world clinical problems. This lecture aims to prepare you for typical engineering challenges in the real-world where - in addition to the development of an elegant solution - interdisciplinary teamwork and effective communication play a key role.

Lecture notes
will be available on the moodle.

Literature
will be available on the moodle.

Prerequisites / notice
On site presence during (most) of the lectures highly encouraged!
Graded innovation project will require on-site presence.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: assessed
- Project Management: assessed

Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

151-0913-00L  Introduction to Photonics
W  4 credits  2V+2U  R. Quidant, J. Ortega Arroyo

Abstract
This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

Objective
Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.
## I- BASICS OF WAVE THEORY
1) General concepts
2) Differential wave equation
3) Wavefront
4) Plane waves and Fourier decomposition of optical fields
5) Spherical waves and Huygens-Fresnel principle

## II- ELECTROMAGNETIC WAVES
1) Maxwell equations
2) Wave equation for EM waves
3) Dielectric permittivity
4) Refractive index
5) Nonlinear optics
6) Polarization and polarization control

## III- PROPAGATION OF LIGHT
1) Waves at an interface
2) The Fresnel coefficients
3) Total internal reflection
4) Evanescent waves
5) Dispersion diagram

## IV- INTERFERENCES
1) General considerations
2) Temporal and spatial coherence
3) The Young double slit experiment
4) Diffraction gratings
5) The Michelson interferometer
6) Multi-wave interference
7) Antireflecting coating and interference filters
8) Optical holography

## V- LIGHT MANIPULATION
1) Optical waveguides
2) Photonic crystals
3) Metamaterials and metasurfaces
4) Optical cavities

## VI- OPTICAL FORCES AND OPTICAL TWEEZERS
1) History of optical forces
2) Theory of optical trapping
3) Atom cooling
4) Optomechanics
5) Applications of optical tweezers

## VII- INTRODUCTION TO OPTICAL MICROSCOPY
1) Basic concepts
2) Direct and Fourier imaging
3) Image formation
4) Fluorescence microscopy
5) Scattering-based microscopy
6) Digital holography
7) Computerized imaging

### Lecture notes
- Class notes and handouts

### Literature
- Optics (Hecht) - Pearson

### Competencies

<table>
<thead>
<tr>
<th>Competency</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>Analytical Competencies</th>
<th>Problem-solving</th>
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<td>Personal Competencies</td>
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### Prerequisites / notice
- Physics

### Notes
- Mass Transfer
  - W 4 credits 2V+2U
  - M. Tibbitt, V. Mavrantzas, C.-J. Shih

### Abstract
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore, the application of these principles to important engineering problems is demonstrated.

### Objective
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore, the application of these principles to important engineering problems is demonstrated.

### Content
Fick's laws; application and significance of mass transfer; comparison of Fick's laws with Newton's and Fourier's laws; derivation of Fick's 2nd law; diffusion in dilute and concentrated solutions; rotating disk; dispersion; diffusion coefficients, viscosity and heat conduction (Pr and Sc numbers); Brownian motion; Stokes-Einstein equation; mass transfer coefficients (Nu and Sh numbers); mass transfer across interfaces; Analogies for mass-, heat-, and momentum transfer in turbulent flows; film-, penetration-, and surface renewal theories; simultaneous mass, heat and momentum transfer (boundary layers); homogeneous and heterogeneous reversible and irreversible reactions; diffusion-controlled reactions; mass transfer and first order heterogeneous reaction. Applications.

### Literature

### Prerequisites / notice
Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.
Competencies | Subject-specific Competencies | Concepts and Theories | assessed
--- | --- | --- | ---
 | Techniques and Technologies | fostered
Method-specific Competencies | Analytical Competencies | assessed
 | Decision-making | fostered
 | Media and Digital Technologies | fostered
 | Problem-solving | assessed
Social Competencies | Communication | fostered
 | Cooperation and Teamwork | fostered
 | Sensitivity to Diversity | fostered
Personal Competencies | Adaptability and Flexibility | fostered
 | Creative Thinking | assessed
 | Critical Thinking | assessed
 | Integrity and Work Ethics | fostered
 | Self-awareness and Self-reflection | fostered
 | Self-direction and Self-management | fostered

151-0927-00L Rate-Controlled Separations in Fine Chemistry | W | 6 credits | 3V+1U | M. Mazzotti, V. Becattini, N. Casas, F. Kiefer

Abstract
The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.

Objective
The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.

Content
The class covers separation techniques that are central in the purification and downstream processing of chemicals and biopharmaceuticals. Examples from both areas illustrate the utility of the methods: 1) Adsorption and chromatography; 2) Membrane processes; 3) Crystallization and precipitation.

Lecture notes
Handouts during the class

Literature
Recommendations for text books will be covered in the class

Prerequisites / notice
Requirements (recommended, not mandatory): Thermal separation Processes I (151-0926-00) and Modelling and mathematical methods in process and chemical engineering (151-0940-00)

Competencies | Subject-specific Competencies | Concepts and Theories | assessed
--- | --- | --- | ---
 | Techniques and Technologies | fostered
Method-specific Competencies | Analytical Competencies | assessed
 | Decision-making | fostered
 | Media and Digital Technologies | fostered
 | Problem-solving | assessed
Social Competencies | Communication | assessed
 | Cooperation and Teamwork | fostered
 | Customer Orientation | fostered
 | Leadership and Responsibility | fostered
 | Self-presentation and Social Influence | fostered
 | Sensitivity to Diversity | fostered
 | Negotiation | fostered
Personal Competencies | Adaptability and Flexibility | fostered
 | Creative Thinking | fostered
 | Critical Thinking | assessed
 | Integrity and Work Ethics | fostered
 | Self-awareness and Self-reflection | fostered
 | Self-direction and Self-management | fostered

151-0951-00L Process Design and Safety | W | 4 credits | 2V+1U | F. Trachsel, C. Hutter

Abstract
The lecture Process Design and Saftey deals with the fundamentals of project management, scale-up, dimensioning and safety of chemical process equipment and plants.

Objective
The objective of the lecture is to expound the engineering design approach of important elements in chemical plant design.

Content
Fundamentals in Chemical engineering Design;
Project Management,
Cost estimate,
Materials and Corrosion,
Piping and Armatures,
Pumps,
Reactors and Scale-up,
Safety of chemical processes,
Patents

Lecture notes
The lecture slides will be distributed.

Literature
A 1-day excursion including a visit of a chemical plant will be part of the lecture.

Prerequisites / notice

151-0957-00L Practica in Process Engineering I | W | 2 credits | 2P | D. J. Norris, M. Tibbitt

Abstract
Practical training at pilot facilities for fundamental processing steps, typical laboratory and pilot facility experiments.

Objective
Getting acquainted with unit operations, measuring tools and data processing
Content

4 modules in total (3 from Prof. Norris, 1 from Prof. Mark Tibbitt)
Details and dates will be communicated at the beginning of the semester.

Residence Time Distribution
Tibbitt
Perovskite Nanocrystals - Synthesis and Characterization
Norris
ICP Elemental Analysis
Norris
Scanning Electron Microscope Imaging (SEM)
Norris

Lecture notes
Scripts of the specific practice will be available shortly before the modules.

Literature

529-0613-01L Process Simulation and Flowsheeting

W 6 credits 3G G. Guillén Gosálbez

Abstract
This course encompasses the theoretical principles of chemical process simulation and optimization, as well as its practical application in process analysis. The techniques for simulating stationary and dynamic processes are presented, and illustrated with case studies.

Objective
This course aims to develop the competency of chemical engineers in process flowsheeting, process simulation and process optimization. Specifically, students will develop the following skills:
- Deep understanding of chemical engineering fundamentals: the acquisition of new concepts and the application of previous knowledge in the area of chemical process systems and their mechanisms are crucial to intelligently simulate and evaluate processes.
- Modeling of general chemical processes and systems: students should be able to identify the boundaries of the system to be studied and develop the set of relevant mathematical relations, which describe the process behavior.
- Mathematical reasoning and computational skills: the familiarization with mathematical algorithms and computational tools is essential to be capable of achieving rapid and reliable solutions to simulation and optimization problems. Hence, students will learn the mathematical principles necessary for process simulation and optimization, as well as the structure and application of process simulation software. Thus, they will be able to develop criteria to correctly use commercial software packages and critically evaluate their results.
- Process optimization: the students will learn how to formulate optimization problems in mathematical terms, the main type of optimization problems that exist (i.e., LP, NLP, MILP and MINLP) and the fundamentals of the optimization algorithms implemented in commercial solvers.

Content
Overview of process simulation and flowsheeting:
- Definition and fundamentals
- Fields of application
- Case studies
Process simulation:
- Modeling strategies of process systems
- Mass and energy balances and degrees of freedom of process units and process systems
Process flowsheeting:
- Flowsheet partitioning and tearing
- Solution methods for process flowsheeting
- Simultaneous methods
- Sequential methods
Process optimization and analysis:
- Classification of optimization problems
- Linear programming, LP
- Non-linear programming, NLP
- Mixed-integer linear programming, MILP
- Mixed-integer nonlinear programming, MINLP
Commercial software for simulation (Aspen Plus):
- Thermodynamic property methods
- Reaction and reactors
- Separation / columns
- Convergence, optimisation & debugging

Literature
An exemplary literature list is provided below:
- Smith, R. Chemical process design and integration, Wiley (2005).

Prerequisites / notice
A basic understanding of material and energy balances, thermodynamic property methods and typical unit operations (e.g., reactors, flash separations, distillation/absorption columns etc.) is required.

► Multidisciplinary Courses
The students are free to choose individually Master’s courses from the Course Catalogue of ETH Zurich, ETH Lausanne and the Universities of Zurich (https://www.uzh.ch/cmsssl/en/studies/application/chmobilityin.html) and St. Gallen.

Course Catalogue of ETH Zurich

► Semester Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>151-1008-00L</td>
<td>Semester Project Process Engineering</td>
<td>O</td>
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Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2547 of 2653
The subject of the Master Thesis and the choice of the supervisor (ETH-professor) are to be approved in advance by the tutor.

Abstract
The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master’s program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

Objective
The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program.

► Industrial Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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Abstract
The main objective of the minimum twelve-week internship is to expose Master's students to the industrial work environment. The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

Objective
The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

► Science in Perspective

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-MAVT

► Master’s Thesis

<table>
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<tr>
<th>Number</th>
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</table>

Abstract
Master's programs are concluded by the master's thesis. The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem. The subject of the master's thesis, as well as the project plan and roadmap, are proposed by the tutor and further elaborated with the student.

Objective
The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem.

Process Engineering Master - Key for Type

<table>
<thead>
<tr>
<th>Key for Type</th>
<th>Description</th>
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<tr>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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Key for Hours

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<tr>
<td>ECTS</td>
<td>European Credit Transfer and Accumulation System</td>
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Data: 15.06.2024 12:39
Autumn Semester 2024
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### History

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>853-0725-00L</td>
<td>History Part One: Europe (The Cradle of Modernity, Britain, 1789-1914)</td>
<td>W</td>
<td>3</td>
<td>2V</td>
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</table>

- **Abstract**: A range of fundamental processes have transformed European societies in the course of the 19th and the 20th centuries. This lecture series looks at several key aspects of these modernization processes and asks about their continuing relevance for our times. The regional focus lies on Britain, where these processes took place for the first time.
- **Objective**: At the end of this lecture course, students can: (a) highlight the most important changes in the "long nineteenth century" in Britain (b) explain their long-term effects (also for other European countries); and (c) relate these changes to global developments today.
- **Content**: The thematic foci include: Industrialization, urban growth, democratisation and mass politics, shifting gender roles and ideals, and the emergence of consumerism and leisure culture.

- **Lecture notes**: Power Point Slides and references will be made available in digital form during the course of the semester.
- **Prerequisites / notice**: This lecture series does not build upon specific previous knowledge by the students.

### Global History of Urban Design I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>052-0801-00L</td>
<td>Global History of Urban Design I</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>T. Avermaete</td>
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</tbody>
</table>

- **Abstract**: This course focuses on the history of the design of cities, as well as on the ideas, processes and actors that engender and lead their development and transformation. The history of urban design will be approached as a cross-cultural field of knowledge that integrates scientific, economic and technical innovation as well as social and cultural advances.
- **Objective**: The lectures deal mainly with the definition of urban design as an independent discipline, which maintains connections with other disciplines (politics, sociology, geography) that are concerned with the transformation of the city. The aim is to make students conversant with the multiple theories, concepts and approaches of urban design as they were articulated throughout time in a variety of cultural contexts, thus offering a theoretical framework for students’ future design work.
- **Content**: In the first semester the genesis of the objects of study, the city, urban culture and urban design, are introduced and situated within their intellectual, cultural and political contexts.

- **Lecture notes**: Prior to each lecture a chapter of the reader (Skript) will be made available through the webpage of the Chair. These chapters will provide an introduction to the lecture, the basic visual references of each lecture, key dates and events, as well as references to the compulsory and additional reading.
- **Literature**: There are three books that will function as main reference literature throughout the course:

- **Prerequisites / notice**: Students are required to familiarize themselves with the conventions of architectural drawing (reading and analyzing plans at various scales).

A list of further recommended literature will be found within each chapter of the reader (Skript).

- These books will be reserved for consultation in the ETH Baubibliothek, and will not be available for individual loans.

### Courses listed for bachelor students after their first-year examination and for all master- or doctoral students. All SiP courses are listed in Type A.

### Courses listed under Type B are only recommendations for enrollment for specific departments.
### 851-0685-00L Data and Society

**Abstract**
This lecture series explores the multifaceted role of data in shaping contemporary society, governance, and individual lives. The course equips students with a critical understanding of how data is made, managed, and preserved, and its implications for societal norms and individual rights.

**Objective**
At the end of the term, students will be able to:
- reflect concepts that capture the performativity of data
- assess the implications of data practices for social and political ordering
- identify key actors, sites, and domain contexts of data practices

**Competencies**
<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Analytical Competencies</th>
<th>Problem-solving competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Communication</td>
<td>Sensitivity to Diversity</td>
</tr>
</tbody>
</table>

**Method-specific Competencies**
- Adaptability and Flexibility
- Critical Thinking
- Self-awareness and Self-reflection

**Social Competencies**
- Communication
- Sensitivity to Diversity

**Personal Competencies**
- Creativity
- Critical Thinking
- Self-awareness and Self-reflection

---

### 851-0067-00L Science Studies between economic growth, social needs and critique

**Abstract**
Science has become a subject of research in its own right since the 20th century: the field of "science studies" examines the organization of science, its social benefits, its contribution to economic growth or its impact on people and nature. The seminar introduces the history of this research and sheds light on its applied and critical dimensions.

**Objective**
The value of science for social and economic development has been an issue of debate since the 20th century. At the same time, science became a subject of research in its own right: the sociology of science in the 1930s dealt with the social benefits ("Science for Social Needs") and the organization of science. Since the 1950s, the research field of the "Science of Science" has quantified scientific publications ("Science Citation Index") and attempted to measure the relationship between research and innovation, between education and economic growth (OECD studies). Science seemed to promise scientific and technological progress, innovation and economic growth - both in the industrialized countries and, with the help of "technology transfer", to the then so-called "developing countries". At the same time, in the field of "technology assessment", the sciences were criticized for causing risks and damages to humans and nature (e.g. through pesticides or biotechnology) or entailting effects of social inequality.

The fact that the sciences have been the subject of debate since the 20th century is not only a matter of general public interest. It is also the effect of the development and funding of research fields that deal with measuring the effects of innovation or with the benefits and risks of science. The seminar deals with the history of this research in its political and economic contexts as well as in its applied and critical function. It examines the knowledge on which historical and current expectations of science in politics and society are based.

**Literature**
- J.D. Bernal: The Social Function of Science (1939)
- Derek de Solla Price: The Little Science, Big Science (1963)
- Christopher Freeman: Economics of Research and Development (1977)
- Ziauddin Sardar, Dawud G. Rosser-Owen: Science Policy and Developing Countries (1977)
- Donna Haraway: Class, Race, Sex, Scientific Objects of Knowledge (1982)

**Competencies**
<table>
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<th>Subject-specific Competencies</th>
<th>Analytical Competencies</th>
<th>Communication</th>
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<td>Concepts and Theories</td>
<td>Sensitivity to Diversity</td>
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**Method-specific Competencies**
- Adaptability and Flexibility
- Critical Thinking
- Self-awareness and Self-reflection

**Social Competencies**
- Sensitivity to Diversity

**Personal Competencies**
- Creativity
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

---

### 851-0077-00L Philosophy of War

**Abstract**
In the course we read classical texts from the field of philosophy of war (Clausewitz, Sun Tzu, Tolstoy, Machiavelli, Kant) and focus on questions such as: what is war? Strategy and tactics in war? Ethics of war? War and Politics?

**Objective**
Students learn about the different types of argumentative texts and their historical, social, political and ethical context. They learn to understand the descriptive and critical value of texts in regard to the topic of war.

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### 851-0019-00L Insect Histories: Bugs That Made the Modern World

**Abstract**
The seminar explores insects as historical actors and their diverse interactions with human societies over time and space. It offers an overview of recent approaches in environmental history and multispecies ethnography while providing an analytical framework to understand global processes of natural resource exploitation, knowledge formation, and imperialism.

**Objective**
The objective is to analyze human-insect interactions by identifying key historical factors (economic, scientific, political). Students will integrate current frameworks in the study of environmental history through the combination of primary sources and interdisciplinary research. They will develop skills rooted in their interest in insects and learn to translate them into feedback to peers.
This course explores the relation between the scientific investigation of life and cultural notions of death from a historical perspective. Scholars typically approach Nature-related histories by focusing on environmental change, the commodification of resources, and the legacy of natural history collections. Examples of this approach include studies on deforestation, dam constructions, the rubber boom, and the colonial history of European museums. In contrast to these commonly explored topics, insects are often underrepresented in historical research, both as living creatures and metaphors. Addressing this gap, the seminar explores human-insect interactions from a global historical perspective between 1600 and 2000. This exploration encompasses a critical and relational understanding of the history of the scientific study of insects (entomology) and the processes of imperial expansion and global territorialization. To achieve this, students will learn how human-insect interactions led to radical transformations in diverse environments, reflecting a particular modern conception of nature influenced by control anxieties related to economic profit and tropical diseases. Moreover, students will examine how ways of knowing about insects and the environment were influenced by broader correlated economic and imperial factors. Focusing on insect (hi)stories, the aim of this seminar is to apply new methodologies for non-human agencies and source analysis on both micro and macro scales in global and environmental histories.
Objective

There is only one certainty in life: death. This brute fact has animated much thought and work in theology, art and philosophy - but also in the natural sciences, such as biology and medicine. Questions regarding health and disease, evolution, extinction and immortality have played a crucial role in this connection. This course aims to explore above relations - the relations between the scientific investigation of life and cultural notions of death - from a historical perspective (assuming there is no such thing as the scientific investigation of death). While the course covers the times from antiquity up to the present, the main emphasis will be placed on the modern life sciences since the 19th century.

851-0540-00L Of Stainless Steel and Biocompatible Ink. History of Materials Science.

Abstract

The seminar examines the history of materials science. Why and how were materials characterised, developed and tested? How did things as diverse as wood, concrete, ceramics and polymers become objects of a single discipline? How did social imaginaries and technical conditions affect scientific work with and on materials?

Objective

Students learn to critically read and interpret different types of texts. They will be familiarised with the interdependencies of technical, scientific and social change. They reflect on (material) scientific practices.

Content

The seminar discusses the socio-technical conditions and effects of materials research from a historical perspective in the 20th century. We observe physicists, chemists and engineers, as well as concrete, foams and electron microscopes, in research laboratories and materials testing institutes, in articles and patents.

Competencies

Subject-specific Competencies

Concepts and Theories

Analytical Competencies

Communication

Cooperation and Teamwork

Personal Competencies

Creative Thinking

Critical Thinking

fostered

851-0541-00L Truth and Historical Injustice: The Production of Knowledge about Past Mass Atrocities

Abstract

The course deals with the scientific production of knowledge about past mass atrocities. It looks at the interplay of different disciplines, methods and technological means that have been involved in this production over time. Further, it poses the question of what truth can mean in this context.

Objective

The students a) know the main features of the discussion about the truth in the reconstruction of past events; b) have an understanding of the interplay, but also the coexistence of different scientific methods and technological means in the multidisciplinary production of knowledge about mass crimes; c) have knowledge of important processes of dealing with past mass crimes from the second half of the 20th century onwards.

Content

When discussing the truthfulness of the academic study of the past, politically and ideologically motivated mass crimes are often cited as historical events in order to substantiate the necessity of a claim to truth. In doing so, moral arguments can be made or historical truth can be asserted as a basic prerequisite for living together in a democratic society under constitutional conditions. The production of knowledge about past atrocities has always been an endeavour in which various scientific disciplines have been involved. The multidisciplinary character of the production of knowledge about mass crimes has become even more accentuated since the second half of the 20th century, not least due to the emergence of new technological possibilities. The course offers a brief introduction to the discussion about the meaning of truth about past events. It looks at how different scientific approaches - from the humanities to the natural sciences - have been involved in coming to terms with mass crimes and how they have been related to each other. It deals with the question of what role certain techniques and technologies have played in the production of knowledge about past atrocities and how this has changed over time. These techniques and technologies range from the evaluation of documents and the taking of testimonies to specialised database programs, genetic analysis or imaging techniques, to digital technologies for the procurement of information on social media and the internet or for the modelling of past events. In addressing these questions, the course looks at processes of dealing with the past from the middle of the 20th century to the 21st century in Europe, Latin America and Africa.

Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Critical Thinking

fostered

assessed

851-0202-00L Digital Humanities: Methods, Challenges, Perspectives

Abstract

In the 21st century, the humanities and the social sciences are undergoing a ground-breaking transformation: Data-driven, collaborative projects open up new opportunities. Which are the promises and the challenges of digital methods? The lecture series provides an overview of the latest developments.

Objective

— exploring the most important theoretical and methodological approaches since 2000

— understanding terms and procedures

— using digital texts, images and metadata

— reflecting on the conditions, opportunities and problems of digital methods

Content

The possibilities (Franco Moretti, Graphs, Maps, Trees, Verso 2005; Andrew Piper, Enumerations, Chicago UP 2018) and pitfalls (Franco Moretti, The Wrong Move, Konstanz UP 2022) of cultural history under digital conditions require critical reflection and evaluation. The lecture will explore showcases and pioneering work, annotated texts, images, metadata and interfaces provided by libraries, archives and museums. Research approaches and practical applications will be presented and evaluated.

851-0297-00L Manipulation in Literature and Cultural History

Abstract

This lecture focuses on the manipulation and control of individuals and the masses. The power of manipulation is based on subtle use of persuasive linguistic elements and knowledge of the desires and fears of the intended audience. In addition to a theoretical overview, the lecture concentrates on the literary and discursive texts that dispute the control of protagonists.

Objective

Students will learn about manipulation as a linguistic and narrative phenomenon steeped in myth and classical rhetoric. Against the backdrop of cultural-historical developments, particularly with regard to major changes in media technology, we will examine how the reach of manipulation was extended from the individual to the masses. Students will be able to refine their critical discourse analysis skills and interdisciplinary abilities by studying texts from literature, politics, sociology, philosophy and psychoanalysis which reflect this shift in emphasis.
Since the dawn of time mankind has tried to exert influence over others through the utilisation of certain techniques: initially for self-preservation – for example the interpretation of Sigmund Freud in Totem und Tabu. Later, desire became the driving force – centre stage: the desire for pleasure, power and control. Manipulation manifests itself in the form of characters and words, it is an authentically linguistic occurrence: classical antiquity, with the rhetoric, develops a system of verbal power of persuasion and, already then, questions were being raised in literary and discursive texts about how people could, or even should, manipulate. The exertion of influence and its impact will be clearly described, propagated, commented upon, criticised and ironised.

In contrast to oppressive overpowering, the power of manipulation (in Latin, manus hand, plere fill) is on the one hand, based on the subtle use of persuasive linguistic elements – it is always a (literary) discourse, too – and on the other, on knowing precisely what the fantasies, desires and fears of the manipulated are. The discourse of manipulation has its beginnings in the age of sophists and their belief in an omnipotence of language and rhetoric. It underwent further transformation under political and psychological signs in the early modern period through Giordano Bruno and Niccolò Machiavelli and culminated in the 20th century in a critique of the deception strategies of the "culture industry" (T. W Adorno) and "psychotechnology" (B. Stiegler) in global capitalism. Nowadays social media is the "radicalisation machine" (J. Eben) that present new challenges for society. Written in the 19th century, the Protocols of the Elders of Zion already gave indications of how present-day conspiracy theorists would manipulate their audience, and its impact can still be felt today. Since manipulation is a linguistic, narrative and also literary phenomenon, the central theme of the lecture is how in literature itself this often politically controversial and manipulative behaviour is picked up and reflected through poetry: such as in Tristan von Gottfried von Strassburg, Goethe's Wilhelm Meister, Friedrich Schiller's Die Verschwörung des Fiesco zu Genua or Heinrich von Kleist's Der zerbrochene Krug, the works of Edgar Allan Poe and Thomas Mann (Mario und der Zauberer) and, most recently in Eckhart Nickel's novel, Hysteria.
Students learn about the different types of argumentative texts and their historical, social, political and ethical context. They learn to foster creative thinking.

Novalis once described poetry as "the mind's inherent way of acting". Thinking takes place in verses and images, rather than concepts and formulae. If this were true, every spontaneous cognition would amount to poetry and each thought essentially to a poem -- a structure combining and concentrating ideas, perceptions, and emotions. Knowledge and poetry would be one.

This course will follow the hope and despair to which "Babel: 1940" gives voice as it echoes across various 20th century literary, scientific, and philosophical discourses. In our survey, we will pay particular attention to how the problem of linguistic difference depending on whether one considers Babel as an act of God, a condition of culture, or an obstacle to communication.

Texts by Ted Chiang, Jorge Luis Borges, Douglas Adams, Johann Gottfried Herder, W.V. Quine, Steven Pinker, Douglas Hofstadter, and Bruno Latour.

Competencies

Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

Method-specific Competencies
- Analytical Competencies: fostered
- Media and Digital Technologies: fostered

Social Competencies
- Communication: assessed
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: fostered

Personal Competencies
- Creative Thinking: fostered
- Critical Thinking: fostered
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered

851-0281-00L

The Knowledge of Poetry

W 3 credits 2V 2S  C. Jany

Abstract

Novalis once described poetry as "the mind's inherent way of acting". Thinking takes place in verses and images, rather than concepts and formulas. If this were true, every spontaneous cognition would amount to poetry and each thought essentially to a poem -- a structure combining and concentrating ideas, perceptions, and emotions. Knowledge and poetry would be one.

Objective

Such is the promise literature has made since its inception, a promise we will examine in this class by considering mainly lyrical compositions in verse, from the beginnings to the present. The central question is: What do poems know and what is the relationship between thinking in verse and technical and scientific knowledge?

851-0077-00L

Philosophy of War

W 3 credits 2V 2S  O. Del Fabbro

Abstract

In the course we read classical texts from the field of philosophy of war (Clausewitz, Sun Tzu, Tolstoy, Machiavelli, Kant) and focus on questions such as: what is war? Strategy and tactics in war? Ethics of war? War and Politics?

Objective

Students learn about the different types of argumentative texts and their historical, social, political and ethical context. They learn to understand the descriptive and critical value of texts in regard to the topic of war.

851-0201-00L

Literature and History

W 3 credits 2V  L.-P. Dalember

Abstract

Literature and history have often coexisted, "dialogued". History is a recurring theme in many literary works. In this seminar, we will explore the relationship between literature and history.

Objective

The aim is to evoke History as a source of creation for writers. The aim is to identify the bridges built by this transdisciplinarity, and to question the way in which History is "rewritten" by literature, after having been at its origin.

Content

Literature and history have often coexisted, "dialogued". History is a recurring theme in many literary works. In this seminar, we will explore the relationship between literature and history. We'll look at several periods of world history, from America to Europe and Africa. The aim is to evoke History as a source of creation for writers. The aim is to identify the bridges built by this transdisciplinarity, and to question the way in which History is "rewritten" by literature, after having been at its origin. To illustrate our points, we will draw on 20th- and 21st-century novels by French, Haitian and Algerian authors...

- Rosalie L'infâme, Évelyne Trouillot
- Le Manuscrict de Port-Ébène, Dominique Bona
- L'Affaire de l'esclave Furcy, Mohammed Alissaoui
- Cris, Laurent Gaudé (First World War)
- Sigmarigen, Pierre Assouline (World War II)
- Avant que les ombres s'effacent, Louis-Philippe Dalember (Second World War)
- Cù j'ai laissé mon âme, Jérôme Ferrari (Second World War & Algerian War)

851-0304-00L

Science Fiction

W 3 credits 2S  A. Kilcher, S. Lohmann

Abstract

Science fiction in general can be seen as fundamentally concerned with the forms and functions of knowledge and (sometimes scientific) understanding, but the genre of science fiction is unique in that it literalises this approach in a far-reaching fashion as the future of science and technology. We will explore knowledge, and the "science of literature" through a diverse range of science fiction texts.

Objective

- Concept and history of science fiction
- Theory of science fiction and related forms (e.g. utopia, fantasy)
- Contexts of the history of knowledge and technology in the 19th and 20th centuries.
- Potential of science fiction to criticise technology and society
This course introduces students to the various forms and functions of knowledge and science in literature, particularly within the realm of science fiction, the genre that most directly epitomizes this fundamental connection within literary texts. In analysing how it shifts our understanding of ourselves and of supposedly inalterable facts about the reality we inhabit, we will examine how science fiction demonstrates that fiction is neither fundamentally in conflict with scientific knowledge, as previously supposed, nor a mere vehicle for its celebration, as still commonly presumed of science fiction. Instead, the genre, with its radical investigations into other forms of being, fearing and hoping, plays a crucial role in the social formation, order and negotiation of knowledge. As such, science fiction also represents a vital thought experiment regarding the “science of fiction”, i.e. the development of a knowledge of literature and the many fascinating ways in which it helps us to know our own world better, in turn.

In this course, we will take a systematic and theory-based approach to a deeper understanding of science fiction, particularly concerning its historical background, unique aesthetic/narrative tools, and relationship with the critical and technocultural contexts that shape it. Employing contemporary theoretical approaches, we will discuss a variety of themes within primary texts alongside diverse critical sources, all of which ultimately relate to knowledge and knowability. Particular areas of focus may include: other worlds and alien existences; altered temporality and alternate history; utopia and dystopia; climate fiction and the Anthropocene; trans-, posthumanist and cyborg identities; robots and AI; and alternative futurisms. Moreover, the course will thereby also engage with the fundamental (and at times overlooked) role of order and presentation of knowledge, i.e. its aesthetic and narrative forms, within science and literature.

851-0297-00L Manipulation in Literature and Cultural History W 3 credits 2V S. S. Leuenberger

Abstract

This lecture focuses on the manipulation and control of individuals and the masses. The power of manipulation is based on subtle use of persuasive linguistic elements and knowledge of the desires and fears of the intended audience. In addition to a theoretical overview, the lecture concentrates on the literary and discursive texts that dispute the control of protagonists.

Objective

Students will learn about manipulation as a linguistic and narrative phenomenon steeped in myth and classical rhetoric. Against the backdrop of cultural-historical developments, particularly with regard to major changes in media technology, we will examine how the reach of manipulation was extended from the individual to the masses. Students will be able to refine their critical discourse analysis skills and interdisciplinary abilities by studying texts from literature, politics, sociology, philosophy and psychoanalysis which reflect this shift in emphasis.

Content

Since the dawn of time mankind has tried to exert influence over others through the utilisation of certain techniques: initially for self-preservation – for example the interpretation of Sigmund Freud in Totem und Tabu. Later, desire became the driving force – centre stage: the desire for pleasure, power and control. Manipulation manifests itself in the form of characters and words, it is an authentically linguistic occurrence: classical antiquity, with the rhetoric, develops a system of verbal power of persuasion and, already then, questions were being raised in literary and discursive texts about how people could, or even should, manipulate. The exertion of influence and its impact will be clearly described, propagated, commented upon, criticised and ironised.

In contrast to oppressive overpowering, the power of manipulation (in Latin, manus hand, plere fill) is on the one hand, based on the subtle use of persuasive linguistic elements – it is always a (literary) discourse, too – and on the other, on knowing precisely what the fantasies, desires and fears of the manipulated are. The discourse of manipulation has its beginnings in the age of sophists and their belief in an omnipotence of language and rhetoric. It underwent further transformation under political and psychological signs in the early modern period through Giordano Bruno and Niccolò Machiavelli and culminated in the 20th century in a critique of the deception strategies of the “culture industry” (T.W Adorno) and “psychotechnology” (B. Stiegler) in global capitalism. Nowadays social media is the “radicalisation machine” (J. Ebner) that present new challenges for society. Written in the 19th century, the Protocols of the Elders of Zion already gave indications of how present-day conspiracy theorists would manipulate their audience, and its impact can still be felt today. Since manipulation is a linguistic, narrative and also literary phenomenon, the central theme of the lecture is how in literature itself this often politically controversial and manipulative behaviour is picked up and reflected through poetry: such as in Tristan von Gottfried von Strassburg, Goethe’s Wilhelm Meister, Friedrich Schiller’s Die Verschwörung der Fiesco zu Genau or Heinrich von Kleist’s Der zerbrochene Krug, the works of Edgar Allan Poe and Thomas Mann (Mario und der Zauberer) and, most recently in Eckhart Nickel’s novel, Hysteria.

Competencies

- Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies

- Method-specific Competencies
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving

- Social Competencies
  - Communication
  - Cooperation and Teamwork
  - Sensitivity to Diversity
  - Negotiation

- Personal Competencies
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

851-0226-00L Postcolonial Readings W 3 credits 2V I. Scego

Abstract

The history of colonialism in the modern age begins with Christopher Columbus who, as Todorov has well told us, did not "discover" anything, but crossed the Ocean in search of riches, bringing with him a baggage of violence, stereotypes and violent conquest of resources and bodies. And from here, from that 1492, the story became one of blood and struggle.

Objective

The course will be based on case studies, linked to national realities (Brazil, Senegal, Eritrea, Great Britain, Italy, Peru, Somalia, etc.) and to physical places (the front, the museum, the field, the street, the body), to see how in different contexts, despite the peculiarity of the context, the dilemmas that are attempted to be answered are in fact very similar.
**Content**

WE are here, because YOU have been there, have you ever heard that phrase? In a university lecture hall? In an anti-racist demonstration? In a play? In a discussion on the bus? The YOU represents Europe and in a broader sense the West, WE the peoples who suffered colonization by the very West that portrayed itself as a beacon of civilization. The history of colonialism in the modern age begins with Christopher Columbus who, as Todrov has well told us, did not "discover" anything, but crossed the Ocean in search of riches, bringing with him a baggage of violence, stereotypes and violent conquest of bodies. And from here, from that 1492, the story became one of blood and struggle. It is a story that has covered a time span from precisely 1492 to the present, ranging from human trafficking to the extractive, and accumulation, policies of our contemporary times. The consequences of all this violence are sadly still visible on the body of the world, open wounds that bleed. Wounds in which lurk prejudice, systemic racism and murder.

To examine these consequences, to understand how contemporary societies in the global north and south, are still torn apart by this history that never seems to pass; we will rely on literature, on "postcolonial" texts that will show us the complexity of what exists. The course will be based on case studies, linked to national realities (Brazil, Senegal, Eritrea, Great Britain, Italy, Peru, Somalia, etc.) and to physical places (the front, the museum, the field, the street, the body), to see how in different contexts, despite the peculiarity of the context, the dilemmas that are attempted to be answered are in fact very similar.

The lecture will examine the body of the colonized/migrant as a field of battle and resistance in real and metaphorical wars. Place where the stereotype is overthrown through a will for personal agency. Colonial space and the consequent postcolonial space is a hierarchical space where instruments of violence and oppression do not provide for the agency of the colonized subject or in the contemporary case of the migrant subject placed by power structures in a space of subalternity. But subjects are born free and though in a confined space seek their own path to freedom and awareness. In ways that are perhaps paradoxical in our eyes, but certainly effective in a very limited space granted. In the three lectures, through literary texts, three case studies related to as many books will be examined to understand precisely this tension between enclosed space and the search for freedom. A tension between (unjust) rules imposed, malevolent looks imposed and one's own body, one's own moral integrity.

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**Economics**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>851-0626-01L</td>
<td>International Development Cooperation</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>I. Günther</td>
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<td>851-0609-06L</td>
<td>Governing the Energy Transition</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>T. Schmidt, L. P. Fesenfeld</td>
</tr>
<tr>
<td>363-0387-00L</td>
<td>Corporate Sustainability</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>V. Hoffmann, C. Bening-Bach, B. Girol, L. Mihé</td>
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</table>
The course includes both lectures and exercises alternately. The goal is to understand the opportunity of user innovation for management assessed fostered.

Principles of Macroeconomics

Concepts and Theories fostered
Analytical Competencies fostered
Decision-making assessed fostered
Problem-solving assessed fostered

Communication fostered
Cooperation and Teamwork fostered
Negotiation fostered

Creative Thinking fostered
Critical Thinking assessed fostered
Self-awareness and Self-reflection fostered

363-0565-00L Principles of Macroeconomics

W 3 credits 2V J.-E. Sturm

Abstract
This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

Objective
This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to everyday economic problems.

Content
This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

Lecture notes
The course Moodle page contains announcements, course information and lecture slides.

Literature

This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filippini).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.

431-0555-00L Open- and User Innovation

W 3 credits 2G S. Häflliger, S. Spaeth

Not for students belonging to D-MTEC!

Abstract
The course introduces the students to the long-standing tradition of actively involving users of technology and other knowledge-intensive products in the development and production process, and through own cases they develop an entrepreneurial understanding of product development under distributed, user-centered, or open innovation strategies.

Objective
The students actively participate in discussions during the lectures and contribute presentations of case studies during the exercises. The combination should allow to compare theory with practical cases from various industries.

Content
The course presents and builds upon recent research and challenges the students to devise innovation strategies that take into account the availability of user expertise, free and public knowledge, and the interaction with communities that span beyond one organization.

Performance assessment will be: a written group essay based on the open/user innovation case that participants will research and present during the block seminar (including the slides). Each group will have to hand in a 15-20 page essay, details on the required format and the content will be distributed during the course. Active class participation is required.

Lecture notes
The slides of the lectures are made available and updated continuously through Moodle.

Literature
Relevant literature for the course includes slides and reading assignments. Papers will be made available through a corresponding Moodle group.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2557 of 2653
The processes of change, overuse or destruction of the natural environment through humans have historically placed high demands on environmental policy examples. To address these demands, the course in Environmental Policy of Switzerland introduces the basics of public policy analysis and the specific characteristics of Swiss environmental policy. It covers environmental policy examples from a political science perspective both theoretically as well as by means of current Swiss environmental policy examples.

Beyond acquiring basic knowledge about public policy analysis, this course teaches students how to analytically address current and concrete questions of environmental policy. Through exercises, the students learn about political science concepts and frameworks as well as real-life political decision-making processes. The well-grounded examination of complex political situations is an important precondition for the entry into the (environmental policy) workforce or a future research career.

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In this seminar we will explore the issues of inequality and injustice. In doing so, we will explore the following questions: What is meant by inequality and injustice? Under what circumstances are inequalities unjust? Have inequalities and injustices increased or decreased over the last 50 years? What are the causes of increasing or decreasing inequality? What do these inequalities and injustices mean for our society? And what public and private measures are needed for more inclusive societies?

- Concepts of inequality and injustice
- Development of inequality over the last 50 years based on different dimensions of inequality: income, wealth, education, health, CO2 emissions, political participation.
- Discrimination of women, people with physical disabilities, people of the "Global South".
- Causes of inequality: globalization, technological progress, political systems and institutions, economic system, social discrimination, stereotypes and norms.
- Consequences of inequality: justice, dignity, inefficiency
- Towards more inclusive societies: the role of policies, civil society, social movements and individual behavior.

The seminar is based on readings of economic and philosophical texts and is complemented by short presentations and discussions with scholars of philosophy and economics. In some cases, practitioners will also be invited to the seminar. Students will apply the concepts, theories and knowledge covered in the course to practical issues related to inequality and inequality.

851-0682-00L  Inequality and Injustice: Economic and Philosophical Perspectives  W  3 credits  2S  I. Günther, N. Mazouz

Does not take place this semester.

Abstract  Globalization and technological progress in recent decades have on the one hand reduced inequality and led to new forms of inequality on the other hand. The question is whether these new forms of inequality lead to more inequality. This course provides an overview of the current philosophical and economic discourse on inequality and injustice.

Objective  Using philosophical and economic texts and discussions, students develop an understanding of the concepts, developments, causes, and consequences of inequality. Students will acquire the ability to participate in an informed discourse on the issues of inequality and injustice and to critically reflect on their actions and position in the world.

Content  In this seminar we will explore the issues of inequality and injustice. In doing so, we will explore the following questions: What is meant by inequality and injustice? Under what circumstances are inequalities unjust? Have inequalities and injustices increased or decreased over the last 50 years? What are the causes of increasing or decreasing inequality? What do these inequalities and injustices mean for our society? And what public and private measures are needed for more inclusive societies?

851-0685-00L  Data and Society  W  3 credits  2V  M. Leese

Abstract  This lecture series explores the multifaceted role of data in shaping contemporary society, governance, and individual lives. The course equips students with a critical understanding of how data is managed, and preserved, and its implications for societal norms and individual rights.

Objective  At the end of the term, students will be able to:

- reflect concepts and theories that capture the performativity of data
- reflect concepts and theories that capture the socio-technical nature of data
- assess the implications of data practices for social and political ordering
- identify key actors, sites, and domain contexts of data practices
fostered
3 credits
This semester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their
WE are here, because YOU have been there, have you ever heard that phrase? In a university lecture hall? In an anti-racist
2V
Subject-specific Competencies
2V
Postcolonial Readings
Type
Analytical Competencies
WE are here, because YOU have been there, have you ever heard that phrase? In a university lecture hall? In an anti-racist
376-1661-00L
Environmental Ethics (University of Zurich)
Objective
Abstract
Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/de/studies/application/deadline s.html
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces
851-0226-00L
Postcolonial Readings
Objective
Abstract
The history of colonialism in the modern age begins with Christopher Columbus who, as Todorov has well told us, did not "discover"
anything, but crossed the Ocean in search of riches, bringing with him a baggage of violence, stereotypes and violent conquest of
resources and bodies. And from here, from that 1492, the story became one of blood and struggle.
Content
WE are here, because YOU have been there, have you ever heard that phrase? In a university lecture hall? In an anti-racist
demonstration? In a play? In a discussion on the bus? The YOU represents Europe and in a broader sense the West, the WE the peoples
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human trafficking to the extractive, and accumulation, policies of our contemporary times. The consequences of all this violence are sadly
still visible on the body of the world, open wounds that bleed. Wounds in which lurk prejudice, systemic racism and murder.
To examine these consequences, to understand how contemporary societies in the global north and south, are still torn apart by this history
that never seems to pass; we will rely on literature, on "postcolonial" texts that will show us the complexity of what exists. The course will
be based on case studies, linked to national realities (Brazil, Senegal, Eritrea, Great Britain, Italy, Peru, Somalia, etc.) and to physical
places (the front, the museum, the field, the street, the body), to see how in different contexts, despite the peculiarity of the context, the
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The lecture will examine the body of the colonized/migrant as a field of battle and resistance in real and metaphorical wars. Place where
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the migrant subject placed by power structures in a space of subalternity. But subjects are born free and though in a confined space seek
their own path to freedom and awareness. In ways that are perhaps paradoxical in our eyes, but certainly effective in a very limited space
granted. In the three lectures, through literary texts, three case studies related to as many books will be examined to understand precisely
this tension between enclosed space and the search for freedom. A tension between (unjust) rules imposed, malevolent looks imposed and
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851-0226-00L
Postcolonial Readings
W 3 credits 2V I. Scego
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Philosophy

Number
Title
Type
ECTS
Hours
Lecturers

701-0703-00L
Environmental Ethics (University of Zurich)
W 3 credits 2V
University lecturers

Abstract
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
UZH Module Code: 07SMMEE266
Please register at:
https://www.uzh.ch/cmsssl/de/studies/application/chmobilit yin.html
after you received your logon information you can enrol to courses at:
https://studentservices.uzh.ch/uzh/application/#/Logon
Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html

Objective
On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general
and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in
environmental ethics, which you have applied and discussed in smaller exercises.

376-1661-00L
Ethics of Life Sciences and Biotechnology
W 3 credits 2V A. Blasimme, E. Vayena

Abstract
This semester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their
technological application. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in
the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences

Objective
This course is tailored to students who want to become familiar with the analysis of ethical issues in all the different domains of life
sciences and biotechnology. The course aims at equipping students with the necessary knowledge and analytic skills to understand,
discuss and address the ethical aspects of science and technology in the domain of human health. The specific learning objectives of this
course are:
A. Identify ethical issues in life sciences and biotechnology.
B. Analyze and critically discuss ethical issues in life sciences and biotechnology.
C. Become aware of relevant legal and public policy frameworks.
D. Distinguish different ethical approaches and argumentation strategies in applied ethics.
E. Recognize how ethical issues relate to different accounts of technology and innovation.
F. Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
G. Autonomously anticipate ethical issues.
H. Propose and communicate solutions to ethical challenges and dilemmas.

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The course starts off with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain of applied ethics. The students will also be introduced to current theoretical accounts of technology and will start to appreciate the relevance of ethics especially with respect to new and emerging technologies. Usable analytic tools will also be provided, thus enabling the students to engage with the discipline in a practical way from the very onset of the semester.

The course will continue with thematic sessions covering a broad variety of topics all of which are relevant to the different study tracks offered by the department. In particular, the course will cover the following domains: digital health technologies and medical AI; food, nutrition and healthy longevity; biomedical engineering; genetics; neuroscience and Neurotechnologies; medical robotics; disability and rehabilitation; environmental ethics. The course will also include sessions on cross-cutting ethically relevant aspects of health sciences and technologies, namely: access to innovation, translational research, and the relation between science and public policy. All the topics of the course will be illustrated and interactively discussed through many case studies, offering the students the opportunity to prepare and present them, and to use them in individual as well as group exercises. Throughout the course, the students will have multiple opportunities to experiment with ethical argumentation and to practice their evolving skills.

### 851-0039-00L Plural Perspectives on Rationality

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### 851-0251-00L Psychedelic Science: Psychology Pharmacology Physiology Psychotherapy Philosophy Religion Politics

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### Objective

- **Abstract**

Rationality has been treated as a “universal” character of human beings. But such understandings, though dominant, also came under androcentric and Eurocentric critiques. They point out that exclusion of women and people of color is not aberrant bad scientific practices, but rather constituent of the principle modern science based on. This seminar offers plural perspectives on rationality.

- **Objective**

Students will be introduced to theories of rationality from different philosophical traditions. Their ways of thinking shall be enriched and their sensibilities towards diversity improved. Students will participate in discussions, gain and sharpen their ability to understand complicated texts and identify arguments.

- **Content**

Understood as a distinctive human attribute, rationality has been treated as a “universal” character of human beings. But the course of philosophy has witnessed how dominant understandings of rationality came under androcentric and Eurocentric critique. Such reflections argue that exclusion of women and people of color is constituent of the principle modern science is based on rather than aberrant bad scientific practices.

What counts as reasonable? What is rational? These questions seem quotidian. We deal with them every day. Telling right from wrong, true from false is considered a basic ability of reasoning. For example, clarity and consistency are what we almost always strive for, while contradictions and ambiguities are what we try our best to avoid. Such tendency, which is to be found not only in everyday life but also in science of different kinds, seems to suggest that there is nothing valuable, nothing worth learning from ways of reasoning that do not share these standards – or even deny that they can count as rationality at all. Nevertheless, when taking into consideration the androcentric and Eurocentric critiques modernity has been receiving so far, it is questionable whether the standard of rationality can really (or justifiably) be so impoverished. How can we think about rationality otherwise? Can we learn anything valuable from, for example, contradictions and ambiguities? Is it so, how to think about these unconventional ways of reasoning? In this seminar we will read and discuss theories of rationality from diverse philosophical traditions.

- **Competencies**

  - **Method-specific Competencies**
    - Analytical Competencies | assessed |
    - Communication | assessed |

  - **Social Competencies**
    - Cooperation and Teamwork | assessed |
    - Sensitivity to Diversity | assessed |

  - **Personal Competencies**
    - Creative Thinking | assessed |
    - Critical Thinking | assessed |
Psychedelic science is a multidisciplinary field of study that involves scholars of the mind and scholars of the natural sciences. In this course, psychedelic science is presented mainly from the point of view of psychology, but will additionally also be considered from the viewpoints of pharmacology, physiology, psychotherapy, philosophy, religion, and politics. All contributions will also be reflected on from the viewpoint of the humanities and psychology. The psychedelic studies treated in this course that involve humans focus on controlled and ethically approved studies where these substances are administered to medically screened, prepared, and supported participants. Private/illicit use of psychedelics is not a topic of this course.

A psychedelic experience can be characterized as a temporary nonordinary state of consciousness (NSC) that is occasioned by classic (serotonergic) psychedelics such as psilocybin, mescaline, N,N-dimethyltryptamine (DMT), and lysergic acid diethylamide (LSD). Psychologically, the psychedelic experience can manifest at the perceptual, cognitive, affective, volitional, and somesthetic level. The nonordinary perceptual spectrum ranges from visions (e.g., patterns or beings) to the subjective experience of an all-encompassing oneness, which also transcends the distinction between the perceiver and the perceived. The nonordinary cognitive spectrum ranges from no longer functionable thinking to very clear thinking, the nonordinary affective spectrum, for example, from deepest sadness to highest bliss, the nonordinary volitional spectrum from the feeling of being able to somewhat influence what is happening to the feeling of having no longer a will of one’s own, and the nonordinary somesthetic spectrum, for example, from feelings of bodily heaviness/compression to feelings of bodily lightness/levitation.

Heuristically, as one possibility, a psychological typology of the psychedelic experience can be characterized to fall into three main types of religious-like experiences (which may be interpreted religiously/spiritually by the individuals having them, but may also be interpreted materialistically or agnostically), autobiographical experiences, and tripartite-mind (cognitionaffectconation) miscellaneous experiences. Investigating the psychedelic experience is a worthwhile endeavor as, for instance, certain aspects of this experience have been associated with increased subjective well-being both for healthy individuals as well as for patients – for example, persisting positive effects on attitudes, mood, and behavior in healthy individuals and sustained symptom reduction in individuals suffering from depression, anxiety, and addiction.

Psychedelic science is overall a large multidisciplinary effort that requires collaboration of scholars of the mind and scholars of the natural sciences to advance the scientific knowledge of it. In this spirit, this course will – besides the main lecturer (PD Dr. phil. Kurt Stocker, a psychologist) – also involve further psychedelic-scientific scholars giving individual lectures in their respective field of expertise psychology (PD Dr. phil. Katrin Peller, University of Zurich & Yale University), pharmacology (Dr. phil. nat. Dino Luehli, University Hospital Basel; Dr. phil. nat. Deborah Rudin, University Hospital Basel; Prof. Dr. phil. Linda Simmler, University of Basel), physiology (PD Dr. sc. nat. Felix Scholkmann, University of Zurich & University of Bern), psychiatry/psychotherapy (Prof. Dr. med. Gregor Hasler, University of Fribourg; Dr. med. Dr. sc. ETH Milan Scheidegger, University of Zurich), and philosophy (Dr. Peter Sjöstedt-Hughes, University of Exeter). Overall, this course will provide an informative overview of the research foundations that have made psychedelic science what it is today, and will also provide an identification of the research frontiers that must be addressed to expand the psychedelic science of tomorrow.

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**851-0622-00L**

**Inequality and Injustice: Economic and Philosophical Perspectives**

*W* 3 credits 2S I. Günther, N. Mazouz

**Abstract**

Does not take place this semester.

**Objective**

Using philosophical and economic texts and discussions, students develop an understanding of the concepts, developments, causes, and consequences of inequality. Students will acquire the ability to participate in an informed discourse on the issues of inequality and injustice and to critically reflect on their actions and position in the world.

**Content**

In this seminar we will explore the issues of inequality and injustice. In doing so, we will explore the following questions: What is meant by inequality and injustice? Under what circumstances are inequalities unjust? Have inequalities and injustices increased or decreased over the last 50 years? What are the causes of increasing or decreasing inequality? What do these inequalities and injustices mean for our society? And what public and private measures are needed for more inclusive societies?

- Concepts of inequality and injustice
- Development of inequality over the last 50 years based on different dimensions of inequality: income, wealth, education, health, CO2 emissions, political participation
- Discrimination of women, people with physical disabilities, people of the “Global South”.
- Causes of inequality: globalization, technological progress, political systems and institutions, economic system, social discrimination, stereotypes and norms.
- Consequences of inequality: justice, dignity, inefficiency
- Towards more inclusive societies: the role of policies, civil society, social movements and individual behavior.

The seminar is based on readings of economic and philosophical texts and is complemented by short presentations and discussions with scholars of philosophy and economics. In some cases, practitioners will also be invited to the seminar. Students will apply the concepts, theories and knowledge covered in the course to practical issues related to inequality and injustice.

**851-0685-00L**

**Data and Society**

*W* 3 credits 2V M. Leese

**Abstract**

This lecture series explores the multifaceted role of data in shaping contemporary society, governance, and individual lives. The course equips students with a critical understanding of how data is made, managed, and preserved, and its implications for societal norms and individual rights.

**Objective**

At the end of the term, students will be able to:
- reflect concepts and theories that capture the performativity of data
- reflect concepts and theories that capture the socio-technical nature of data
- assess the implications of data practices for social and political ordering
- identify key actors, sites, and domain contexts of data practices

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**851-0038-00L**

**Philosophical Ethics of Life and Death**

*W* 3 credits 2G N. Mazouz
Abstract
This course discusses ethical issues relating to life and death, e.g. reproductive technology, euthanasia, organ transplantation, genetic engineering, animal and nature conservation, human enhancement, animal welfare, nature conservation, biodiversity and our relation to nature more generally.

Objective
Students will get an overview of different historical and contemporary approaches in bioethics. They are enabled to further developing their abilities to understand complex theories, to critically reflect on them and to put them up for discussion.

Content
Bioethics is a very broad field, encompassing ethical issues relating to life and death, e.g. reproductive technology, euthanasia, organ transplantation, genetic engineering, human enhancement, animal welfare, biodiversity and our relation to nature more generally. Bioethics is addressed in various contexts and disciplines, in politics, in law, in religious contexts, in the social sciences, religious studies, medicine and the biosciences. The focus in this course is on the fundamental debates in ethics as a philosophical discipline. In addition, topics are selected for discussion depending on the students' interests.

Literature

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851-0037-00L Ethics of Building

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851-0186-00L Feminist and New Materialist Philosophies of Science and Technology

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851-0077-00L Philosophy of War

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851-0407-00L The Philosophy of Physics: Complex Systems

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Objective

Participants should acquire knowledge about how to characterize complex systems adequately, to be aware of the problems involved in their prediction and control, and to apply their knowledge in an interdisciplinary context.

Content

Basic concepts for the treatment of complex systems are state spaces, observables, partitions, dynamics, stability, and information. They are introduced in general and concretized by means of examples. Furthermore, various definitions of complexity are introduced, which are linked to concepts such as emergence, meaning, non-commutative observables, and scaling laws. Finally, different types of networks are discussed, as well as learning processes and other types of dynamics in such networks.

Literature

Wird am ersten Termin vorgestellt und dient als begleitendes Material.

Prerequisites / notice

Elementare Kenntnisse der formalen Darstellung von Systemen, sowie grundlegendes Interesse an deren konzeptuelem Verstaendniss.

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Analytical Competencies assessed

Critical Thinking assessed

851-0125-65L

A Sampler of Histories and Philosophies of Mathematics

 Particularly suitable for students D-CHAB, D-INFK, D-ITET, D-MATH, D-PHYS

Abstract

This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

Objective

The course aims are:
1. To introduce students to the historicity of mathematics
2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
3. To develop critical reflection concerning the nature of mathematical objects
4. To introduce various theoretical approaches to the philosophy and history of mathematics
5. To open the students' horizons to the plurality of mathematical cultures and practices

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Analytical Competencies assessed

Critical Thinking assessed

851-0453-00L

Artificial Intelligence and Human Values

W 3 credits 2G M. Boening-Liptzin, K. Wodajo

Abstract

This course introduces students to the ethical, political and legal debates and transformations in relation to Artificial Intelligence and provides students with concepts and methods from the constructivist and interpretive social sciences to work towards responsible and democratic human-technology futures.

Objective

The main objectives of the course are to enable students to 1) identify the ways in which human values and developments of AI technologies are entangled, 2) articulate what is significant about contemporary transformations in AI and society, and 3) participate and shape the relationship between human values and AI as citizens and professionals.

Content

The growing presence of AI tools for public use, for public administration, inside corporations and in scientific research raises many questions about the ethical, political, legal consequences of these technologies. This course is built around multiple sites of encounter among human values and AI, including bodies, persons, cities, labs, law, and environment. In each site, we inquire about what and whose values are being prioritized and with what consequences. The course also investigates existing best-practices around how to "align" human values with AI (e.g. human-centric design, alignment, reproducibility, transparency, explainability) and introduces students to regimes of ethics and governance of AI being proposed in jurisdictions around the world. Students learn to unpack the values and assumptions in existing techniques and frameworks for the design and governance of AI and to engage constructively with diverse stakeholders to shape the human-technology future towards aims that are reflexive, responsible, and democratic.

851-0455-00L

Science, Trust and Politics

W 3 credits 2S G. Dorthé

Abstract

The seminar aims to inspire a nuanced understanding of the dynamics of expertise in society. Cross-fertilizing literature from science and technology studies (STS) and from activists' movements, it focuses on contemporary controversies around emerging technologies and climate policy, where trust in science is said to be undermined (e.g. climate skepticism or anti-vaccine movements).

Objective

1) Introduce to the role and functions of expertise in democratic societies. 2) Familiarize with assumptions about science and society embedded in contemporary controversies. 3) Inspire critical perspectives on (dis)trust in science through activists' movements on contested environmental and technological issues. 4) Develop a creative position on the relations between science, trust and politics.

Content

Engineers and scientists often pursue their studies and research in the hope that their knowledge can contribute to make a better world, inform democratic deliberation and help public understanding of complex issues. Yet this special status of science and technology is being increasingly contested by marginalized publics, lobbies, exposed populations, and by members of the scientific communities themselves. Climate skepticism or vaccine hesitancy are some of the most vivid examples of this confusing situation. In this seminar, students will learn to reflect on expertise as a form of scientific engagement in the messiness of democratic deliberation and public life, beyond the noble but outdated ideal of "speaking truth to power".

The exercise of expertise is stumbling upon several conundrums. Which knowledge is relevant in which situation? How to make sure that some crucial perspectives are not left in the shadows? How to identify representative experts and make sure that they speak on behalf of a structured community? Whose voices are being silenced? On the other side of the spectrum, the public is often said to lack proper understanding of science and thus in need of being educated or disciplined. Or it is suspected of being manipulated by lobbies or foreign hostile powers, or of being too attached to its own privileges and unwilling to act in favor of the common good. Whose agency is being acknowledged in sociotechnical controversies and whose agency is being denied and why? The seminar will provide a deep understanding of these perspectives, by putting them in a broader historical and epistemological context. Students will thus learn to critically assess their strengths as well as their blind spots.

Whereas opposing technological developments (anti 5G or anti-vaccine activists) or pushing to act accordingly to science (pro climate movements such as Extinction Rebellion or Scientist Rebellion), activists' movements take up for a rich field of investigation on the dynamics of expertise and of how various publics can make sense of scientific knowledge. Cross-fertilizing activist's texts and experiences with literature in science and technology studies and anthropology, this class will be organized as a structured conversation and a collective mapping of actors and key concepts of sociotechnical controversies. Over the course of the semester, students will learn not only to navigate some of the most heated contemporary debates, but also to articulate their own position on an issue of their choice.
After successful completion of the course, students will be able to discuss, identify and position themselves with regard to issues of ethics assessed

Critical Thinking

Students will gain an overview of the current ethical debates surrounding the legitimacy of homicide-rescue-cases in specific types of assessed

Subject-specific Competencies

Analytical Competencies assessed

Communication fostered

Cooperation and Teamwork fostered

Sensitivity to Diversity fostered

Negotiation fostered

Adaptability and Flexibility fostered

Creative Thinking fostered

Critical Thinking assessed

Self-awareness and Self-reflection assessed

The Ethics of Climate Change

W 3 credits 2S F. Altner

Objective

After successful completion of the course, students will be able to discuss, identify and position themselves with regard to issues of ethics and justice that arise in relation to anthropocentric climate change.

Content

Man-made climate change confronts us with difficult ethical problems. Our use of fossil fuels and the associated warming of the climate increases the likelihood of extreme climate events such as droughts and floods and often jeopardizes the livelihoods of people in the poorest countries that are not among the main emitters. What characterizes climate change as an ethical problem is that 1) the causal responsibility for it lies neither with any one individual nor with any one individual state, 2) that most of the consequences, such as rising sea levels, will be borne by future generations or people other than the polluters, and that 3) solutions to mitigate warming require fundamental societal changes that raise questions of activism and personal responsibility.

The course addresses these questions by critically reviewing utilitarian approaches, exemplified by John Broome's book "Climate Matters: Ethics in a warming world" (e.g. the use of cost-benefit analyses to assess the ethical consequences of global warming) and contrasting them with virtue ethics and Kantian approaches. Specifically the course examines the ethical implications of our individual contributions to global warming, questions of justice and political responsibility borne by citizens, states and companies. Proposals that combine utilitarian theories with economic models, such as a market for carbon certificates and carbon off-setting, will form the starting point in the seminar in order to reflect on and critically examine one's own ethical role and the ethical foundations of social measures.

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Analytical Competencies assessed

Communication fostered

Cooperation and Teamwork fostered

Sensitivity to Diversity fostered

Negotiation fostered

Adaptability and Flexibility fostered

Creative Thinking fostered

Critical Thinking assessed

Self-awareness and Self-reflection assessed

Can it Be Permissible to Kill a Few in Order to Save Many?

W 3 credits 2S N. Mazouz

Objective

Students will gain an overview of the current ethical debates surrounding the legitimacy of homicide-rescue-cases in specific types of situations. They will be enabled to interpret complex texts, identify the argumentation, to reflect it critically and to put it up for discussion.

Content

Killing innocents is generally thought to be morally impermissible – or so it seems from an intuitive point of view. However, there are situations where people can only be saved if less others are killed, for example in some traffic cases, in some cases in natural disasters, medical emergencies, terrorist attacks or humanitarian interventions. In some of these situations our intuitions stay clear and disaproving: it is not permissible to kill, even in order to save many lives, for example, to take the vital organs of one patient in order to save many more other patients. In other scenarios, the intuitions are less clear or even revert for most of us, like in the famous trolley-bystander case, in situations where people can only be saved if less others are killed, for example in some traffic cases, in some cases in natural disasters, medical emergencies, terrorist attacks or humanitarian interventions. In some of these situations our intuitions stay clear and disaproving: it is not permissible to kill, even in order to save many lives, for example, to take the vital organs of one patient in order to save many more other patients. In other scenarios, the intuitions are less clear or even revert for most of us, like in the famous trolley-bystander case, in which a bystander can divert an out-of-control trolley heading towards five to a track where one person is trapped. How are these moral intuitions to be justified, if they are? In this seminar the relevant literature on moral justifications in such trolley cases will be reviewed as well as on methodological problems pertaining to the role of intuitions in moral justifications. Neupyschological research on such cases as well as critique of the methods and normative presuppositions used in that research will be debated. Finally, attempts to apply such moral reasoning on allegedly analogous cases arising in autonomous robots will be discussed.

Understanding in Science and Mathematics: A

W 2 credits 2S

Objective

The main objective of this seminar is to gain an in-depth understanding of the recent literature on understanding in the philosophy of science, the philosophy of mathematics, and epistemology. Another practical objective is to increase your skills in giving clear and engaging oral presentations.
Understanding is a central goal of science and mathematics: scientists seek to understand various phenomena in the natural world, while mathematicians aim to increase our understanding of the mathematical world. But what exactly is the nature of understanding in science and mathematics? This issue has been largely neglected in twentieth century philosophy of science, philosophy of mathematics, and epistemology. Yet, in the past twenty years, there has been a regain of philosophical interest into the notion of understanding, leading to a flourishing literature. The aim of this seminar is to gain an in-depth understanding of these recent philosophical developments.

To this end, we will read a number of key philosophical contributions on understanding in philosophy of science, philosophy of mathematics, and epistemology. Along the way, we will address general issues on understanding such as: What is the relation between understanding and knowing? Understanding necessarily requires explaining how understanding is transmitted? What exactly is the value of understanding? We will also look into specific case studies of scientific and mathematical understanding.

Each session will be decomposed into three blocks. In blocks 1 and 2, we will have a short presentation (~15 minutes) of a contribution in the philosophy of understanding followed by a discussion. Block 3 will be methodological and will be concerned with how to give good oral presentations, an essential skill in academia. We will use this block to debrief on the presentations of the day and see how they could be improved. We will also discuss resources on best practices in oral communication.

### Political Science

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<td>D. Möckli Weder</td>
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<tr>
<td>853-0047-01L</td>
<td>World Politics Since 1945: The History of International</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>A. Wenger</td>
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**Abstract**

This course analyzes the foundations and challenges of Swiss foreign policy. After reviewing the history of foreign policy conceptions since the early 20th century, we will discuss the determining factors of Swiss foreign policy and examine, together with guest speakers from the foreign ministry, current international developments and respective foreign policy challenges.

**Objective**

Students should acquire a sound understanding of Swiss foreign policy and the relevant academic and political debates associated with it. Concerning the history of the international Neuordnungen the history of Aussenpolitik in Zentrum. Auf dieser Basis analyseren wir die derzeitigen geopolitischen Entwicklungen der Schweiz und nutzen dabei die internationalen Auswirkungen der Schweiz auf die Weltgeopolitik.

**Content**

The lecture will examine the body of the colonized/migrant as a field of battle and resistance in real and metaphorical wars. Place where the stereotypes are overthrown through a will for personal agency. Colonial space and the consequent postcolonial space is a hierarchical space where instruments of violence and oppression do not provide for the agency of the colonized subject or in the contemporary case of the migrant subject placed by power structures in a space of subalternity. But subjects are born free and though in a confined space seek their own path to freedom and awareness. In ways that are perhaps paradoxical in our eyes, but certainly effective in a very limited space granted. In the three lectures, through literary texts, three case studies related to as many books will be examined to understand precisely this tension between enclosed space and the search for freedom. A tension between (unjust) rules imposed, malevolent looks imposed and one's own body, one's own moral integrity.
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Social Competencies
Communication fostered
Leadership and Responsibility fostered
Sensitivity to Diversity fostered
Negotiation assessed
Personal Competencies
Creative Thinking fostered
Critical Thinking fostered

853-0015-01L Conflict Research I: Political Violence  W 3 credits 2V A. Juon
Abstract
Introduction to research on political violence in domestic and international politics. This course covers the causes and solutions to different types of political violence including interstate wars, civil wars, terrorism or social protests.

Objective
Knowledge on different types of political violence and their causes.

Content
This course offers an introduction to research on the causes and solutions to political violence in domestic and international politics. First, we discuss the definitions and concepts used in conflict research, the data and methods commonly applied and their historical development. Second, we focus on interstate wars und examine in this context state formation, nationalism and democracy. The third part of the course focuses on different types of political violence, including civil war, terrorism or social protests.

Prerequisites / notice
The course «Conflict Research II» in the following semester further examines civil wars.

853-0302-01L European Integration (Seminar without Tutorial)  W 2 credits 2S C. Freudlsperger
Abstract
The lecture course covers the theory, development, and core policy fields of European integration as well as structures and processes of the EU as a decision- and policy-making system.

Objective
The seminar is designed to help students understand the European Union as a particular kind of political system that differs both from the nation-state and from other international organizations. It imparts basic knowledge on the development, institutions, procedures, and policies of the EU and provides an introduction to major approaches to integration theory and political science research on the EU.

Content
1. Introduction
2. Theories of European integration
3. Institutional development of European integration
4. Development of political integration
5. Internal market and monetary union
6. Internal and external security policies
7. Constitutionalization
8. Widening and differentiation
9. European integration in crisis
10. Institutions
11. Law-making and law enforcement
12. Statehood and democracy
13. Switzerland, the EEA and Neighbourhood Policies

Lecture notes
The seminar covers the theory, development, and core policy fields of European integration as well as structures and processes of the EU as a decision- and policy-making system.

Literature
Die Literatur wird auf Moodle bereitgestellt.

Prerequisites / notice
The grade is based on a written exam.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Method-specific Competencies
Analytical Competencies assessed
Personal Competencies
Critical Thinking assessed

860-0023-00L International Environmental Politics  W 3 credits 2V T. Bernauer
Abstract
This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined.

Objective
The objectives in this course are to (1) gain an overview of important questions pertaining to international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions in this policy area and how to address them in a conceptually and methodologically meaningful and insightful way; (3) gain an overview of important global and regional environmental problems and how they are or could be solved.

Content
This course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined, for example international efforts to reduce air pollution, manage international water resources, mitigate and adapt to global warming, protect the stratospheric ozone layer, address biodiversity challenges, deal with plastic waste, and prevent pollution of the oceans.

Lecture notes
Reading materials and slides will be available via Moodle.

Literature
Reading materials and slides will be available via Moodle.
The lecture provides an introduction to the role of security and military technologies in the formulation and implementation of national and international security policies. The focus is on challenges posed by new and developing technologies, the transformation of military capabilities, and the question of regulation. Participants will gain an in-depth overview of the many ways in which technology is becoming part of security policies and practices, both in the social sciences and environmental policy. This course will take place on campus (ETH Main Building, HG F.3). There will be no live-streaming, and the course is NOT in hybrid (on-campus plus online) format. However, the lecture will be recorded and the recordings will be made available via the Moodle platform for this course a few days after the respective lecture for students who are unable to attend in person. All electronic correspondence will take place via the ETH mystudies system and Moodle, so please make sure you are properly registered there with a functioning email address/account.

### Prerequisites / notice
The course is open to all ETH students and visiting students from other universities. Participation does not require previous coursework in the social sciences or environmental policy. This course will take place on campus (ETH Main Building, HG F.3). There will be no live-streaming, and the course is NOT in hybrid (on-campus plus online) format. However, the lecture will be recorded and the recordings will be made available via the Moodle platform for this course a few days after the respective lecture for students who are unable to attend in person. All electronic correspondence will take place via the ETH mystudies system and Moodle, so please make sure you are properly registered there with a functioning email address/account.

### Credits and Exam
After passing a written test at the end of the course (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test). Visiting students (e.g., from the University of Zurich, exchange students) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory. Students who obtain a grade of < 4.0 for the test will have a second chance (see table below). Students who did not participate in the test on 18 December 2023 will not have access to the repeat test unless they submit compelling and documented (e.g. medical, other exam in parallel at ETH) reasons for why they were unable to participate in the first test. It covers all contents of the lectures and the reading assignments. Visiting students (e.g., from the University of Zurich or other universities) are subject to the same conditions. Registration for the course in the mystudies system of ETH is compulsory. No separate registration for the exam is required, registration for the course as such covers everything. The exam will take place on campus, either in the F3 lecture hall or in a computer room. That is, you must be present in person at ETH Zurich on the exam date/time.

### Competencies

**Subject-specific Competencies**
- Concepts and Theories
  - assessed

**Method-specific Competencies**
- Analytical Competencies
  - assessed
- Decision-making
  - fostered
- Media and Digital Technologies
  - fostered
- Problem-solving
  - assessed

**Social Competencies**
- Communication
  - fostered
- Cooperation and Teamwork
  - fostered
- Sensitivity to Diversity
  - fostered

**Personal Competencies**
- Critical Thinking
  - assessed
- Self-direction and Self-management
  - fostered

### Literature

The lecture is being supported by a website on Moodle. Literature for each session will be available on Moodle. The lecture notes and literature on 18 December 2023 will not have access to the repeat test unless they submit compelling and documented (e.g. medical, other exam in parallel at ETH) reasons for why they were unable to participate in the first test. It covers all contents of the lectures and the reading assignments. Visiting students (e.g., from the University of Zurich or other universities) are subject to the same conditions. Registration for the course in the mystudies system of ETH is compulsory. No separate registration for the exam is required, registration for the course as such covers everything. The exam will take place on campus, either in the F3 lecture hall or in a computer room. That is, you must be present in person at ETH Zurich on the exam date/time.
Abstract
In this course students deepen their knowledge about global development and sustainability issues. We will show five movies each of them linked to one of the five P’s (Planet, People, Prosperity, Peace and Partnerships) reflecting the topics of the 2030 Agenda. Afterwards the movie will be critically discussed with researchers and relevant stakeholders from the broader society.

Objective
1. Students get a broad understanding of some of the most important issues and discussions related to sustainable development.
2. Students get exposed to diverse realities of young people in developing countries.
3. Students can critically reflect upon the information that is presented to them in the movies and relate it to the broader discussions around sustainable development.
4. Students reflect on issues concerning communicating research and the realities of low-income settings to a wider public.

Content
The aim of the course is to deepen student’s knowledge about global issues and to inspire them to reflect critically upon complex topics, which are embedded in contemporary controversies. For each lecture we will invite one researcher or one decision maker from policy, the private sector or civil society to reflect on one particular SDG. These talks will be followed by discussions with students and the general public. Most lectures will be given online.

Lecture notes
1 short paper will be posted on the Moodle each week that should be read before the talks.

Prerequisites / notice
Open to advanced Bachelor and all Master level students enrolled at ETH Zurich
Content

Engineers and scientists often pursue their studies and research in the hope that their knowledge can contribute to make a better world, inform democratic deliberation and help public understanding of complex issues. Yet this special status of science and technology is being increasingly contested by marginalized publics, lobbyists, exposed populations, and by members of the scientific communities themselves. Climate skepticism or vaccine hesitancy are some of the most vivid examples of this confusing situation. In this seminar, students will learn to reflect on expertise as a form of scientific engagement in the messiness of democratic deliberation and public life, beyond the noble but outdated ideal of “speaking truth to power”.

The exercise of expertise is stumbling upon several conundrums. Which knowledge is relevant in which situation? How to make sure that some crucial perspectives are not left in the shadows? How to identify representative experts and make sure that they speak on behalf of a structured community? Whose voices are being silenced? On the other side of the spectrum, the public is often said to lack proper understanding of science and thus in need of being educated or disciplined. Or it is suspected of being manipulated by lobbyists or foreign hostile powers, or of being too attached to its own privileges and unwilling to act in favor of the common good. Whose agency is being acknowledged in sociotechnical controversies and whose agency is being denied and why? The seminar will provide a deep understanding of these perspectives, by putting them in a broader historical and epistemological context. Students will thus learn to critically assess their strengths as well as their blind spots.

Whereas opposing technological developments (anti 5G or anti-vaccine activists) or pushing to act accordingly to science (pro climate movements such as Extinction Rebellion or Scientist Rebellion), activists’ movements make up for a rich field of investigation on the dynamics of expertise and of how various publics can make sense of scientific knowledge. Cross-fertilizing activists’ texts and experiences with literature in science and technology studies and anthropology, this class will be organized as a structured conversation and a collective mapping of actors and key concepts of sociotechnical controversies. Over the course of the semester, students will learn not only to navigate some of the most heated contemporary debates, but also to articulate their own position on an issue of their choice.

Competencies

Subject-specific Competencies

- Method-specific Competencies: Concepts and Theories
- Analytical Competencies: assessed
- Communication: fostering
- Cooperation and Teamwork: fostering
- Sensitivity to Diversity: fostering
- Negotiation: fostering

Social Competencies

- Adaptability and Flexibility: fostering
- Creative Thinking: fostering
- Critical Thinking: assessed
- Self-awareness and Self-reflection: assessed

Personal Competencies

Objective

- Students will learn how digital technologies are impacting modern conflicts and what are the actual and future trends in this domain.
- Students will focus on the implications for tech companies, understanding the new challenges from a technological, policy and legal perspective.

Content

1. Introduction: International Humanitarian Law (IHL; 101); International Committee of the Red Cross (ICRC); perspective; Terminology.
2. Digital Capabilities in Armed Conflict: Overview; Established cyber capabilities; The cyber weapons dilemma; Attribution and self- attribution; Other digital means during armed conflicts.
3. Connectivity in Crisis: No connectivity; the connectivity gap; Loss or limitation of connectivity; Stable connectivity: connected in crisis.
4. Hybrid and Unconventional Warfare: Kinetic and cyber offensive operation coordination; Disruption of digital services; The dual-use dilemma; The public-private partnership dilemma; Civilization of digital warfare, Total offense and whole-of-societies: a digital perspective of society’s active participation; The cognitive warfare: a digital perspective of modern low-intensity constant warfare.
5. The Potential Human Cost of Cyber Operations.
7. Case Studies (based on scenarios).

Psychology, Pedagogics

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
871-0240-00L | Human Learning (EW1) | W | 2 credits | 2V | E. Stern, M. Rau

This lecture is only apt for students who intend to enrol in the programs "Teaching Diploma" or "Teaching Certificate". It is about learning in childhood and...
This course looks into scientific theories and also empirical studies on human learning and relates them to the school.

Objective

Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

Content

This seminar will introduce key topics, theories and methodology in human-computer interaction (HCI) and usability, with a focus on methodologies. The final project demonstrates class topic adoption by deeply exploring one HCI problem using the covered methods and tools. Students will choose a research topic and execute their research plan. They will individually write a formal report including problem definition, results regularly and also present their findings to the class once per semester.

Prerequisites / notice

This lecture is only apt for students who intend to enrol in the programs "Lehrdiplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.

871-0238-01L Support and Diagnosis of Knowledge Acquisition Processes (EW3) W

Enrolment only possible with matriculation in Teaching Diploma (except for students of Sport Teaching Diploma, who complete the sport-specific course unit EW3) and for students who intend to enrol in the "Teaching Diploma".

Prerequisites: successful participation in 871-0240-00L "Human Learning (EW1)".

Abstract

In this seminar students learn advanced techniques to support and to diagnose knowledge acquisition processes in school.

Objective

The main goals are:

1) You have a deep understanding about the cognitive mechanisms of knowledge acquisition.
2) You have a basic understanding about psychological test theory and can appropriately administer tests.
3) You know various techniques of formative assessment and can apply these to uncover students' misconceptions.

Competencies

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving

Social Competencies

Communication
Cooperation and Teamwork
Leadership and Responsibility
Sensitivity to Diversity

Personal Competencies

Creative Thinking
Critical Thinking

851-0252-01L Human-Computer Interaction: Cognition and Usability

Particularly suitable for students of D-ARCH, D-INFK, D-ITET.

Abstract

This seminar will introduce key topics, theories and methodology in human-computer interaction (HCI) and usability, with a focus on applying them to real situations.

Objective

Presentations will cover the basics of human-computer interaction and selected topics:

- History of HCI
- Research ethics
- Literature reviews
- Participant-free methods: cognitive walkthrough and heuristic evaluation
- Card sorting and information architecture
- Usability studies
- Unmoderated research and diary studies
- Surveys
- User Logs and metric frameworks

On a weekly basis, students will conduct authentic research in class covering the topics above. They will submit their in-class research results regularly and also present their findings to the class once per semester.

The final project demonstrates class topic adoption by deeply exploring one HCI problem using the covered methods and tools. Students will choose a research topic and execute their research plan. They will individually write a formal report including problem definition, literature review, methodology, findings and discussion.

363-0311-00L Psychological Aspects of Risk Management and Technology

Using uncertainty management by organizations and individuals as conceptual framework, risk management and risk implications of new technologies are put in a position where they can further educate themselves in the field of research into teaching and learning.

Abstract

Using uncertainty management by organizations and individuals as conceptual framework, risk management and risk implications of new technologies are put in a position where they can further educate themselves in the field of research into teaching and learning.

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Objective
- You know how risk and risk management is defined and applied in different industries
- You know the challenges of decision making under risk and uncertainty and its effects on organisations
- Know about (and partially) apply some risk management tools
- Gain some more in-depth knowledge in a selected field within risk management through the semester project (e.g. transport systems, IT, insurance)

This course consists of three main elements:

A) Attendance of lectures that provide the theoretical foundations of “Psychological Aspects of Risk Management and Technology” together with reading assignments for each lecture.

B) Attendance of guest lectures that provide a rich source of practical insights and enable the transfer of theory into practice by discussing real-life cases with experts from various industries.

C) Furthermore, this course enables you to apply what you have learned in the classroom into practice by participating in a group assignment in which you gain insights into various risk industries (e.g., aviation, healthcare, insurance) and topics (e.g., risks in cyber-attacks, mountaineering, autonomous vehicles). These projects help students understand key aspects through in-depth application of the course material on real-life topics. Each group project will be mentored and graded by one of the lecturers (70% of course grade). To round off the course at the end of the year, you will have the opportunity to present your group’s findings to the lecturers and to your peers (30% of course grade).

Content
The course is organized into fourteen sessions. Sessions comprise a mixture of (guest) lectures, case discussions, and presentations. Through class discussion we will further deepen understanding of the topics and themes of the class. For each session you are required to prepare by reading the assigned literature or case material provided on the Moodle e-learning platform. Topics covered include:

- Elements of risk management:
  - Risk identification and evaluation
  - Risk mitigation
  - Risk communication

- Psychological and organizational concepts relevant in risk management
  - Decision-making under uncertainty
  - Risk perception
  - Resilient organizational processes for managing uncertainty

- Case studies on different elements of risk management (e.g., rule-making, training, managing project risks, automation)

- Group projects related to company case studies

Lecture notes
There is no script, but slides will be made available before the lectures.

Literature
There are texts for each of the course topics made available before the lectures.

Prerequisites / notice
The course is restricted to 40 participants who will work closely with the lecturers on case studies prepared by the lecturers on topics relevant in their own companies (SWICA, SWISS, University Hospital Zurich).

Competencies
Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

Method-specific Competencies
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity

Social Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Personal Competencies

701-0721-00L Psychology W 3 credits 2V R. Hansmann, A. Bearth, M. Siegrist

Abstract
This course provides an introduction to psychological research and modelling, focusing on cognitive psychology and the psychological experiment. Participants learn to formulate problems for psychological investigation and apply basic forms of psychological experiment.

Objective
Students are able to:
- describe the areas, concepts, theories, methods and findings of psychology.
- differentiate scientific psychology from "everyday" psychology.
- structure the conclusions and significance of an experiment, according to a theory of psychology.
- formulate a problem for psychological investigation.

Content
Einführung in die psychologische Forschung und Modellbildung unter besonderer Berücksichtigung der kognitiven Psychologie und des psychologischen Experiments. Themen sind u.a.: Wahrnehmung; Lernen und Entwicklung; Denken und Problemlösen; Kognitive Sozialpsychologie; Risiko und Entscheidung.
At the beginning of the course, the students will receive an introduction to usable IT security and privacy and relevant concepts. Afterwards, students are taught a variety of analytic techniques that can be used to evaluate architectural design. The concept of evidence-based design is introduced, and complemented with theoretical background on space syntax and spatial cognition. This is a project-oriented course, students implement a range of methods on a sample project. The course is tailored for architecture design students.

Students will build on their previous projects as part of the course "Evidence-Based Design: Methods and Tools for Evaluating Architectural Design" (851-0252-08L). Students enrolled will participate in an international workshop with GAPP at Columbia University Designing the post-pandemic hospital with evidence. For people. The course is funded by an ETH innovedum project entitled cogARCH: linking cognition and architecture to design resilient hospitals architecture.

The course is tailored for students studying for B-ARCH and M-ARCH degrees. As an alternative to obtaining D-GESS credit, architecture students can obtain course credit in "Vertiefungsfach" or "Wahlfach".

Course requirements: Completion of the course Evidence-Based Design: Methods and Tools For Evaluating Architectural Design (851-0252-08L).

Students will gain advanced knowledge and practical hands-on experience with agent-based simulations and spatial analysis tools to evaluate hospital layouts from the perspective of end-users. The students' human-centered solution can take the form of a concept (e.g., a concept for a product or app), interface (e.g., a visual or tangible interface), or prototype (e.g., sketches, a click-dummy or a built prototype). The solution will then be subject to evaluations. The students' human-centered solution can take the form of a concept (e.g., a concept for a product or app), interface (e.g., a visual or tangible interface), or prototype (e.g., sketches, a click-dummy or a built prototype). The solution will then be subject to evaluations. The course covers a range of methods including visibility analysis, network analysis, conducting real-world observations, and virtual reality for architectural design. Students apply these methods to a case study of their choice, which can be at building or urban scale. For students taking a B-ARCH or M-ARCH degree, this can be a completed or ongoing design studio project. The course gives students the chance to implement the methods iteratively and explore how best to address the needs of the eventual end-user during the design process.

The course is particularly suitable for students of D-ARCH.

Students enrolled will participate in an international workshop with GAPP at Columbia University. Designing the post-pandemic hospital with evidence. For people. The course is funded by an ETH Innovedum project entitled cogARCH: linking cognition and architecture to design resilient hospitals architecture.

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The course is tailored for students studying for B-ARCH and M-ARCH degrees. As an alternative to obtaining D-GESS credit, architecture students can obtain course credit in "Vertiefungsfach" or "Wahlfach".

Course requirements: Completion of the course Evidence-Based Design: Methods and Tools For Evaluating Architectural Design (851-0252-08L).

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The course is particularly suitable for students of D-ARCH.

Students enrolled will participate in an international workshop with GAPP at Columbia University. Designing the post-pandemic hospital with evidence. For people. The course is funded by an ETH Innovedum project entitled cogARCH: linking cognition and architecture to design resilient hospitals architecture.

The course is tailored for students studying for B-ARCH and M-ARCH degrees. As an alternative to obtaining D-GESS credit, architecture students can obtain course credit in "Vertiefungsfach" or "Wahlfach".

Course requirements: Completion of the course Evidence-Based Design: Methods and Tools For Evaluating Architectural Design (851-0252-08L).

Students will gain advanced knowledge and practical hands-on experience with agent-based simulations and spatial analysis tools to evaluate hospital layouts from the perspective of end-users. The students' human-centered solution can take the form of a concept (e.g., a concept for a product or app), interface (e.g., a visual or tangible interface), or prototype (e.g., sketches, a click-dummy or a built prototype). The solution will then be subject to evaluations. The students' human-centered solution can take the form of a concept (e.g., a concept for a product or app), interface (e.g., a visual or tangible interface), or prototype (e.g., sketches, a click-dummy or a built prototype). The solution will then be subject to evaluations. The course covers a range of methods including visibility analysis, network analysis, conducting real-world observations, and virtual reality for architectural design. Students apply these methods to a case study of their choice, which can be at building or urban scale. For students taking a B-ARCH or M-ARCH degree, this can be a completed or ongoing design studio project. The course gives students the chance to implement the methods iteratively and explore how best to address the needs of the eventual end-user during the design process.

The course is particularly suitable for students of D-ARCH.
Psychedelic science is a multidisciplinary field of study that involves scholars of the mind and scholars of the natural sciences. In this course, psychedelic science is presented mainly from the point of view of psychology, but will additionally also be considered from the viewpoints of pharmacology, physiology, psychotherapy, philosophy, religion, and politics. All contributions will also be reflected on from the viewpoint of the humanities and psychology. The psychedelic studies treated in this course that involve humans focus on controlled and ethically approved studies where these substances are administered to medically screened, prepared, and supported participants. Private/illicit use of psychedelics is not a topic of this course.

A psychedelic experience can be characterized as a temporary nonordinary state of consciousness (NSC) that is occasioned by classic (serotonergic) psychedelics such as psilocybin, mescaline, N,N-dimethyltryptamine (DMT), and lysergic acid diethylamide (LSD). Psychologically, the psychedelic experience can manifest at the perceptual, cognitive, affective, volitional, and somesthetic level. The nonordinary perceptual spectrum ranges from visions (e.g., patterns or beings) to the subjective experience of an all-encompassing oneness, which also transcends the distinction between the perceiver and the perceived. The nonordinary cognitive spectrum ranges from no longer functionable thinking to very clear thinking, the nonordinary affective spectrum, for example, from deepest sadness to highest bliss, the nonordinary volitional spectrum from the feeling of being able to somewhat influence what is happening to the feeling of having no control at all, and the nonordinary somesthetic spectrum, for example, from feelings of bodily heaviness/compression to feelings of bodily lightness/floatation.

Heuristically, as one possibility, a psychological typology of the psychedelic experience can be characterized to fall into three main types: religious-like experiences (which may be interpreted religiously/spiritually by the individuals having them, but may also be interpreted materialistically or agnostically), autobiographical experiences, and tripartite-mind (cognitionaffectconation) miscellaneous experiences. Investigating the psychedelic experience is a worthwhile endeavor as, for instance, certain aspects of this experience have been associated with increased subjective well-being both for healthy individuals as well as for patients – for example, persisting positive effects on attitudes, mood, and behavior in healthy individuals and sustained symptom reduction in individuals suffering from depression, anxiety, and addiction.

Psychelic science is overall a large multidisciplinary effort that requires collaboration of scholars of the mind and scholars of the natural sciences to advance the scientific knowledge of it. In this spirit, this course will – besides the main lecturer (PD Dr. phil. Kurt Stocker, a psychologist) – also involve further psychedelic-scientific scholars giving individual lectures in their respective field of expertise psychology (PD Dr. phil. Katrin Preller, University of Zurich & Yale University), pharmacology (PD Dr. phil. nat. Dino Luethi, University Hospital Basel; Dr. phil. nat. Deborah Rudin, University Hospital Basel; Prof. Dr. phil. Linda Simmler, University of Basel), physiology (PD Dr. sc. nat. Felix Scholkmann, University of Zurich & University of Bern), psychiatry/psychotherapy (Prof. Dr. med. Gregor Hasler, University of Fribourg; Dr. med. Dr. sc. ETH Milan Scheidegger, University of Zurich), and philosophy (Dr. Peter Sjöstedt-Hughes, University of Exeter). Overall, this course will provide an informative overview of the research foundations that have made psychedelic science what it is today, and will also provide an identification of the research frontiers that must be addressed to expand the psychedelic science of tomorrow.
Abstract

In this seminar, we consider how the human brain processes social information. The approach focuses on exploring the neural bases of social cognition in healthy individuals, as well as providing case studies from atypical populations, whose pathologies are typified by dysfunction in social information processing, such as autism spectrum disorder and schizophrenia.

Objective

- To familiarise students with forms of social cognition in humans, as well as the neural systems that support social cognition.
- To critically evaluate theories and data relating to Social Cognition and Social Neuroscience.
- To relate how knowledge of typical brain function can inform our understanding of individuals who process social information differently, and vice versa.
- To develop effective scientific communication skills in oral and written formats.

Content

This seminar will consider how the human brain understands and organises social behaviour. The approach will focus on exploring the neural bases of social cognition in healthy individuals, as well as providing case studies from atypical populations, whose pathologies are typified by dysfunction in social information processing. Examples of such pathologies include autism spectrum disorder, schizophrenia and attention deficit hyperactivity disorder. By examining healthy and atypical populations, this module will highlight how disorders of social cognition can inform the understanding of healthy brain function, as well as how understanding healthy brain function can inform disorders of social cognition.

851-0392-00L Privacy Quantification and Usable Protection

W 3 credits 2S N. Zufferey, V. Zimmermann

Mechanisms

Abstract

Students will gain an overview of the main privacy metrics that are used to evaluate privacy risks related to the use of a given technology. They will also be introduced to the concepts of privacy/utility balance and usable security. Practical exercises and reading of recently published scientific articles will be used to present practical cases of the theoretical tools presented in class.

Objective

This course aims to provide the students with a global knowledge of the concepts related to privacy, and the methodology and tools to identify, analyze, and address threats while taking the user into account in the process. They will adopt a "privacy mindset", thus enabling them to think about privacy in an active and usable way, when designing or analyzing a system.

Content

First, the course will introduce the different definitions and approaches of privacy (e.g., privacy by control, privacy by design) as well as the ethical concerns and considerations related to information security and privacy research (e.g., responsible disclosure, full disclosure).

Second, the students will be introduced to the different methods, properties, and metrics to assess and/or guarantee a certain level of privacy. They will be introduced to the properties and metrics related to anonymization (e.g., k-anonymity, l-diversity), data aggregation (e.g., randomized responses, ε-differential privacy), as well as other privacy assessment methodologies (e.g., inferential privacy).

Third, the course will address usability issues and the role of individuals (i.e., users) in privacy management (i.e., usable security and privacy) and the design of privacy-enhancing technologies. In this context, we will analyze the main concepts seen during the course and discuss their advantages and disadvantages in terms of usability, as well as their implementation for mass-market and large-scale technologies.

Across all three parts of the course, practical exercises, as well as recent research articles reading, and presentations will be used as a complement to support the concepts seen in class, as well as to provide concrete examples of methodologies related to the assessment of privacy in general.

Literature


Competencies

Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Method-specific Competencies

Analytical Competencies

Communication

Personal Competencies

Creative Thinking

Critical Thinking

Integrity and Work Ethics

851-0271-00L Neuroaesthetics - Exploring the Science of Aesthetic Experience

W 2 credits 2S E. Cross, I. Bara

Abstract

This seminar introduces students to theory and research, challenges, and opportunities in neuroaesthetics, with a clear emphasis on the interdisciplinary nature of the discipline situated at the intersection of neuroscience, psychology, and art appreciation. Foundational empirical methods and critical perspectives of research approaches in neuroaesthetics are considered.

Objective

- to familiarize students with concepts, models, methods, brain and behavioral findings related to aesthetic experience.
- to develop a critical understanding in evaluating the theoretical and empirical findings in neuroaesthetics.
- to integrate the acquired knowledge to critically debate and discuss the conceptual and empirical issues related to the science of aesthetic experience.

Content

In this seminar, students will learn about the foundational principles of neuroaesthetics, which explores the cognitive and brain processes involved in aesthetic experience. A key focus will be placed on developing an appreciation of the interdisciplinary methods used in the neuroaesthetics field — ranging from neuroscience, psychology, philosophy, and art history. The seminar is based on the active engagement of students in reading, presenting, and critically discussing selected papers in the field. In a final small-group assignment, students are expected to incorporate and elaborate upon the content covered in the seminar by presenting and discussing a novel research proposal for tackling a timely research question related to aesthetic experience.
This seminar introduces the fundamentals and latest research developments of brain imaging in real-world contexts. We explore topics from imaging multiple people's brains simultaneously as they interact to neuro-ethics and neuro-art, while maintaining a strong focus on critical evaluation of research practices and applications of brain imaging of and during social interaction.

Rapid advances in the technologies and empirical approaches used in imaging the human brain have opened exciting windows into how the human brain coordinates social interaction. These advances include imaging the brain's function during real social interactions, training behaviours with feedback based on real-time brain activity, and even generating art directly from brain signals. With them, these advances have brought novel ethical implications regarding their implementation in research and potentially, their use by the public, for both therapeutic and possible “neurohacking” applications. In this seminar, students will be introduced to various neuroimaging approaches for social neuroscience generally, as well as to approaches for measuring social brain function in real life, and will gain insights into related ethical considerations.

The seminar builds on the active participation of students in reading, presenting, and critically discussing selected papers in the field. In a final small-group assignment, students are required to integrate and elaborate upon topics covered in the seminar by presenting and debating a novel research proposal for addressing a timely research question related to the use of brain imaging in the context of social interactions. No prior experience or knowledge in brain imaging is required.

- To familiarize students with current concepts, theories, methods, and findings from social brain-imaging sciences
- To develop a critical view of extant findings and the tools for evaluating the quality of evidence and data, as well as ethical implications

Specific competencies within the seminar include:

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

851-0272-00L The Cutting Edge of Social Brain Imaging  

Abstract: This seminar introduces the fundamentals and latest research developments of brain imaging in real-world contexts. We explore topics from imaging multiple people's brains simultaneously as they interact to neuro-ethics and neuro-art, while maintaining a strong focus on critical evaluation of research practices and applications of brain imaging of and during social interaction.

Objective: Rapid advances in the technologies and empirical approaches used in imaging the human brain have opened exciting windows into how the human brain coordinates social interaction. These advances include imaging the brain's function during real social interactions, training behaviours with feedback based on real-time brain activity, and even generating art directly from brain signals. With them, these advances have brought novel ethical implications regarding their implementation in research and potentially, their use by the public, for both therapeutic and possible “neurohacking” applications. In this seminar, students will be introduced to various neuroimaging approaches for social neuroscience generally, as well as to approaches for measuring social brain function in real life, and will gain insights into related ethical considerations.

Content: The seminar builds on the active participation of students in reading, presenting, and critically discussing selected papers in the field. In a final small-group assignment, students are required to integrate and elaborate upon topics covered in the seminar by presenting and debating a novel research proposal for addressing a timely research question related to the use of brain imaging in the context of social interactions. No prior experience or knowledge in brain imaging is required.

Competencies |
---|---|---|
Subject-specific Competencies | Concepts and Theories | fostered |
| | Techniques and Technologies | fostered |
Method-specific Competencies | Analytical Competencies | fostered |
| | Decision-making | fostered |
| | Media and Digital Technologies | fostered |
| | Problem-solving | fostered |
| | Project Management | fostered |
Social Competencies | Communication | fostered |
| | Cooperation and Teamwork | fostered |
| | Customer Orientation | fostered |
| | Leadership and Responsibility | fostered |
| | Self-presentation and Social Influence | fostered |
| | Sensitivity to Diversity | fostered |
| | Negotiation | fostered |
Personal Competencies | Adaptability and Flexibility | fostered |
| | Creative Thinking | fostered |
| | Critical Thinking | fostered |
| | Integrity and Work Ethics | fostered |
| | Self-awareness and Self-reflection | fostered |
| | Self-direction and Self-management | fostered |

Law

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<td>Workshop &amp; Lecture Series on the Law &amp; Economics of Innovation</td>
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<td>2 credits</td>
<td>2S</td>
<td>S. Bechtold</td>
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Abstract: This series is a joint project by ETH Zurich and the Universities of St. Gallen and Zurich. It provides an overview of interdisciplinary research on intellectual property, innovation, antitrust, privacy & technology policy. Scholars from law, economics, management and related fields present their current research. All speakers are internationally well-known experts from Europe, the U.S. & beyond.

Objective: After the workshop and lecture series, participants should be acquainted with interdisciplinary approaches towards intellectual property, innovation, antitrust, privacy and technology policy research. They should also have an overview of current topics of international research in these areas.

Content: The workshop and lecture series will present a mix of speakers who represent the wide range of current social science research methods applied to intellectual property, innovation, antitrust, privacy and technology policy issues. In particular, theoretical models, empirical and experimental research as well as legal research methods will be represented.

Lecture notes: Papers discussed in the workshop and lecture series are posted in advance on the course web page.
Contract Design I is taught by Professor stremitzer and aims to bridge the gap between economic contract theory, contract law, and the economic structure of intellectual property law. This course is particularly the art of writing real-world contracts. In other words, Contract Design will provide you with analytical tools to design contracts that help you be better lawyers, business leaders, and startup founders.

We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting and apply the theoretical insights to real-life case studies ranging from purchases & sales of assets, oil & gas exploration, movie financing, production & distribution, construction & development, M&A deals, venture capital financing, to executive compensation and many other types of transactions.

The course follows a flipped-classroom model: You will watch learning videos specifically produced for this course ahead of class. We will use class time to discuss real-world case studies. The videos will be made available before the lecture each week and need to be watched ahead of coming to class. Computer-graded quizzes at the beginning of each class will test students’ understanding of the concepts introduced in the videos.

As the emphasis of this class is on class discussion, attendance is mandatory. Absent important reasons, you cannot miss class more than twice.

The lectures will be recorded but only made available to those who miss lectures with excused absence.

For ETH students: Your grade will consist of two parts:
1) You will take weekly computer-based quizzes during class time. Thus, it is important that you attend the lectures to be able to finish the quizzes and pass this course.
2) You compose short responses to take-home questions on case studies we assign and upload them ahead of class (Pass/Fail).

Note that UZH and UNISG students enrolling in this course need to earn more ECTS for completing this course than ETH students (due to curricula reasons). This is why UZH and UNISG students must complete a written assignment in addition to the weekly quizzes and take-home questions. UZH students also have to complete an additional group project. UZH and UNISG students should check out the description of the class at their respective home institutions.

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Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Analytical Competencies
Decision-making
Problem-solving

Social Competencies

Communication
Cooperation and Teamwork
Customer Orientation
Negotiation

Personal Competencies

Creative Thinking

851-0703-04L Law and Urban Space W 2 credits 2V O. Streiff Gnöpff

Particularly suitable for students of D-ARCH.

Abstract
Legal rules are tied to urban space. Illustrative is the relation between land ownership and urban morphology. Legal concepts with spatial impacts are introduced and related to the theory of urban design. Moreover, it is discussed how these concepts shape specific places. The course includes interactive sequences for which active participation is expected.

Objective
Students recognize the interplay between legal structures and urban space. They can describe legal concepts with spatial impact. Moreover, they are able to compare legally binding targets with theoretical approaches in urban design. By analysing a specific place, students learn to find relevant norms, to analyse and to judge them with regard to urban design theories. Thereby, they are able to distinguish design and policy questions.

Content
Using the the term «lawscape» (Philippopoulos-Mihalopoulos), we initially discuss general aspects of the interplay between legal rules and urban space. In the following weeks we consider the interplay with reference to different dimensions of urban space (e.g. morphological, social, functional dimension).

Working tools are theoretical texts, legal rules, court decisions as well as site analyses. Students prepare the texts for joint discussions and undertake a case study in small groups. Selected case studies are presented and discussed in a final meeting.

Lecture notes
See Literature.

Literature
Documents will be available online (see https://moodle-app2.let.ethz.ch/course/view.php?id=20128).

Prerequisites / notice
Number of participants limited to: 40

Competencies

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Analytical Competencies
Decision-making
Problem-solving

Social Competencies

Communication
Cooperation and Teamwork
Customer Orientation
Negotiation

Personal Competencies

Creative Thinking

851-0707-00L Space Planning Law and Environment W 2 credits 2G O. Bucher

Particularly suitable for students of D-ARCH, D-BAUG, D-USYS.

Abstract
System of swiss planning law, Constitutional and statutory provisions, Space planning and fundamental rights, Instruments, Application, legal protection, enforcement, Practical training.

Objective
Basic understanding of nature and function of space planning from a legal point of view. Basic knowledge of space planning instruments, relationship between space planning and constitutional law (especially property rights), solving of practical cases.

Content

Lecture notes
Haller, Walter/Karlen, Peter, Raumplanung-, Bau- und Umweltrecht, 3.A., Zürich 1999

Hänni, Peter, Planungs-, Bau- und besonderes Umweltgeschutzrecht, 7.A., Bern 2021

Competencies

Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Method-specific Competencies

Analytical Competencies
Decision-making
Problem-solving

Social Competencies

Communication

Personal Competencies

Creative Thinking

Critical Thinking

851-0709-00L Introduction to Civil Law W 2 credits 2V H. Peter

The course Private Law focuses on the Swiss Code of Obligations (contracts, torts) and on Property Law (ownership, mortgage and easements). In addition, the course will provide a short overview of Civil Procedure and Enforcement.

Objective
Teaching of the principles of law, particularly private law. Introduction to law.

Content
Le cours de droit civil porte notamment sur le droit des obligations (droit des contrats et responsabilité civile) et sur les droits réels (propriété, gages et servitudes). De plus, il est donné un bref aperçu du droit de la procédure et de l'exécution forcée.

Sont indispensables:
- le Code civil et le Code des obligations;
- Sont conseillés:
  - Nef, Urs Ch.: Le droit des obligations à l'usage des ingénieurs et des architectes, trad. Bovay, J., éd. Payot, Lausanne
  - Boillod, J.-P.: Manuel de droit, éd Slatkine, Genève

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### Competencies

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### Lecture notes

Es wird mit Folien gearbeitet, die als PDF über Moodle vorgängig abrufbar sind. Auf dem Termin- und Themenplan (ebenfalls online abrufbar) sind Links zu Gesetzestexten und weiteren Unterlagen abrufbar. Schliesslich wird jede Vorlesung auch als Podcast aufgezeichnet, der jedoch nur für die Studierenden mit einem Passwort (erhältlich beim Dozenten) zugänglich sind.

### Literature

Weiterführende Materialien, Links und Literatur sind auf dem Termin- und Themenplan aufgeführt (zu gegebener Zeit abrufbar via Moodle).

### Prerequisites / notice

- Der Termin- und Themenplan ist zu gegebener Zeit über Moodle abrufbar.

### Content

- The objective is knowing and understanding key legal concepts relevant for doing e-business, in particular understanding how e-business is regulated by law nationally and internationally, how contracts are concluded and performed electronically, which rules have to be obeyed in particular in the Internet with regard to third party and own content and client data, the concept of liability applied in e-business and the role of the law in the practical implementation and operation of e-business applications.

### Objective

The course deals with the basic legal framework for doing e-business as well as using information technology. It discusses a variety of legal concepts and rules to be taken into account in practice, be it when designing and planning new media business models, be it when implementing online projects and undertaking information technology activities.

### Prerequisites

- BSSE, D-CHAB, D-ITET, D-MAVT.
- Particularly suitable for students of D-INFK, D-ITET.

### Subject-specific Competencies

- They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company.
- They shall be able to contribute to the legal management of the company and to discuss legal issues.
- They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise.
- They shall be able to contribute to the legal management of the company and to discuss legal issues.
- They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company.

### Lecture notes

A comprehensive script will be made available online on the moodle platform.

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Subject-specific Competencies
3 credits
The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.

Objective
In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

Competencies
- Subject-specific Competencies
  Concepts and Theories  assessed

- Method-specific Competencies
  Problem-solving  assessed

- Personal Competencies
  Critical Thinking  assessed
  Self-awareness and Self-reflection  assessed

851-0760-00L Building a Robot Judge: Data Science for Decision-Making
Does not take place this semester.
Particularly suitable for students of D-INFK, D-ITET, D-MTEC.

Abstract
This course explores the automation of decisions in the legal system. We delve into the machine learning tools needed to predict judge decision-making and ask whether techniques in model explanation and algorithmic fairness are sufficient to address the potential risks.

Objective
Data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, there are serious risks that automated systems could replicate or amplify existing legal biases and rigidities. Given the stakes, these technologies force us to think carefully about notions of fairness and justice and how they should be applied.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is a criminal defendant to commit another crime? How much additional revenue will this new tax law collect? Students will investigate and implement the relevant machine learning tools for making these types of predictions, including regression, classification, and deep neural networks models.

We then use these predictions to better understand the operation of the legal system. Under what conditions do judges tend to make errors? Against which types of defendants do parole boards exhibit bias? Which jurisdictions have the most tax loopholes? Students will be introduced to emerging applied research in this vein. In a semester paper, students (individually or in groups) will conceive and implement an applied data-science research project.

851-0724-01L Real Estate Property Law
Particularly suitable for students of D-ARCH, D-BAUG, D-USYS.

Abstract
Real estate property law (esp. content, acquisition, restrictions under private and public law, transmission and loss). Legal presentation: land register, surveying, cadastral. Basic questions of contract and tax law.

Objective
The legal principles of real estate property law can be correctly interpreted and applied in daily life.

Content
Real estate property law (esp. content, acquisition, restrictions under private and public law, transmission and loss). Legal presentation: land register, surveying, cadastral. Basic questions of contract and tax law.

Lecture notes
Abgegebene Unterlagen: Skript in digitaler Form

Literature
- Adrian Mühlematter / Stephan Stucki: Grundbuchrecht für die Praxis, Zürich 2016
- Wolfgang Ernst / Samuel Zogg: Sachenrecht in a nutshell, Zürich 2020
- Jörg Schmid / Bettina Hürlimann-Kaup: Sachenrecht, Zürich 2017
- Meinrad Huser, Schweizerisches Vermessungsrecht, unter besonderer Berücksichtigung des Geoinformationsrechts und des Grundbuchrechts, Zürich 2014
- Meinrad Huser, Geo-Informationsrecht, Rechtlicher Rahmen für Geographische Informationssysteme, Zürich 2005
- Meinrad Huser, Darstellung von Grenzen zur Sicherung dinglicher Rechte, in ZBGR 2013, 236 ff.
This course introduces students to scientific and technological developments that require regulation or enable legal innovation. We focus particularly on the challenges to current law posed by prominent near-future technologies.

Objective

The course is designed for a wide range of ETH students as well as for law students who are keen to deepen their understanding of cutting-edge technology. It offers an overview of key legal areas important for technology regulation, complemented by guest lectures on emerging technological trends.

In previous years, the course has featured esteemed speakers from various sectors, including industry leaders like Google, NGOs such as Digital Society Switzerland and The European Consumer Organization, regulatory bodies like the Swiss Competition Commission, and noted academics.

The course is open to ETH students through the Science in Perspective program of the Department of Humanities, Social and Political Sciences.

Content

The planned course outline is below.

- Overview of Law and Technology
- Fundamental Rights
- AI & Discrimination
- Landmark Big Tech Cases
- Regulation of Digital Platforms & Content Moderation
- Online Consumer Protection
- Law and Tech Scholarship Series

A number of recent regulations will be discussed, including the EU's AI Act, the Digital Services Act (DSA), and the Digital Markets Act (DMA), as well as emerging internet phenomena, like ChatGPT.

Prerequisites / notice

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for "Law & Tech (851-0732-06L, HS 2024)" and enroll.

Competencies

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This lecture series explores the multifaceted role of data in shaping contemporary society, governance, and individual lives. The course equips students with a critical understanding of how data is made, managed, and preserved, and its implications for societal norms and individual rights.

Objective

At the end of the term, students will be able to:

• reflect concepts and theories that capture the performativity of data
• reflect concepts and theories that capture the socio-technical nature of data
• assess the implications of data practices for social and political ordering
• identify key actors, sites, and domain contexts of data practices

Competencies

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This course does not take place this semester.

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This course has four main goals: to learn about the most important topics within Behavioural Finance, to effectively select, review and present information using modern telecommunication tools, to practice working on group projects in hybrid working conditions (online + in-person), and to solve an applied behavioral finance business case stemming from an industry partner. Throughout the semester, students work on solutions to real business cases stemming from a company partner. They can receive feedback and guidance from project leaders of the industry partner and from the academic supervisors. In the final meeting of the semester, students pitch solutions to their business cases.

Students must have some data science and/or statistics experience. Some programming experience in Python, Stata, or R is required. Apply tools from data science and social science to a new project, potentially in a group, to develop a paper or app. Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.
Objective

The following topics will be covered:

- Introduction to network models and their applications
- Stylized models:
  * uniform random graph models
  * small world models
  * preferential attachment models
- Models for testing hypotheses while controlling for the network structure:
  * Quadratic assignment procedure regression (QAP regression)
- Models for testing hypotheses on the network structure:
  * Models for one single observation of a network: exponential random graph models (ERGMs)
  * Models for panel network data: stochastic actor-oriented models (SAOMs)

The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

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- Introduction to network models and their applications
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- Models for testing hypotheses on the network structure:
  * Models for one single observation of a network: exponential random graph models (ERGMs)
  * Models for panel network data: stochastic actor-oriented models (SAOMs)
  * Models for relational event data: dynamic network actor models (DyNAMs)

The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

Lecture notes

Slides and lecture notes are distributed via the associated course moodle.

Literature


Prerequisites / notice

Students are required to have basic knowledge in inferential statistics and should be familiar with linear and logistic regression models.

851-0252-15L

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<tr>
<th>Network Analysis</th>
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Abstract

Network science is a distinct domain of data science that is characterized by a specific kind of data being studied. While areas of application range from archaeology to zoology, we concern ourselves with social networks for the most part. Emphasis is placed on descriptive and analytic approaches rather than theorizing, modeling, or data collection.

Objective

Students will be able to identify and categorize research problems that call for network approaches while appreciating differences across application domains and contexts. They will master a suite of mathematical and computational tools, and know how to design or adapt suitable methods for analysis. In particular, they will be able to evaluate such methods in terms of appropriateness and efficiency.

Content

The following topics will be covered with an emphasis on structural and computational approaches and frequent reference to their suitability with respect to substantive theory:

* Empirical Research and Network Data
* Macro and Micro Structure
* Centrality
* Roles
* Cohesion
* Influence

Lecture notes

Slides and lecture notes are distributed via the associated course moodle.

Literature

Computational Social Science

W 3 credits 2S
D. Helbing, C. I. Hausladen, J. C.-Y. Yang

Abstract
The seminar aims at three-fold integration: (1) bringing modeling and computer simulation of techno-socio-economic processes and phenomena together with related empirical, experimental, and data-driven work, (2) combining perspectives of different scientific disciplines (e.g. sociology, computer science, physics, complexity science, engineering), (3) bridging between fundamental and applied work.

Objective
Participants of the seminar should understand how tightly connected systems lead to networked risks, and why this can imply systems we do not understand and cannot control well, thereby causing systemic risks and extreme events.

They should also be able to explain how systemic instabilities can be understood by changing the perspective from a component-oriented to an interaction- and network-oriented view, and what fundamental implications this has for the proper design and management of complex dynamical systems.

Computational Social Science and Global Systems Science serve to better understand the emerging digital society with its close co-evolution of information and communication technology (ICT) and society. They make current theories of crises and disasters applicable to the solution of global-scale problems, taking a data-based approach that builds on a serious collaboration between the natural, engineering, and social sciences, i.e. an interdisciplinary integration of knowledge.

Literature
Ball: Why Society Is A Complex Matter
• Helbing: Social Self-Organization
• Helbing: Managing Complexity
• Colander/Kupers: Complexity and the Art of Public Policy
• Mitchell: Complexity
• Buckley: Society – A Complex Adaptive System
• Castellani/Hafferty: Sociology and Complexity Science
• Mikhailov/Calenbuhr: From Cells to Society
• Mainzer: Thinking in Complexity
• Sawyer: Social Emergence
• Books published by the Santa Fe Institute

Computational Social Science
https://science.sciencemag.org/content/sci/323/5915/721.full.pdf

Manifesto of Computational Social Science
https://link.springer.com/article/10.1140/epjst/e2012-01697-8

Social Self-Organisation

How simple rules determine pedestrian behaviour and crowd disasters
https://www.pnas.org/content/108/17/6884.short

Peer review and competition in the Art Exhibition Game
https://www.pnas.org/content/113/30/8414.short

Generalized network dismantling
https://www.pnas.org/content/116/14/6554.short

Computational Social Science: Obstacles and Opportunities
https://science.sciencemag.org/content/369/6507/1060?rss=1=

Bit by Bit: Social Research in the Digital Age
https://www.amazon.co.uk/Bit-Social-Research-Digital-Age-ebook/dp/B072MPPFX2/

Further literature will be recommended in the lectures.

Prerequisites / notice
Students need to present a new subject, for which they have not earned any credit points before.

Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Chatham House rules apply to this course. Materials may not be shared without previous written permission.
Competencies  Subject-specific Competencies

Concepts and Theories  assessed
Techniques and Technologies  assessed

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Decision-making  fostered
Media and Digital Technologies  fostered
Problem-solving  fostered
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Social Competencies

Communication  assessed
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Advanced Topics in Evidence-Based Design for Architecture

Course requirements: Completion of the course Evidence-Based Design: Methods and Tools For Evaluating Architectural Design (851-0252-08L).

Abstract
Students will gain advanced knowledge and practical hands-on experience with agent-based simulations and spatial analysis tools to evaluate hospital layouts from the perspective of end-users.

Objective
Students will build on their previous projects as part of the course "Evidence-Based Design: Methods and Tools For Evaluating Architectural Design" (851-0252-08L). Students enrolled will participate in an international workshop with GSAPP at Columbia University Designing the post-pandemic hospital with evidence for people. The course is funded by an ETH innovemum project entitled cogARCH: linking cognition and architecture to design resilient hospitals architecture.

Complex Social Systems: Modeling Agents, Learning, and Games

Prerequisites: Basic programming skills, elementary probability and statistics.

Abstract
This course introduces mathematical and computational models to study techno-socioeconomic systems and the process of scientific research. Students develop a significant project to tackle techno-socio-economic challenges in application domains of complex systems. They are expected to implement a model and to communicate their results through a project report and a short oral presentation.

Objective
See your own field of study in a wider context ("Science in Perspective"), e.g. see the psychological, social, economic, environmental, historical, ethical, or philosophical connections and implications. Learn to think critically and out of the box. Question what you believe you know for sure. Get to know surprising, counterintuitive properties of complex (non-linearly interacting, networked, multi-component) systems. Learn about collaboration.

Content
By the end of the course, the students should be able to better understand the literature on complex social systems, develop their own models for studying specific phenomena and report results according to the standards of the relevant scientific literature by presenting their results both numerically and graphically.

At the end of the course, the students will deliver a report, computer code and a short oral presentation. To collect credit points, students will have to actively contribute and give a circa 30 minutes presentation in the course on a subject agreed with the lecturers, after which the presentation will be discussed. The presentation will be graded.

Students are expected to implement themselves models of techno-socio-economic processes and systems, particularly agent-based models, complex networks models, decision making, group dynamics, human crowds, or game-theoretical models. Credit points are finally earned for the implementation of a mathematical or empirical model from the complexity science literature, its presentation, and documentation by a project report.

Lecture notes
The lecture slides will be presented on the course Moodle after each lecture.

Literature
Agent-Based Modeling
https://link.springer.com/chapter/10.1007/978-3-642-24004-1_2

Social Self-Organization

Traffic and related self-driven many-particle systems
Reviews of Modern Physics 73, 1067
https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.73.1067

An Analytical Theory of Traffic Flow (collection of papers)
https://www.researchgate.net/publication/261629187

Pedestrian, Crowd, and Evacuation Dynamics
https://www.research-collection.ethz.ch/handle/20.500.11850/45424

The hidden geometry of complex, network-driven contagion phenomena (relevant for modeling pandemic spread)
https://science.sciencemag.org/content/342/6164/1337

Prerequisites / notice
The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.

Good programming skills and a good understanding of probability & statistics and calculus are expected.

Students need to present a new subject, for which they have not earned any credit points before.

Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Chatham House rules apply to this course. Materials may not be shared without previous written permission.
From Traffic Modeling to Smart Cities and Digital Democracies

Abstract
This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution.

Objective
To collect credit points, students must actively contribute and give an individual, circa 20-minute presentation in the seminar on a subject agreed upon with the lecturer. After the presentation, it will be discussed and graded.

Content
This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will also reflect on the question of how democracy could be digitally upgraded, and how citizen participation could contribute to innovation, sustainability, resilience, and quality of life. This includes questions around collective intelligence and digital platforms that support creativity, engagement, coordination and cooperation.

Literature
Dirk Helbing
- An Analytical Theory of Traffic Flow (collection of papers)
- Michael Batty, Kay Axhausen et al.
  - Smart cities of the future
- Books by Michael Batty:
  - How social influence can undermine the wisdom of crowd effect
- Evidence for a collective intelligence factor in the performance of human groups
- Optimal incentives for collective intelligence
- Collective Intelligence: Creating a Prosperous World at Peace
- Big Mind: How Collective Intelligence Can Change Our World
- Programming Collective Intelligence
- Urban architecture as connective-collective intelligence. Which spaces of interaction?
- Build digital democracy
- How to make democracy work in the digital age
- Digital Democracy: How to make it work?
- Proof of witness presence: Blockchain consensus for augmented democracy in smart cities
- Iterative Learning Control for Multi-agent Systems Coordination
- Decentralized Collective Learning for Self-managed Sharing Economies

Prerequisites / notice
Students need to present a new subject, for which they have not earned any credit points before.

Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Chatham House rules apply to this course. Materials may not be shared without previous written permission.
Humans and Social Networks in the Digital Age

Abstract
The digital transformation profoundly impacts humans and how they behave online and offline. Interactions in online social networks offer new opportunities (e.g., political movements, global cultural diffusion) and risks (e.g., fake news). In this seminar, we examine recent sociological and psychological research on how the digital transformation affects individuals and their social behaviors.

Objective
By the end of this seminar, students will be able to identify and compare different approaches in (online) social network research. They will be familiar with recent publications in the fields of social networks and computational social science and be able to critically participate in a number of open debates in these fields. Among others, these debates are centered around the types and measurement of social behavior in online and offline settings, ethical challenges in conducting social networks research, the effects of the digital transformation on people’s feelings, thoughts, preferences, and behaviors (e.g., digital mental health), and how online social and cultural phenomena emerge (e.g., the diffusion of culture and the spread of social movements).

Content
The digital transformation has made the “online world” increasingly important for the “offline world”. Hence, interactions in online social networks ultimately affect how people feel, think, behave and interact in offline settings. This course aims to present and structure open debates in online and offline social network research with a focus on social network processes, individual outcomes, and emergent phenomena. By taking a social networks perspective, we view individuals and their behavior in online and offline settings as part of a larger social environment and social phenomena as emerging from interrelated social behavior.

Data and Society

Abstract
This lecture series explores the multifaceted role of data in shaping contemporary society, governance, and individual lives. The course equips students with a critical understanding of how data is made, managed, and preserved, and its implications for societal norms and individual rights.

Objective
At the end of the term, students will be able to:
• reflect concepts and theories that capture the performativity of data
• reflect concepts and theories that capture the socio-technical nature of data
• assess the implications of data practices for social and political ordering
• identify key actors, sites, and domain contexts of data practices

AI Personhood, Social Justice, and Cross-Cultural Dialogues in the Digital Age

Abstract
The course fosters critical, culturally conscious reflection on AI development and regulation by 1) exploring cross-cultural assessment of the concept of personhood and collective in digital society and how these concepts are reflected in AI development and governance 2)inspiring reflection on social justice issues stemming from major (mis)conceptions of personhood in AI development and governance

Objective
• Understand and differentiate various concepts of personhood and collective in digital societies
• Critically evaluate emerging regulations in the field of AI
• Examine the implications of these regulatory frameworks and their conception of personhood for the AI human future
• Develop creative & culturally conscious analytical skill on issues of social justice in
On 13 March 2024, the European Parliament voted in favour of the long-awaited EU AI Act. On October 30, 2023, the US passed an Executive Order on the safe, secure, and trustworthy development and use of AI. Meanwhile, China has been adopting regulations: the 2021 regulation on recommendation algorithms, 2022 rules for deep synthesis (synthetically generated content), and draft rules on generative AI on August 15, 2023. In the face of this race to develop and regulate AI across various legal, regulatory, and cultural settings, this course exposes students to the overarching question: How can we envision an AI-human future that accommodates a pluriverse and ensures a just future?

In everyday life, from education, policy deliberation, planning and prediction, governance of the human behavior and the beyond human, to social and private life center and AI-enabled products play a significant role. At the very center of this sociotechnical system is the human, often referred to as the ‘data subject’. This raises foundational questions: Who or what is this ‘data subject’? What warrants its protection or what makes it worthy of protection – is it the human dignity, autonomy, rationality, legally protected rights or something beyond and within all these? Who/what is considered a protected ‘data subject’, and who/what is not? While these questions might seem new, they revisit old ethical dilemmas.

However, there is no one-fits-all answer to these questions. Responses vary greatly depending on local and cultural contexts across different jurisdictions and societies. The way AI development and regulatory practices conceptualize the subject of protection – that is, the human and its environ diverges, leading to varied interpretations of personhood and what warrants protection. What personhood means and what is protected and not are not only matters of policy or legislative interpretations and standardization but a matter of social justice.

With this consideration, the course invites and encourages students to explore the concept of personhood from a cross-cultural perspective, incorporating epistemologies from the ‘South’, including Afro-communitarianism, pluriverse theories, and Confucianism. Students are then guided to critically examine personhood and community within the context of competing AI regulatory frameworks, such as those in the EU, China, Brazil, and the US, as well as in their own interactions with AI systems. By identifying conceptual limitations in current understandings of personhood and the centrality of the collective within contemporary AI regulation and practice, students can address core social justice issues. These include the overemphasis on individualism, which overlooks the communal and relational aspects of existence (including human and the beyond human), the instrumentalization of the environment, and exploitative business models.

851-0455-00L Science, Trust and Politics

**Abstract**

The seminar aims to inspire a nuanced understanding of the dynamics of expertise in society. Cross-fertilizing literature from science and technology studies (STS) and from activists’ movements, it focuses on contemporary controversies around emerging technologies and climate policy, where trust in science is said to be undermined (e.g., through climate skepticism or anti-vaccine movements).

**Objective**

1. Introduce to the role and functions of expertise in democratic societies.
2. Familiarize with assumptions about science and society embedded in contemporary controversies.
3. Inspire critical perspectives on (dis)trust in science through activists’ movements on contested environmental and technological issues.
4. Develop a creative position on the relations between science, trust and politics.

**Content**

Engineers and scientists often pursue their studies and research in the hope that their knowledge can contribute to make a better world, to reflect on expertise as a form of scientific engagement in the messiness of democratic deliberation and public life, beyond the noble but outdated ideal of “speaking truth to power.” The exercise of expertise is stumbling upon several conundrums. Which knowledge is relevant in which situation? How to make sure that what personhood means and what is protected and not are not only matters of policy or legislative interpretations and standardization but a matter of social justice.

Whereas opposing technological developments (anti 5G or anti-vaccine activists) or pushing to act accordingly to science (pro climate change or pro COVID-19 activists), activists’ movements make up for a rich field of investigation on the dynamics of expertise and of how various publics can make sense of scientific knowledge. Cross-fertilizing activist’s texts and experiences with literature in science and technology studies and anthropology, this class will be organized as a structured conversation and a collective mapping of actors and key concepts of sociotechnical controversies. Over the course of the semester, students will learn not only to navigate some of the most heated contemporary debates, but also to articulate their own position on an issue of their choice.
Abstract
This course is intended to demonstrate how environmental decisions can be optimized and conflicts better dealt with by using mediation. Case studies will focus on construction of windmills for electricity purpose, landfills, sustainable city-planning or Human-Wildlife Conflict and Coexistence.

Objective
- Develop comprehension of legal and social responses to environmental conflicts
- Recognize the most important participative techniques and their ranges
- Develop concepts for doing and evaluating mediation processes
- Estimate the potential and limitations of cooperative environmental planning
- Train communicative skills (presentation, moderation, discussion design, negotiation), especially by participating at a mediation

Content
To this end, we will look at the most important techniques of mediation and put them into the context of today's legislation, participation and conflict culture. The potential and limitations of the individual techniques will be discussed using current Swiss and international case studies, namely in the field of windenergy as well as of landfills and Human-Wildlife Conflict and Coexistence (wolves, bears, elephants). Students can do conflict analyses, for instance, as part of individual and group analyses and a half-day mediation-simulation, develop technique concepts and train their own communicative and negotiation skills.

Lecture notes
A reader will be handed out.

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Science Research

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<tr>
<td>851-0020-00L</td>
<td>Gender and Science</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>E. Valdameri</td>
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Abstract
This lecture series offers an introduction to the relationship between gender and science, with a focus on the specific intersections with the sciences taught at ETH.

Objective
This lecture series is designed to acquaint students from all levels and departments with the various ways in which gender perspectives matter for specific scientific disciplines, as well as for science in general. Students will learn to recognize and analyse the specific ways in which scientific theories and methods are gendered. They will be able to discuss and reflect how these topics are connected to their own scientific disciplines.

Content
There is agreement across academic disciplines today that gender influences and structures the production of knowledge and that scientific knowledge production in turn shapes gender notions. Even within "hard" sciences such as mathematics, physics, engineering, etc., gender is a significant factor in determining what counts as "objective" knowledge, who can know it, what kind of knowledge is produced, or how this knowledge is acquired and justified. Feminist research aims to reveal how dominant conceptions of science and knowledge practices disadvantage women*, and other subordinate groups, with the goal of re-forming these practices. An important part of feminist critique is to show that such efforts substantially improve the overall quality of research.

The semester will start with two introductory lectures acquainting students with research questions in the field of Gender and Science by summarizing its key concepts and methods. It will then continue as a series of weekly guest lectures by scholars from different scientific disciplines that provide accessible insights into the intersection between gender studies and the guest lecturer's research field. Students will thereby be encouraged to learn from concrete examples rather than abstract theory. The goal is for students to understand how to apply concepts and methods of gender studies to their particular disciplines. Intermediate discussions with the students will provide a forum for critically reflecting the content of the lectures and the connections to their own academic fields and practices.

All lectures by the guest speakers will also be open to the broader ETH public, while the introductory and discussion sessions are only for registered course participants.

Type B: Reflection About Subject-Specific Methods and Contents
Subject-specific courses. Particularly relevant for students interested in those subjects.

D-ARCH

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<tr>
<td>851-0703-00L</td>
<td>Introduction to Law</td>
<td>W</td>
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Abstract
This class introduces students into basic features of the legal system. Fundamental issues of constitutional law, administrative law, private law and the law of the EU are covered. The focus is on legal problems related to space. Active participation is expected in short interactive sequences.

Objective
Students are able to identify basic structures of the legal system. They understand selected topics of public and private law. They are able to apply the fundamentals in more advanced law classes and to recognize the relevance of law in their own field.

Content
Basic concepts of law, sources of law, private law: Contract law (particularly contract for work and services), tort law, property law. Public law: Human rights, administrative law, procurement law, procedural law.

Lecture notes
Jaap Hage, Bram Akkermans (Eds.), Introduction to Law, Cham 2017 (Online Resource ETH Library)

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851-0742-00L Contract Design I
You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for "Contract Design I (851-0742-00L; Fall 2023)" and enroll. The
It is NOT a legal drafting class focused on contractual language.

Number of participants limited to 160.
Max 80 ETHZ and 80 UZH Students

Abstract
Contract Design I is taught by Professor Stremitzer and aims to bridge the gap between economic contract theory, contract law, and the writing of real-world contracts. In this course, we take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction takes place and then engineer contracts that achieve the desired outcome.

Objective
Contracts are agreements between parties to engage in transactions. A good contract creates value by giving parties the right incentives to meet their objectives. A good contract designer scrutinizes the economic situation in which parties find themselves and tailors the contract to the challenges at hand. To help you become sophisticated contract designers, we draw from insights for which more than half a dozen Nobel Prizes were awarded in the past two decades and transfer them to the art of writing real-world contracts. In other words, Contract Design will provide you with analytical tools to design contracts that help you be better lawyers, business leaders, and startup founders.

We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting and apply the theoretical insights to real-life case studies ranging from purchases & sales of assets, oil & gas exploration, movie financing, production & distribution, construction & development, M&A deals, venture capital financing, to executive compensation and many other types of transactions.

The course follows a flipped-classroom model: You will watch learning videos specifically produced for this course ahead of class. We will use class time to discuss real-world case studies. The videos will be made available before the lecture each week and need to be watched ahead of coming to class. Computer-graded quizzes at the beginning of each class will test students’ understanding of the concepts introduced in the videos.

As the emphasis of this class is on class discussion, attendance is mandatory. Absent important reasons, you cannot miss class more than twice.

The lectures will be recorded but only made available to those who miss lectures with excused absence.

For ETH students: Your grade will consist of two parts:
1) You will take weekly computer-based quizzes during class time. Thus, it is important that you attend the lectures to be able to finish the quizzes and pass this course.
2) You compose short responses to take-home questions on case studies we assign and upload them ahead of class (Pass/Fail).

Note that UZH and UNISG students enrolling in this course need to earn more ECTS for completing this course than ETH students (due to curricula reasons). This is why UZH and UNISG students must complete a written assignment in addition to the weekly quizzes and take-home questions. UZH students also have to complete an additional group project.

UZH and UNISG students should check out the description of the class at their respective home institutions.

Prerequisites / notice
Attendance is mandatory. You are only allowed to miss two lectures unless there are special circumstances.

Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, D-MATH, D-MTEC, D-INFK, and D-MAVT.

If you have any questions regarding the course, please write an email to the teaching assistants, Lucas Gericke (lucas.gericke@gess.ethz.ch) or Serge von Steiger (serge.vonsteiger@gess.ethz.ch).

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851-0703-04L Law and Urban Space

Abstract
Legal rules are tied to urban space. Illustrative is the relation between land ownership and urban morphology. Legal concepts with spatial impacts are introduced and related to the theory of urban design. Moreover, it is discussed how these concepts shape specific places. The course includes interactive sequences for which active participation is expected.

Objective
Moreover, they are able to compare legally binding targets with theoretical approaches in urban design. By analysing a specific place, students learn to find relevant norms, to analyse and to judge them with regard to urban design theories. Thereby, they are able to distinguish design and policy questions.

Content
Using the the term «landscape» (Philippopoulos-Mihalopoulos), we initially discuss general aspects of the interplay between legal rules and urban space. In the following weeks we consider the interplay with reference to different dimensions of urban space (e.g. morphological, social, functional dimension).

Lecture notes
See Literature.

Literature
Documents will be available online (see https://moodle-app2.let.ethz.ch/course/view.php?id=20128).

Prerequisites / notice
Number of participants limited to: 40

Competencies

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Space Planning Law and Environment

**Objective**
Basic understanding of nature and function of space planning from a legal point of view. Basic knowledge of space planning instruments, relationship between space planning and constitutional law (especially property rights), solving of practical cases.

**Abstract**
System of swiss planning law, Constitutional and statutory provisions, Space planning and fundamental rights, Instruments, Application, legal protection, enforcement, Practical training.

**Content**

**Competencies**

- **Concepts and Theories**
  - Concepts and Theories

- **Analytical Competencies**
  - Analytical Competencies

- **Decision-making**
  - Decision-making

- **Problem-solving**
  - Problem-solving

**Social Competencies**
- Communication

**Personal Competencies**
- Creative Thinking
- Critical Thinking

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Human-Computer Interaction: Cognition and Usability

**Objective**
Presentations will cover the basics of human-computer interaction and selected topics:

- History of HCI
- Research ethics
- Literature reviews
- Participant-free methods: cognitive walkthrough and heuristic evaluation
- Card sorting and information architecture
- Usability studies
- Unmoderated research and diary studies
- Surveys
- User Logs and metric frameworks

On a weekly basis, students will conduct authentic research in class covering the topics above. They will submit their in-class research results regularly and also present their findings to the class once per semester.

The final project demonstrates class topic adoption by deeply exploring one HCI problem using the covered methods and tools. Students will choose a research topic and execute their research plan. They will individually write a formal report including problem definition, literature review, methodology, findings and discussion.

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Evidence-Based Design: Methods and Tools for Evaluating Architectural Design

**Objective**
The course aims to teach students how to evaluate a design project from the perspective of the end user. The concept of evidence-based design is introduced, and complemented with theoretical background on space syntax and spatial cognition. This is a project-oriented course, students implement a range of methods on a sample project. The course is tailored for architecture design students.

**Abstract**
Students are taught a variety of analytic techniques that can be used to evaluate architectural design. The concept of evidence-based design is introduced, and complemented with theoretical background on space syntax and spatial cognition, with a view to applying this knowledge during the design process. The course covers a range of methods including visibility analysis, network analysis, conducting real-world observations, and virtual reality for architectural design. Students apply these methods to a case study of their choice, which can be at building or urban scale. For students taking a B-ARCH or M-ARCH degree, this can be a completed or ongoing design studio project. The course gives students the chance to implement the methods iteratively and explore how best to address the needs of the eventual end-user during the design process.

The course is tailored for students studying for B-ARCH and M-ARCH degrees. As an alternative to obtaining D-GESS credit, architecture students can obtain course credit in "Vertiefungsfach" or "Wahlfach".

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Real Estate Property Law

**Objective**
The legal principles of real estate property law can be correctly interpreted and applied in daily life.

**Abstract**
Real estate property law (esp. content, acquisition, restrictions under private and public law, transmission and loss). Legal presentation: land register, surveying, cadastrre. Basic questions of contract and tax law.

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**Data:** 15.06.2024 12:39  **Autumn Semester 2024**  **Page 2592 of 2653**
This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will also reflect on the question of how democracy could be digitally upgraded, and how citizen participation could contribute to innovation, sustainability, resilience, and quality of life. This includes questions around collective intelligence and digital platforms that support creativity, engagement, coordination and cooperation.

### Literature

- Adrian Mühlematter / Stephan Stucki: Grundbuchrecht für die Praxis, Zürich 2016
- Wolfgang Ernst / Samuel Zogg: Sachenrecht in a nutshell, Zürich 2020
- Jörg Schmid / Bettina Hürlimann-Kaup: Sachenrecht, Zürich 2017
- Meinrad Huser, Schweizerisches Vermessungsrecht, unter besonderer Berücksichtigung des Geoinformationsrecht und des Grundbuchrechts, Zürich 2014
- Meinrad Huser, Geo-Informationsrecht, Rechtlicher Rahmen für Geographische Informationssysteme, Zürich 2005
- Meinrad Huser, Darstellung von Grenzen zur Sicherung dinglicher Rechte, in ZBGR 2013, 238 ff.

### Competencies

**Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

**Social Competencies**
- Communication: fostered
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: fostered
- Sensitivity to Diversity: assessed
- Negotiation: assessed

**Personal Competencies**
- Adaptability and Flexibility: fostered
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: fostered

### Prerequisites / notice

Students need to present a new subject, for which they have not earned any credit points before.

Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Chatham House rules apply to this course. Materials may not be shared without previous written permission.
Building practices have often been associated with utopian visions and promises of a more just way of living together. But to what extent are we to understand ethics in general if it is to respond to such questions. The question is on the extent to which the built environment takes on ethical significance for human (and other) forms of life, and how can the built environment contribute to a better society? What role can mathematical models or data analyses play in questions of distributive justice in the city? Is it ever possible to build sustainably, or is building always also destroying the environment?

The course introduces students to the ethical, political and legal debates and transformations in relation to Artificial Intelligence and provides students with concepts and methods from the constructivist and interpretive social sciences to work towards responsible and democratic human-technology futures.

The main objectives of the course are to enable students to 1) identify the ways in which human values and developments of AI technologies are entangled, 2) articulate what is significant about contemporary transformations in AI and society, and 3) participate and shape the relationship between human values and AI as citizens and professionals.

The growing presence of AI tools for public use, for public administration, inside corporations and in scientific research raises many questions about the ethical, political, legal consequences of these technologies. This course is built around multiple sites of encounter among human values and AI, including bodies, persons, cities, labs, law, and environment. In each site, we inquire about what and whose values are being prioritized and with what consequences. The course also investigates existing best-practices around how to "align" human values with AI (e.g. human-centric design, alignment, reproducibility, transparency, explainability) and introduces students to regimes of ethics and governance of AI being proposed in jurisdictions around the world. Students learn to unpack the values and assumptions in existing techniques and frameworks for the design and governance of AI and to engage constructively with diverse stakeholders to shape the human-technology future towards aims that are reflexive, responsible, and democratic.

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The course introduces students to the ethical, political and legal debates and transformations in relation to Artificial Intelligence and provides students with concepts and methods from the constructivist and interpretive social sciences to work towards responsible and democratic human-technology futures.

The main objectives of the course are to enable students to 1) identify the ways in which human values and developments of AI technologies are entangled, 2) articulate what is significant about contemporary transformations in AI and society, and 3) participate and shape the relationship between human values and AI as citizens and professionals.

The growing presence of AI tools for public use, for public administration, inside corporations and in scientific research raises many questions about the ethical, political, legal consequences of these technologies. This course is built around multiple sites of encounter among human values and AI, including bodies, persons, cities, labs, law, and environment. In each site, we inquire about what and whose values are being prioritized and with what consequences. The course also investigates existing best-practices around how to "align" human values with AI (e.g. human-centric design, alignment, reproducibility, transparency, explainability) and introduces students to regimes of ethics and governance of AI being proposed in jurisdictions around the world. Students learn to unpack the values and assumptions in existing techniques and frameworks for the design and governance of AI and to engage constructively with diverse stakeholders to shape the human-technology future towards aims that are reflexive, responsible, and democratic.
This seminar introduces students to theory and research, challenges, and opportunities in neuroaesthetics, with a clear emphasis on the interdisciplinary nature of the discipline situated at the intersection of neuroscience, psychology, and art appreciation. Foundational empirical methods and critical perspectives of research approaches in neuroaesthetics are considered.

Objective
- to familiarize students with concepts, models, methods, brain and behavioral findings related to aesthetic experience.
- to develop a critical understanding in evaluating the theoretical and empirical findings in neuroaesthetics
- to integrate the acquired knowledge to critically debate and discuss the conceptual and empirical issues related to the science of aesthetic experience

Content
In this seminar, students will learn about the foundational principles of neuroaesthetics, which explores the cognitive and brain processes involved in aesthetic experience. A key focus will be placed on developing an appreciation of the interdisciplinary methods used in the neuroaesthetics field – ranging from neuroscience, psychology, philosophy, and art history. The seminar is based on the active engagement of students in reading, presenting, and critically discussing selected papers in the field. In a final small-group assignment, students are expected to incorporate and elaborate upon the content covered in the seminar by presenting and discussing a novel research proposal for tackling a timely research question related to aesthetic experience.
### Contract Design I

**851-0742-00L**

**Contract Design I**

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for “Contract Design I (851-0742-00L; Fall 2023)” and enroll. The password is “ContractDesign01”.

It is NOT a legal drafting class focused on contractual language.

**Number of participants limited to 160. Max 80 ETHZ and 80 UZH Students**

**Abstract**

Contract Design I is taught by Professor Stremitzer and aims to bridge the gap between economic contract theory, contract law, and the writing of real-world contracts. In this course, we take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction takes place and then engineer contracts that achieve the desired outcome.

**Objective**

Contracts are agreements between parties to engage in transactions. A good contract creates value by giving parties the right incentives to meet their objectives. A good contract designer scrutinizes the economic situation in which parties find themselves and tailors the contract to the challenges at hand. To help you become sophisticated contract designers, we draw from insights for which more than half a dozen Nobel Prizes were awarded in the past two decades and transfer them to the art of writing real-world contracts. In other words, Contract Design will provide you with analytical tools to design contracts that help you be better lawyers, business leaders, and startup founders.

We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting and apply the theoretical insights to real-life case studies ranging from purchases & sales of assets, oil & gas exploration, movie financing, production & distribution, construction & development, M&A deals, venture capital financing, to executive compensation and many other types of transactions.

The course follows a flipped-classroom model: You will watch learning videos specifically produced for this course ahead of class. We will use class time to discuss real-world case studies. The videos will be made available before the lecture each week and need to be watched ahead of coming to class. Computer-graded quizzes at the beginning of each class will test students’ understanding of the concepts introduced in the videos.

As the emphasis of this class is on class discussion, attendance is mandatory. Absent important reasons, you cannot miss class more than twice.

The lectures will be recorded but only made available to those who miss lectures with excused absence.

For ETH students: Your grade will consist of two parts:
1. You will take weekly computer-based quizzes during class time. Thus, it is important that you attend the lectures to be able to finish the quizzes and pass this course.
2. You compose short responses to take-home questions on case studies we assign and upload them ahead of class (Pass/Fail).

Note that UZH and UNISG students enrolling in this course need to earn more ECTS for completing this course than ETH students (due to curricula reasons). This is why UZH and UNISG students must complete a written assignment in addition to the weekly quizzes and take-home questions. UZH students also have to complete an additional group project.

UZH and UNISG students should check out the description of the class at their respective home institutions.

**Lecture notes**

Handouts, prerecorded videos, slides, case studies, and other materials available on a dedicated webpage: contractdesign.org. Access to this webpage is free of charge for ETH students as ETH purchased a license for ETH students.

As the emphasis of this class is on class discussion, attendance is mandatory. Absent important reasons, you cannot miss class more than twice.

The lectures will be recorded but only made available to those who miss lectures with excused absence.

For ETH students: Your grade will consist of two parts:
1. You will take weekly computer-based quizzes during class time. Thus, it is important that you attend the lectures to be able to finish the quizzes and pass this course.
2. You compose short responses to take-home questions on case studies we assign and upload them ahead of class (Pass/Fail).

Note that UZH and UNISG students enrolling in this course need to earn more ECTS for completing this course than ETH students (due to curricula reasons). This is why UZH and UNISG students must complete a written assignment in addition to the weekly quizzes and take-home questions. UZH students also have to complete an additional group project.

UZH and UNISG students should check out the description of the class at their respective home institutions.

**Prerequisites / notice**

Attendance is mandatory. You are only allowed to miss two lectures unless there are special circumstances.

Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, DMATH, D-MTEC, D-INF, and D-MAVT.

If you have any questions regarding the course, please write an email to the teaching assistants, Lucas Gericke (lucas.gericke@gess.ethz.ch) or Serge von Steiger (serge.vonsteiger@gess.ethz.ch).

**Competencies**

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<thead>
<tr>
<th>Subject-specific Competencies</th>
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**Space Planning Law and Environment**

**851-0707-00L**

**Space Planning Law and Environment**

Particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, DMATH, D-MTEC, D-INF, and D-MAVT.

**Abstract**

System of swiss planning law, Constitutional and statutory provisions, Space planning and fundamental rights, Instruments, Application, legal protection, enforcement, Practical training.

**Objective**

Basic understanding of nature and function of space planning from a legal point of view. Basic knowledge of space planning instruments, relationship between space planning and constitutional law (especially property rights), solving of practical cases.
Content

Lecture notes
Haller, Walter/Karlen, Peter, Raumplanung-, Bau- und Umweltrecht, 3.A., Zürich 1999
Hänni, Peter, Planungs-, Bau- und besonderes Umweltschutzrecht, 7.A., Bern 2021

Competencies
Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Problem-solving assessed

Social Competencies
- Communication assessed

Personal Competencies
- Creative Thinking assessed
- Critical Thinking assessed

Environmental Ethics (University of Zurich)
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
UZH Module Code: 07SMEEE266
Please register at: https://www.uzh.ch/cmsssl/de/studies/application/chmobilit yin.html
after you received your logon information you can enrol to courses at: https://studentservices.uzh.ch/uzh/application/#/Logon
Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html

Abstract
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.

Objective
On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

Global History of Urban Design I

Abstract
This course focuses on the history of the design of cities, as well as on the ideas, processes and actors that engender and lead their development and transformation. The history of urban design will be approached as a cross-cultural field of knowledge that integrates scientific, economic and technical innovation as well as social and cultural advances.

Objective
The lectures deal mainly with the definition of urban design as an independent discipline, which maintains connections with other disciplines (politics, sociology, geography) that are concerned with the transformation of the city. The aim is to make students conversant with the multiple theories, concepts and approaches of urban design as they were articulated throughout time in a variety of cultural contexts, thus offering a theoretical framework for students’ future design work.

Content
In the first semester the genesis of the objects of study, the city, urban culture and urban design, are introduced and situated within their intellectual, cultural and political contexts:

01. The History and Theory of the City as Project
02. Of Rituals, Water and Mud: The Urban Revolution in Mesopotamia and the Indus
03: The Idea of the Polis: Rome, Greece and Beyond
04: The Long Middle Ages and their Counterparts: From the Towns of Tuscany to Delhi
05: Between Ideal and Laboratory: Of Middle Eastern Grids and European Renaissance Principles
06: Of Absolutism and Enlightenment: Baroque, Defense and Colonization
07: The City of Labor: Company Towns as Cross-Cultural Phenomenon
08: Garden Cities of Tomorrow: From the Global North to the Global South and Back Again
09: Civilized Wilderness and City Beautiful: The Park Movement of Olmsted and The Urban Plans of Burnham
10: The Extension of the European City: From the Viennese Ringstrasse to Amsterdam Zuid

Lecture notes
Prior to each lecture a chapter of the reader (Skript) will be made available through the webpage of the Chair. These chapters will provide an introduction to the lecture, the basic visual references of each lecture, key dates and events, as well as references to the compulsory and additional reading.

Literature
There are three books that will function as main reference literature throughout the course:


These books will be reserved for consultation in the ETH Baubibliothek, and will not be available for individual loans.

A list of further recommended literature will be found within each chapter of the reader (Skript).

Prerequisites / notice
Students are required to familiarize themselves with the conventions of architectural drawing (reading and analyzing plans at various scales).
Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making fostered
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork assessed
Leadership and Responsibility fostered
Self-presentation and Social Influence assessed
Sensitivity to Diversity assessed
Negotiation fostered

Personal Competencies
Creative Thinking fostered
Critical Thinking assessed
Integrity and Work Ethics fostered

851-0724-01L Real Estate Property Law

Particularly suitable for students of D-ARCH, D-BAUG, D-USYS.

W 3 credits 3V S. Stucki, R. Müller-Wyss

Abstract
Real estate property law (esp. content, acquisition, restrictions under private and public law, transmission and loss). Legal presentation: land register, surveying, cadastre. Basic questions of contract and tax law.

Objective
The legal principles of real estate property law can be correctly interpreted and applied in daily life.

Content
Real estate property law (esp. content, acquisition, restrictions under private and public law, transmission and loss). Legal presentation: land register, surveying, cadastre. Basic questions of contract and tax law.

Lecture notes
Abgegebene Unterlagen: Skript in digitaler Form

Literature
- Adrian Mühlematter / Stephan Stucki: Grundbuchrecht für die Praxis, Zürich 2016
- Wolfgang Ernst / Samuel Zogg: Sachenrecht in a nutshell, Zürich 2020
- Jörg Schmid / Bettina Hürlimann-Kaup: Sachenrecht, Zürich 2017
- Meinrad Huser, Schweizerisches Vermessungsrecht, unter besonderer Berücksichtigung des Geoinformationsrecht und des Grundbuchrechts, Zürich 2014
- Meinrad Huser, Geo-Informationsrecht, Rechtlicher Rahmen für Geographische Informationssysteme, Zürich 2005
- Meinrad Huser, Darstellung von Grenzen zur Sicherung dinglicher Rechte, in ZBGR 2013, 238 ff.

Competencies

Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies fostered
Problem-solving assessed
Project Management fostered

Social Competencies
Communication fostered
Cooperation and Teamwork assessed
Customer Orientation assessed
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity assessed
Negotiation assessed

Personal Competencies
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management fostered

851-0763-00L Supervised Research (Law, Economics, and Data Science)

Does not take place this semester.

Abstract
This is a supervised student project for 3 ECTS, supervised by the professorship of Elliott Ash (D-GESS). Students will adapt tools from econometrics and machine learning to questions in law, data science, and social science.

Objective
Students must have some data science and/or statistics experience. Some programming experience in Python, Stata, or R is required.

Prerequisites / notice
Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2598 of 2653
This course introduces students to scientific and technological developments that require regulation or enable legal innovation. We focus particularly on the challenges to current law posed by prominent near-future technologies.

The planned course outline is below.

### Competencies

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**851-0732-06L**  
**Law & Tech**  
**W 3 credits 2S**  
**A. Stremitzer, J. Merane**  
**Objective**  
This course introduces students to scientific and technological developments that require regulation or enable legal innovation. We focus particularly on the challenges to current law posed by prominent near-future technologies.

The planned course outline is below.

- Overview of Law and Technology
- Fundamental Rights
- AI & Discrimination
- Landmark Big Tech Cases
- Regulation of Digital Platforms & Content Moderation
- Online Consumer Protection
- Law and Tech Scholarship Series

A number of recent regulations will be discussed, including the EU's AI Act, the Digital Services Act (DSA), and the Digital Markets Act (DMA), as well as emerging internet phenomena, like ChatGPT.

**Prerequisites / notice**  
You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for “Law & Tech (851-0732-06L, HS 2024)” and enroll.

**Content**  
The course is open to ETH students through the Science in Perspective program of the Department of Humanities, Social and Political Sciences.

**376-1661-00L**  
**Ethics of Life Sciences and Biotechnology**  
**W 3 credits 2V**  
**A. Blasimme, E. Vayena**  
**Abstract**  
This semester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their technological application. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences.

**Objective**  
This course is tailored to students who want to become familiar with the analysis of ethical issues in all the different domains of life sciences and biotechnology. The course aims at equipping students with the necessary knowledge and analytic skills to understand, discuss and address the ethical aspects of science and technology in the domain of human health. The specific learning objectives of this course are:

A. Identify ethical issues in in life sciences and biotechnology.
B. Analyze and critically discuss ethical issues in life sciences and biotechnology.
C. Become aware of relevant legal and public policy frameworks.
D. Distinguish different ethical approaches and argumentative strategies in applied ethics.
E. Recognize how ethical issues relate to different accounts of technology and innovation.
F. Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
G. Autonomously anticipate ethical issues.
H. Propose and communicate solutions to ethical challenges and dilemmas.
The course starts off with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain of applied ethics. The students will also be introduced to current theoretical accounts of technology and will start to appreciate the relevance of ethics especially with respect to new and emerging technologies. Usable analytic tools will also be provided, thus enabling the students to engage with the discipline in a practical way from the very onset of the semester.

The course will continue with thematic sessions covering a broad variety of topics all of which are relevant to the different study tracks offered by the department. In particular, the course will cover the following domains: digital health technologies and medical AI; food, nutrition and healthy longevity; biomedical engineering; genetics; neuroscience and Neurotechnologies; medical robotics; disability and rehabilitation; environmental ethics. The course will also include sessions on cross-cutting ethically relevant aspects of health sciences and technologies, namely: access to innovation, translational research, and the relation between science and public policy.

All the topics of the course will be illustrated and interactively discussed through many case studies, offering the students the opportunity to prepare and present them, and to use them in individual as well as group exercises. Throughout the course, the students will have multiple opportunities to experiment with ethical argumentation and to practice their evolving skills.

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**851-0763-00L Supervised Research (Law, Economics, and Data Science)**

Abstract

This is a supervised student project for 3 ECTS, supervised by the professorship of Elliott Ash (D-GESS). Students will adapt tools from econometrics and machine learning to questions in law, data science, and social science.

Objective

Students must have some data science and/or statistics experience. Some programming experience in Python, Stata, or R is required.

Prerequisites / notice

Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

**851-0157-28L Life and Death**

Abstract

This course explores the relation between the scientific investigation of life and cultural notions of death from a historical perspective (assuming there is no such thing as the scientific investigation of death). While the course covers the times from antiquity up to the present, the main emphasis will be placed on the modern life sciences since the 19th century.

Objective

There is only one certainty in life: death. This brute fact has animated much thought and work in theology, art and philosophy - but also in the natural sciences, such as biology and medicine. Questions regarding health and disease, evolution, extinction and immortality have played a crucial role in this connection. This course aims to explore above relations - the relations between the scientific investigation of life and cultural notions of death - from a historical perspective (assuming there is no such thing as the scientific investigation of death). While the course covers the times from antiquity up to the present, the main emphasis will be placed on the modern life sciences since the 19th century.

**851-0272-00L The Cutting Edge of Social Brain Imaging**

Abstract

This seminar introduces the fundamentals and latest research developments of brain imaging in real-world contexts. We explore topics from imaging multiple people’s brains simultaneously as they interact to neuro-ethics and neuro-art, while maintaining a strong focus on critical evaluation of research practices and applications of brain imaging of and during social interaction.

Objective

- To familiarize students with current concepts, theories, methods, and findings from social brain-imaging sciences
- To develop a critical view of extant findings and the tools for evaluating the quality of evidence and data, as well as ethical implications

Content

Rapid advances in the technologies and empirical approaches used in imaging the human brain have opened exciting windows into how the human brain coordinates social interaction. These advances include imaging the brain’s function during real social interactions, training behaviours with feedback based on real-time brain activity, and even generating art directly from brain signals. With them, these advances have brought novel ethical implications regarding their implementation in research and potentially, their use by the public, for both therapeutic and possible “neurohacking” applications. In this seminar, students will be introduced to various neuroimaging approaches for social neuroscience generally, as well as to approaches for measuring social brain function in real life, and will gain insights into related ethical considerations.

The seminar builds on the active participation of students in reading, presenting, and critically discussing selected papers in the field. In a final small-group assignment, students are required to integrate and elaborate upon topics covered in the seminar by presenting and debating a novel research proposal for addressing a timely research question related to the use of brain imaging in the context of social interactions. No prior experience or knowledge in brain imaging is required.
Abstract
This seminar introduces students to theory and research, challenges, and opportunities in neuroaesthetics, with a clear emphasis on the interdisciplinary nature of the discipline situated at the intersection of neuroscience, psychology, and art appreciation. Foundational empirical methods and critical perspectives of research approaches in neuroaesthetics are considered.

Objective
- to familiarize students with concepts, models, methods, brain and behavioral findings related to aesthetic experience.
- to develop a critical understanding in evaluating the theoretical and empirical findings in neuroaesthetics.
- to integrate the acquired knowledge to critically debate and discuss the conceptual and empirical issues related to the science of aesthetic experience.

Content
In this seminar, students will learn about the foundational principles of neuroaesthetics, which explores the cognitive and brain processes involved in aesthetic experience. A key focus will be placed on developing an appreciation of the interdisciplinary methods used in the neuroaesthetics field – ranging from neuroscience, psychology, philosophy, and art history. The seminar is based on the active engagement of students in reading, presenting, and critically discussing selected papers in the field. In a final small-group assignment, students are expected to incorporate and elaborate upon the content covered in the seminar by presenting and discussing a novel research proposal for tackling a timely research question related to aesthetic experience.

Competencies
Subject-specific Competencies
- Concepts and Theories fostered
- Techniques and Technologies fostered

Method-specific Competencies
- Analytical Competencies fostered
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving fostered
- Project Management fostered

Social Competencies
- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking assessed
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management assessed

851-0738-01L The Role of Intellectual Property in the Engineering and Technical Sector

Abstract
The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.
In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

Objective

The lecture addresses students in the fields of engineering, science and other related technical fields.

Prerequisites / Competencies

Subject-specific Competencies
Concepts and Theories
- analyzed

Method-specific Competencies
Problem-solving
- analyzed

Personal Competencies
Critical Thinking
- analyzed

Self-awareness and Self-reflection
- assessed

851-0783-00L Supervised Research (Law, Economics, and Data Science) W 3 credits E. Ash

Does not take place this semester.

Abstract

This is a supervised student project for 3 ECTS, supervised by the professorship of Elliott Ash (D-GECS). Students will adapt tools from econometrics and machine learning to questions in law, data science, and social science.

Prerequisites / notice

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

Objective

Apply tools from data science and social science to a new project, potentially in a group, to develop a paper or app.

Prerequisites / notice

Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

Number of participants limited to 160.

Max 80 ETHZ and 80 UZH Students

Contract Design I is taught by Professor Stremitzer and aims to bridge the gap between economic contract theory, contract law, and the writing of real-world contracts. In this course, we take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction takes place and then engineer contracts that achieve the desired outcome.

Contracts are agreements between parties to engage in transactions. A good contract creates value by giving parties the right incentives to meet their objectives. A good contract designer scrutinizes the economic situation in which parties find themselves and tailors the contract to the challenges at hand. To help you become sophisticated contract designers, we draw from insights for which more than half a dozen Nobel Prizes were awarded in the past two decades and transfer them to the art of writing real-world contracts. In other words, Contract Design will provide you with analytical tools to design contracts that help you be better lawyers, business leaders, and startup founders.

We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting and apply the theoretical insights to real-life case studies ranging from purchases & sales of assets, oil & gas exploration, movie financing, production & distribution, construction & development, M&A deals, venture capital financing, to executive compensation.

The course follows a flipped-classroom model: You will watch learning videos specifically produced for this course ahead of class. The videos will be made available before the lecture each week and need to be watched ahead of coming to class. Computer-graded quizzes at the beginning of each class will test students' understanding of the concepts introduced in the videos.

As the emphasis of this class is on class discussion, attendance is mandatory. Absent important reasons, you cannot miss class more than twice.

The lectures will be recorded but only made available to those who miss lectures with excused absence.

For ETH students: Your grade will consist of two parts:
1) You will take weekly computer-based quizzes during class time. Thus, it is important that you attend the lectures to be able to finish the quizzes and pass this course.
2) You compose short responses to take-home questions on case studies we assign and upload them ahead of class (Pass/Fail).

Note that UZH and UNISG students enrolling in this course need to earn more ECTS for completing this course than ETH students (due to curricula reasons). This is why UZH and UNISG students must comprise a written assignment in addition to the weekly quizzes and take-home questions. UZH students also have to complete an additional group project.

UZH and UNISG students should check out the description of the class at their respective home institutions.

Lecture notes

Handouts, prerecorded videos, slides, case studies, and other materials available on a dedicated webpage: contractdesign.org. Access to this webpage is free of charge for ETH students as ETH purchased a license for ETH students.
Prerequisites / notice

Attendance is mandatory. You are only allowed to miss two lectures unless there are special circumstances.

Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, D-MATH, D-MTEC, D-INFK, and D-MAVT.

If you have any questions regarding the course, please write an email to the teaching assistants, Lucas Gericke (lucas.gericke@gess.ethz.ch) or Serge von Steiger (serge.vonsteiger@gess.ethz.ch).

Competencies

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<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Analytical Competencies</td>
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<td>Decision-making</td>
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<tr>
<td>Personal Competencies</td>
<td>Creative Thinking</td>
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851-0738-01L The Role of Intellectual Property in the Engineering and Technical Sector

Abstract

The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.

Objective

In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

Prerequisites / notice

The lecture addresses students in the fields of engineering, science and other related technical fields.

Competencies

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<td>Personal Competencies</td>
<td>Critical Thinking</td>
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<td>Self-awareness and Self-reflection</td>
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851-0251-00L Psychedelic Science: Psychology Pharmacology Physiology Psychotherapy Philosophy Religion Politics

Abstract

This lecture series covers psychedelic science mainly psychologically, and additionally pharmacologically, physiologically, psychotherapeutically, philosophically, religiously, and politically. All contributions will also be reflected on from the viewpoint of the humanities and psychology.

Objective

To provide students with a multidisciplinary introduction to psychedelic science, and to also comprehensively embed this in a reflection from a humanities/psychology viewpoint.
Psychedelic science is a multidisciplinary field of study that involves scholars of the mind and scholars of the natural sciences. In this course, psychedelic science is presented mainly from the point of view of psychology, but will additionally also be considered from the viewpoints of pharmacology, physiology, psychotherapy, philosophy, religion, and politics. All contributions will also be reflected on from the viewpoint of the humanities and psychology. The psychedelic studies treated in this course that involve humans focus on controlled and ethically approved studies where these substances are administered to medically screened, prepared, and supported participants.

Private/illlicit use of psychedelics is not a topic of this course.

A psychedelic experience can be characterized as a temporary nonordinary state of consciousness (NSC) that is occasioned by classic (serotonergic) psychedelics such as psilocybin, mescaline, N,N-dimethyltryptamine (DMT), and isyergic acid diethylamide (LSD). Psychologically, the psychedelic experience can mainly manifest at the perceptual, cognitive, affective, volitional, and somesthetic level.

The nonordinary perceptual spectrum ranges from visions (e.g., patterns or beings) to the subjective experience of an all-encompassing oneness, which also transcends the distinction between the perceiver and the perceived. The nonordinary cognitive spectrum ranges from no longer functional thinking to very clear thinking, the nonordinary affective spectrum, for example, from deepest sadness to highest bliss, the nonordinary volitional spectrum from the feeling of being able to somewhat influence what is happening to the feeling of having no longer a will of one’s own, and the nonordinary somesthetic spectrum, for example, from feelings of bodily heaviness/compression to feelings of bodily lightness/ floating.

Heuristically, as one possibility, a psychological typology of the psychedelic experience can be characterized to fall into three main types of religious-like experiences (which may be interpreted religiously/spiritually by the individuals having them, but may also be interpreted materialistically or aagnostically), autobiographical experiences, and tripartite-mind (cognition/affection/conation) miscellaneous experiences.

Investigating the psychedelic experience is a worthwhile endeavor as, for example, certain aspects of this experience have been associated with increased subjective well-being both for healthy individuals as well as for patients – for example, persisting positive effects on attitudes, mood, and behavior in healthy individuals and sustained symptom reduction in individuals suffering from depression, anxiety, and addiction.

Psychedelic science is overall a large multidisciplinary effort that requires collaboration of scholars of the mind and scholars of the natural sciences to advance the scientific knowledge of it. In this spirit, this course will – besides the main lecturer (PD Dr. phil. Kurt Stocker, a psychologist) – also involve further psychedelic-scientific scholars giving individual lectures in their respective field of expertise psychology (PD Dr. phil. Katrin Preller, University of Zurich & Yale University), pharmacology (PD Dr. phil. Ivan Lo Curto, University Hospital Basel; PD Dr. phil. nat. Deborah Rudin, University Hospital Basel Prof. Dr. phil. Linda Simmler, University of Basel), physiology (PD Dr. sc. nat. Felix Scholkmann, University of Zurich & University of Bern), psychiatrypsychotherapy (Prof. Dr. med. Gregor Hasler, University of Fribourg; Dr. med. Dr. sc. ETH Milan Scheidegger, University of Zurich), and philosophy (Dr. Peter SJÖSTEDT-HUGHES, University of Exeter). Overall, this course will provide an informative overview of the research foundations that have made psychedelic science what it is today, and will also provide an identification of the research fronts that must be addressed to expand the psychedelic science of tomorrow.

Competencies

Subject-specific Competencies

- Concepts and Theories fostered
- Critical Thinking fostered

Personal Competencies

- Sensitivity to Diversity
- Social Competencies
- Personal Competencies

Prerequisites / some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

Abstract

This is a supervised student project for 3 ECTS, supervised by the professorship of Elliott Ash (D-GESS). Students will adapt tools from econometrics and machine learning to questions in law, data science, and social science.

Objective

Students must have some data science and/or statistics experience. Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

Subject-specific Competencies

- Concepts and Theories assessed
- Critical Thinking assessed

Method-specific Competencies

- Analytical Competencies assessed

Social Competencies

- Sensitivity to Diversity fostered

Personal Competencies

- Critical Thinking fostered

Abstract

This course will explore several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

Objective

- The course aims are:
- 1. To introduce students to the historicity of mathematics
- 2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
- 3. To develop critical reflection concerning the nature of mathematical objects
- 4. To introduce various theoretical approaches to the philosophy and history of mathematics
- 5. To open the students’ horizons to the plurality of mathematical cultures and practices

Prerequisites / some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

Subject-specific Competencies

- Concepts and Theories assessed

Method-specific Competencies

- Analytical Competencies assessed

Social Competencies

- Sensitivity to Diversity fostered

Personal Competencies

- Critical Thinking fostered

Abstract

This course explores the relation between the scientific investigation of life and cultural notions of death from a historical perspective (assuming there is no such thing as the scientific investigation of death). While the course covers the times from antiquity up to the present, the main emphasis will be placed on the modern life sciences since the 19th century.

Objective

There is only one certainty in life: death. This brute fact has animated much thought and work in theology, art and philosophy - but also in the natural sciences, such as biology and medicine. Questions regarding health and disease, evolution, extinction and immortality have played a crucial role in this connection. This course aims to explore these relations - the relations between the scientific investigation of life and cultural notions of death - from a historical perspective (assuming there is no such thing as the scientific investigation of death). While the course covers the times from antiquity up to the present, the main emphasis will be placed on the modern life sciences since the 19th century.
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.

**Prerequisites / notice**

Some programming experience in Python, Stata, or R is required. Some data science and social science experience is required.

**Content**

The workshop begins with some fundamentals: the nature of ethics, of consent and big data, of AI ethics, public trust and health ethics. Students will then be introduced to key ethical concepts such as fairness, autonomy, trust, accountability, justice, as well different ways of reasoning about the ethics of digital technologies.

A range of practical problems and issues in the domains of education, media, society, digital health and justice will be then considered. These domains are represented respectively by unique and interesting case studies. Each case study has been selected not only for its timeliness and engaging nature, but also for its relevance. Through the analysis of these case studies key ethical questions (such as fairness, accountability, explainability, access etc.) will be highlighted and questions of responsibility and tools for ethical practice will be explored.

Throughout, the emphasis will be on learning to make sound arguments about the ethical aspects of policy, practice and research.

**Competencies**

- Conceptual Competencies
  - Assessed
  - Techniques and Technologies
- Method-specific Competencies
  - Assessed
  - Analytical Competencies
- Social Competencies
  - Assessed
  - Communication
  - Cooperation and Teamwork
- Personal Competencies
  - Assessed
  - Negotiation

**Objective**

On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

**Abstract**

This workshop focuses on understanding and managing the ethical and social issues arising from the integration of new technologies in various aspects of daily life.

**Objective**

- Explain relevant concepts in ethics.
- Evaluate the ethical dimensions of new technology uses.
- Identify impacted stakeholders and who is ethically responsible.
- Engage constructively in the public discourse relating to new technology impacts.
- Review tools and resources currently available that facilitate resolutions and ethical practice.
- Work in a more ethically reflective way.

**Content**

This workshop focuses on understanding and managing the ethical and social issues arising from the integration of new technologies in various aspects of daily life.

**Objective**

Apply tools from data science and social science to a new project, potentially in a group, to develop a paper or app.

**Abstract**

After an introduction on usable security as the intersection of computer science and psychology, students will form teams and work on exemplary security- or privacy-related research questions. The teams will develop and evaluate a concept for a human-centered solution.

**Competencies**

- Subject-specific Competencies
  - Assessed
  - Techniques and Technologies
- Method-specific Competencies
  - Assessed
  - Analytical Competencies
- Social Competencies
  - Assessed
  - Communication
  - Cooperation and Teamwork
- Personal Competencies
  - Assessed
  - Negotiation

**Objective**

V. Zimmermann

On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

**Abstract**

The workshop will begin with some fundamentals: the nature of ethics, of consent and big data, of AI ethics, public trust and health ethics. Students will then be introduced to key ethical concepts such as fairness, autonomy, trust, accountability, justice, as well different ways of reasoning about the ethics of digital technologies.

A range of practical problems and issues in the domains of education, media, society, digital health and justice will be then considered. These domains are represented respectively by unique and interesting case studies. Each case study has been selected not only for its timeliness and engaging nature, but also for its relevance. Through the analysis of these case studies key ethical questions (such as fairness, accountability, explainability, access etc.) will be highlighted and questions of responsibility and tools for ethical practice will be explored.

Throughout, the emphasis will be on learning to make sound arguments about the ethical aspects of policy, practice and research.

**Competencies**

- Subject-specific Competencies
  - Assessed
  - Techniques and Technologies
- Method-specific Competencies
  - Assessed
  - Analytical Competencies
- Social Competencies
  - Assessed
  - Communication
  - Cooperation and Teamwork
- Personal Competencies
  - Assessed
  - Negotiation

**Objective**

Does not take place this semester.

**Abstract**

This is a supervised student project for 3 ECTS, supervised by the professorship of Elliott Ash (D-GESS). Students will adapt tools from econometrics and machine learning to questions in law, data science, and social science.

**Objective**

Students must have some data science and/or statistics experience. Some programming experience in Python, Stata, or R is required.

**Abstract**

Apply tools from data science and social science to a new project, potentially in a group, to develop a paper or app.

**Competencies**

- Subject-specific Competencies
  - Assessed
  - Techniques and Technologies
- Method-specific Competencies
  - Assessed
  - Analytical Competencies
- Social Competencies
  - Assessed
  - Communication
  - Cooperation and Teamwork
- Personal Competencies
  - Assessed
  - Negotiation

**Objective**

Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.
Objective
The course makes students experience an exemplary human-centered design process. They will learn about and practically apply human-centered design and evaluation methods that will allow them to view their solution from the human perspective, e.g., the user, developer or website owner perspective. By taking part in the evaluation of other teams, they will also take the user perspective themselves.

Content
At the beginning of the course, the students will receive an introduction to usable IT security and privacy and relevant concepts. Afterwards, a selection of current research questions from that area will be presented. The students form teams and select one of the proposed research questions. This question will accompany the students throughout the semester. They will design and evaluate a concept for a human-centered solution to that question. To be able to do so, they will receive input on human-centered design and evaluation tools. Their progress and the inclusion of the human perspective will be subject to feedback in milestone presentations. The students' human-centered solution can take the form of a concept (e.g., a concept for a product or app), interface (e.g., a visual or tangible interface), or prototype (e.g., sketches, a click-dummy or a built prototype). The solution will then be subject to evaluations. The solutions will be user-tested by members of other teams that thereby take the perspective of a user themselves. In addition, the solutions will be analyzed from different stakeholders' perspectives, such as developers or website owners. Finally, the students will reflect on potential changes that results from the evaluations and their consequences.

Literature

Literature Recommendations:

Prerequisites / notice
This course is especially recommended after the related lecture "851-0390-00 G Human-Centered IT Security and Privacy". However, previous participation in the lecture is not a requirement and not necessary for succeeding in the course.

Competencies

Subject-specific Competencies
- Concepts and Theories assessed
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management assessed

Method-specific Competencies
- Communication fostered
- Cooperation and Teamwork assessed
- Customer Orientation fostered
- Sensitivity to Diversity fostered

Social Competencies
- Adaptable and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management fostered

Personal Competencies

851-0251-00L Psychedelic Science: Psychology Pharmacology W 3 credits 2V K. Stocker

Abstract
This lecture series covers psychedelic science mainly psychologically, and additionally pharmacologically, physiologically, psychotherapeutically, philosophically, religiously, and politically. All contributions will also be reflected on from the viewpoint of the humanities and psychology.

Objective
To provide students with a multidisciplinary introduction to psychedelic science, and to also comprehensively embed this in a reflection from a humanities/psychology viewpoint.
The main objectives of the course are to enable students to 1) identify the ways in which human values and developments of AI shape the relationship between human values and AI as citizens and professionals.

Psychologically, the psychedelic experience can mainly manifest at the perceptual, cognitive, affective, volitional, and somesthetic level. The nonordinary perceptual spectrum ranges from visions (e.g., patterns or beings) to the subjective experience of an all-encompassing oneness, which also transcends the distinction between the perceiver and the perceived. The nonordinary cognitive spectrum ranges from no longer functioning to think to very clear thinking, the nonordinary affective spectrum, for example, from deepest sadness to highest bliss, the nonordinary volitional spectrum from the feeling of being able to somewhat influence what is happening to the feeling of having no longer a will of one's own, and the nonordinary somesthetic spectrum, for example, from feelings of bodily heaviness/compression to feelings of bodily lightness/levitation.

Heuristically, as one possibility, a psychological typology of the psychedelic experience can be characterized to fall into three main types - religious-like experiences (which may be interpreted religiously/spiritually by the individuals having them, but may also be interpreted materialistically or egocentrically), autobiographical experiences, and tripartite-mind (cognition/affectionation) miscellaneous experiences.

Investigating the psychodelic experience is a worthwhile endeavor as, for instance, certain aspects of this experience have been associated with increased subjective well-being both for healthy individuals as well as for patients – for example, persisting positive effects on attitudes, mood, and behavior in healthy individuals and sustained symptom reduction in individuals suffering from depression, anxiety, and addiction.

Psychodelic science is overall a large multidisciplinary effort that requires collaboration of scholars of the mind and scholars of the natural sciences to advance the scientific knowledge of it. In this spirit, this course will – besides the main lecturer (PD Dr. phil. Kurt Stocker, a psychologist) – also involve further psychodelic-scientific scholars giving individual lectures in their respective field of expertise psychology (PD Dr. phil. Katrin Preller, University of Zurich & Yale University), pharmacology (Dr. phil. nat. Dino Luethi, University Hospital Basle; Dr. phil. nat. Deborah Rudin, University Hospital Basle; Prof. Dr. phil. Linda Simmler, University of Basel), physiology (PD Dr. sc. nat. Felix Scholkmann, University of Zurich & Bernard of Bern), psychiatry/psychotherapy (Prof. Dr. med. Gregor Hasler, University of Fribourg; Dr. med. sc. ETH Milan Scheidegger, University of Zurich), and philosophy (Dr. Peter Sjöstedt-Hughes, University of Exeter). Overall, this course will provide an informative overview of the research frontiers that have emerged from the research science what it is today, and will also provide an identification of the research frontiers that must be addressed to expand the psychodelic science of tomorrow.

Competencies

Subject-specific Competencies

Concepts and Theories

Personal Competencies

Critical Thinking

851-0763-00L

Supervised Research (Law, Economics, and Data Science) Does not place this semester.

W 3 credits E. Ash

Abstract

This is a supervised student project for 3 ECTS, supervised by the professorship of Elliott Ash (D-GESS). Students will adapt tools from economics and machine learning to questions in law, data science, and social science.

Objective

Students must have some data science and/or statistics experience. Some programming experience in Python, Stata, or R is required. Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

851-0453-00L

Artificial Intelligence and Human Values

W 3 credits 2G M. Boenig-Liptsin, K. Wodajo

Abstract

This course introduces students to the ethical, political and legal debates and transformations in relation to Artificial Intelligence and provides students with concepts and methods from the constructivist and interpretive social sciences to work towards responsible and democratic human-technology futures.

Objective

The main objectives of the course are to enable students to 1) identify the ways in which human values and developments of AI technologies are entangled, 2) articulate what is significant about contemporary transformations in AI and society, and 3) participate and shape the relationship between human values and AI as citizens and professionals.

Content

The growing presence of AI tools for public use, for public administration, inside corporations and in scientific research raises many questions about the ethical, political, legal consequences of these technologies. This course is built around multiple sites of encounter among human values and AI, including bodies, persons, cities, labs, law, and environment. In each site, we inquire about what and whose values are being prioritized and with what consequences. The course also investigates existing best-practices around how to "align" human values with AI (e.g. human-centric design, alignment, reproducibility, transparency, explainability) and introduces students to regimes of ethics and governance of AI being proposed in jurisdictions around the world. Students learn to unpack the values and assumptions in existing techniques and frameworks for the design and governance of AI and to engage constructively with diverse stakeholders to shape the human-technology future towards aims that are reflexive, responsible, and democratic.

851-0157-28L

Life and Death

Particularly suitable for students of D-BIOL, D-HEST, D-CHAB, D-USYS

W 3 credits 2V M. Hagner

Abstract

This course explores the relation between the scientific investigation of life and cultural notions of death from a historical perspective (assuming there is no such thing as the scientific investigation of death). While the course covers the times from antiquity up to the present, the main emphasis will be placed on the modern life sciences since the 19th century.

Objective

There is only one certainty in life: death. This brute fact has animated much thought and work in theology, art and philosophy - but also in the natural sciences, such as biology and medicine. Questions regarding health and disease, evolution, extinction and immortality have played a crucial role in this connection. This course aims to explore above relations - the relations between the scientific investigation of life and cultural notions of death - from a historical perspective (assuming there is no such thing as the scientific investigation of death). While the course covers the times from antiquity up to the present, the main emphasis will be placed on the modern life sciences since the 19th century.

851-0272-00L

The Cutting Edge of Social Brain Imaging

W 2 credits 2S E. Cross, R. Moffat

Abstract

This seminar introduces the fundamentals and latest research developments of brain imaging in real-world contexts. We explore topics from imaging multiple people's brains simultaneously as they interact to neuro-ethics and neuro-art, while maintaining a strong focus on critical evaluation of research practices and applications of brain imaging and during social interaction.

Objective

- To familiarize students with current concepts, theories, methods, and findings from social brain-imaging sciences
- To develop a critical view of extant findings and the tools for evaluating the quality of evidence and data, as well as ethical implications
Rapid advances in the technologies and empirical approaches used in imaging the human brain have opened exciting windows into how the human brain coordinates social interaction. These advances include imaging the brain's function during real social interactions, training behaviors with feedback based on real-time brain activity, and even generating art directly from brain signals. With them, these advances have brought novel ethical implications regarding their implementation in research and potentially, their use by the public, for both therapeutic and possible "neurohacking" applications. In this seminar, students will be introduced to various neuroimaging approaches for social neuroscience generally, as well as to approaches for measuring social brain function in real life, and will gain insights into related ethical considerations.

The seminar builds on the active participation of students in reading, presenting, and critically discussing selected papers in the field. In a final small-group assignment, students are required to integrate and elaborate upon topics covered in the seminar by presenting and debating a novel research proposal for addressing a timely research question related to the use of brain imaging in the context of social interactions. No prior experience or knowledge in brain imaging is required.

### Competencies

#### Subject-specific Competencies

- Concepts and Theories: fostered

#### Method-specific Competencies

- Analytical Competencies: fostered
- Decision-making: fostered

#### Social Competencies

- Communication: assessed
- Leadership and Responsibility: fostered

#### Personal Competencies

- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered

### Literature


Abstract

This seminar introduces students to theory and research, challenges, and opportunities in neuroaesthetics, with a clear emphasis on the interdisciplinary nature of the discipline situated at the intersection of neuroscience, psychology, and art appreciation. Foundational empirical methods and critical perspectives of research approaches in neuroaesthetics are considered.

Objective

- to familiarize students with concepts, models, methods, brain and behavioral findings related to aesthetic experience.
- to develop a critical understanding in evaluating the theoretical and empirical findings in neuroaesthetics
- to integrate the acquired knowledge to critically debate and discuss the conceptual and empirical issues related to the science of aesthetic experience

Content

In this seminar, students will learn about the foundational principles of neuroaesthetics, which explores the cognitive and brain processes involved in aesthetic experience. A key focus will be placed on developing an appreciation of the interdisciplinary methods used in the neuroaesthetics field – ranging from neuroscience, psychology, philosophy, and art history. The seminar is based on the active engagement of students in reading, presenting, and critically discussing selected papers in the field. In a final small-group assignment, students are expected to incorporate and elaborate upon the content covered in the seminar by presenting and discussing a novel research proposal for tackling a timely research question related to aesthetic experience.

Competencies

Subject-specific Competencies

- Concepts and Theories fostered
- Techniques and Technologies fostered

Method-specific Competencies

- Analytical Competencies fostered
- Decision-making fostered
- Media and Digital Technologies fostered
- Problem-solving fostered
- Project Management fostered

Social Competencies

- Communication fostered
- Cooperation and Teamwork fostered
- Customer Orientation fostered
- Leadership and Responsibility fostered
- Self-presentation and Social Influence fostered
- Sensitivity to Diversity fostered
- Negotiation fostered

Personal Competencies

- Adaptability and Flexibility fostered
- Creative Thinking fostered
- Critical Thinking fostered
- Integrity and Work Ethics fostered
- Self-awareness and Self-reflection fostered
- Self-direction and Self-management fostered

D-INFK

Number Title Type ECTS Hours Lecturers

851-0252-01L Human-Computer Interaction: Cognition and Usability W 3 credits 2S C. Hölscher, I. Barisic, B. Davison

Abstract

This seminar will introduce key topics, theories and methodology in human-computer interaction (HCI) and usability, with a focus on applying them to real situations.

Objective

Presentations will cover the basics of human-computer interaction and selected topics:
- History of HCI
- Research ethics
- Literature reviews
- Participant-free methods: cognitive walkthrough and heuristic evaluation
- Card sorting and information architecture
- Usability studies
- Unmoderated research and diary studies
- Surveys
- User Logs and metric frameworks

On a weekly basis, students will conduct authentic research in class covering the topics above. They will submit their in-class research results regularly and also present their findings to the class once per semester.

The final project demonstrates class topic adoption by deeply exploring one HCI problem using the covered methods and tools. Students will choose a research topic and execute their research plan. They will individually write a formal report including problem definition, literature review, methodology, findings and discussion.

851-0742-00L Contract Design I W 3 credits 2V A. Stremitzer, A. Tacconelli

Abstract

Contract Design I is taught by Professor Stremitzer and aims to bridge the gap between economic contract theory, contract law, and the writing of real-world contracts. In this course, we take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction takes place and then engineer contracts that achieve the desired outcome.
Contracts are agreements between parties to engage in transactions. A good contract creates value by giving parties the right incentives to meet their objectives. A good contract designer scrutinizes the economic situation in which parties find themselves and tailors the contract to the challenges at hand. To help you become sophisticated contract designers, we draw from insights for which more than half a dozen Nobel Prizes were awarded in the past two decades and transfer them to the art of writing real-world contracts. In other words, Contract Design will provide you with analytical tools to design contracts that help you be better lawyers, business leaders, and startup founders.

We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting and apply the theoretical insights to real-life case studies ranging from purchases & sales of assets, oil & gas exploration, movie financing, production & distribution, construction & development, M&A deals, venture capital financing, to executive compensation and many other types of transactions.

The course follows a flipped-classroom model: You will watch learning videos specifically produced for this course ahead of class. We will use class time to discuss real-world case studies. The videos will be made available before the lecture each week and need to be watched ahead of coming to class. Computer-graded quizzes at the beginning of each class will test students' understanding of the concepts introduced in the videos.

As the emphasis of this class is on class discussion, attendance is mandatory. Absent important reasons, you cannot miss class more than twice.

The lectures will be recorded but only made available to those who miss lectures with excused absence.

For ETH students: Your grade will consist of two parts:
1) You will take weekly computer-based quizzes during class time. Thus, it is important that you attend the lectures to be able to finish the quizzes and pass this course.
2) You compose short responses to take-home questions on case studies we assign and upload them ahead of class (Pass/Fail).

Note that UZH and UNISG students enrolling in this course need to earn more ECTS for completing this course than ETH students (due to curricula reasons). This is why UZH and UNISG students must complete a written assignment in addition to the weekly quizzes and take-home questions. UZH students also have to complete an additional group project. UZH and UNISG students should check out the description of the class at their respective home institutions.

Lecture notes
Handouts, prerecorded videos, slides, case studies, and other materials available on a dedicated webpage: contractdesign.org. Access to this webpage is free of charge for ETH students as ETH purchased a license for ETH students.

Prerequisites / notice
Attendance is mandatory. You are only allowed to miss two lectures unless there are special circumstances.

Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, D-MAVT.

If you have any questions regarding the course, please write an email to the teaching assistants, Lucas Gericke (lucas.gericke@gess.ethz.ch) or Serge von Steiger (serge.vonsteiger@gess.ethz.ch).

Competencies

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851-0727-02L E-Business-Law W 2 credits 2V D. Rosenthal

Abstract
The course deals with the basic legal framework for doing e-business as well as using information technology. It discusses a variety of legal concepts and rules to be taken into account in practice, be it when designing and planning new media business models, be it when implementing online projects and undertaking information technology activities.

Objective
The objective is knowing and understanding key legal concepts relevant for doing e-business, in particularly understanding how e-business is regulated both nationally and internationally, how contracts are concluded and performed electronically, which rules have to be obeyed in particular in the Internet with regard to third party and own content and client data, the concept of liability applied in e-business and the role of the law in the practical implementation and operation of e-business applications.

Content
Vorgesehenen Strukturierung der Vorlesung:

1) Welches Recht gilt im E-Business?
   - Internationalität des Internets
   - Regulierte Branchen

2) Gestaltung und Vermarktung von E-Business-Angeboten
   - Verwendung fremder und Schutz der eigenen Inhalte
   - Haftung im E-Business (und wie sie beschränkt werden kann)
   - Domain-Namen

3) Beziehung zu E-Business-Kunden
   - Verträge im E-Business, Konsumentenschutz
   - E-Handelschuldrecht
   - Datenschutz
   - Spam

4) Verträge mit E-Business-Providern

Änderungen, Umstellungen und Kürzungen bleiben vorbehalten. Der aktuelle Termin- und Themenplan ist zu gegebener Zeit über Moodle abrufbar.

Lecture notes
Es wird mit Folien gearbeitet, die als PDF über Moodle vorgängig abrufbar sind. Auf dem Termin- und Themenplan (ebenfalls online abrufbar) sind Links zu Gesetzestexten und weiteren Unterlagen abrufbar. Schliesslich wird jede Vorlesung auch als Podcast aufgezeichnet, der jedoch nur für die Studierenden mit einem Passwort (erhältlich beim Dozenten) zugänglich sind.

Der Termin- und Themenplan ist zu gegebener Zeit über Moodle abrufbar.
The following topics will be covered:

Network Modeling

Particularly suitable for students of D-MATH, D-INFK and in the MSc Data Science

Students are required to have basic knowledge in inferential statistics, such as regression models.

Objective

- Introduction to network models and their applications
- Stylized models:
  - uniform random graph models
  - small world models
  - preferential attachment models
- Models for testing hypotheses while controlling for the network structure:
  * Quadratic assignment procedure regression (QAP regression)
  * Models for one single observation of a network: exponential random graph models (ERGMs)
  * Models for panel network data: stochastic actor-oriented models (SAOMs)

The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

Content

- Introduction to network models and their applications
- Stylized models:
  - uniform random graph models
  - small world models
  - preferential attachment models
- Models for testing hypotheses while controlling for the network structure:
  * Quadratic assignment procedure regression (QAP regression)
  * Models for panel network data: stochastic actor-oriented models (SAOMs)
  * Models for relational event data: dynamic network actor models (DyNAMs)

The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

Lecture notes

Slides and lecture notes are distributed via the associated course moodle.


Prerequisites / notice

Students are required to have basic knowledge in inferential statistics and should be familiar with linear and logistic regression models.
Content

The following topics will be covered with an emphasis on structural and computational approaches and frequent reference to their suitability with respect to substantive theory:

* Empirical Research and Network Data
* Macro and Micro Structure
* Centrality
* Roles
* Cohesion
* Influence

Lecture notes

Slides and lecture notes are distributed via the associated course moodle.

Literature


Competencies

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Law & Tech

851-0732-06L

Abstract

This course introduces students to scientific and technological developments that require regulation or enable legal innovation. We focus particularly on the challenges to current law posed by prominent near-future technologies.

Objective

The course is designed for a wide range of ETH students as well as for law students who are keen to deepen their understanding of cutting-edge technology. It offers an overview of key legal areas important for technology regulation, complemented by guest lectures on emerging technological trends.

In previous years, the course has featured esteemed speakers from various sectors, including industry leaders like Google, NGOs such as Digital Society Switzerland and The European Consumer Organization, regulatory bodies like the Swiss Competition Commission, and noted academics.

The course is open to ETH students through the Science in Perspective program of the Department of Humanities, Social and Political Sciences.

Content

The planned course outline is below.

- Overview of Law and Technology
- Fundamental Rights
- AI & Discrimination
- Landmark Big Tech Cases
- Regulation of Digital Platforms & Content Moderation
- Online Consumer Protection
- Law and Tech Scholarship Series

A number of recent regulations will be discussed, including the EU’s AI Act, the Digital Services Act (DSA), and the Digital Markets Act (DMA), as well as emerging internet phenomena, like ChatGPT.

Prerequisites / notice

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for “Law & Tech (851-0732-06L, HS 2024)” and enroll.

Competencies

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Complex Social Systems: Modeling Agents, Learning, and Games

851-0101-86L

Abstract

This course introduces mathematical and computational models to study techno-socioeconomic systems and the process of scientific research. Students develop a significant project to tackle techno-socio-economic challenges in application domains of complex systems. They are expected to implement a model and to communicate their results through a project report and a short oral presentation.

Objective

See your own field of study in a wider context (“Science in Perspective”), e.g. see the psychological, social, economic, environmental, historical, ethical, or philosophical connections and implications. Learn to think critically and out of the box. Question what you believe you know for sure. Get to know surprising, counterintuitive properties of complex (non-linearly interacting, networked, multi-component) systems. Learn about collaboration.
By the end of the course, the students should be able to better understand the literature on complex social systems, develop their own models for studying specific phenomena and report results according to the standards of the relevant scientific literature by presenting their results both numerically and graphically.

At the end of the course, the students will deliver a report, computer code and a short oral presentation. To collect credit points, students will have to actively contribute and give a circa 30 minutes presentation in the course on a subject agreed with the lecturers, after which the presentation will be discussed. The presentation will be graded.

Students are expected to implement themselves models of techno-socio-economic processes and systems, particularly agent-based models, complex networks models, decision making, group dynamics, human crowds, or game-theoretical models. Credit points are finally earned for the implementation of a mathematical or empirical model from the complexity science literature, its presentation, and documentation by a project report.

The lecture slides will be presented on the course Moodle after each lecture.

Agent-Based Modeling
https://link.springer.com/chapter/10.1007/978-3-642-24004-1_2

Social Self-Organization

Traffic and related self-driven many-particle systems
Reviews of Modern Physics 73, 1067
https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.73.1067

An Analytical Theory of Traffic Flow (collection of papers)
https://www.researchgate.net/publication/261629187

Pedestrian, Crowd, and Evacuation Dynamics
https://www.research-collection.ethz.ch/handle/20.500.11850/45424

The hidden geometry of complex, network-driven contagion phenomena (relevant for modeling pandemic spread)
https://science.sciencemag.org/content/342/6164/1337

Prerequisites / notice
The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.

Good programming skills and a good understanding of probability & statistics and calculus are expected.

Students need to present a new subject, for which they have not earned any credit points before.

Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Chatham House rules apply to this course. Materials may not be shared without previous written permission.

Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies fostered
- Problem-solving assessed
- Project Management assessed

Social Competencies
- Communication assessed
- Cooperation and Teamwork assessed
- Customer Orientation fostered
- Leadership and Responsibility assessed
- Self-presentation and Social Influence assessed
- Sensitivity to Diversity assessed
- Negotiation fostered

Personal Competencies
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

851-0760-00L Building a Robot Judge: Data Science for Decision-Making

W 3 credits 2V E. Ash

Does not take place this semester.
Particularly suitable for students of D-INFK, D-ITET, D-MTEC.

Abstract
This course explores the automation of decisions in the legal system. We delve into the machine learning tools needed to predict judge decision-making and ask whether techniques in model explanation and algorithmic fairness are sufficient to address the potential risks.

Objective
This course introduces students to the data science tools that may provide the first building blocks for a robot judge. While building a working robot judge might be far off in the future, some of the building blocks are already here, and we will put them to work.
Content

Data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, there are serious risks that automated systems could replicate or amplify existing legal biases and rigidities. Given the stakes, these technologies force us to think carefully about notions of fairness and justice and how they should be applied.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is a criminal defendant to commit another crime? How much additional revenue will this new tax law collect? Students will investigate and implement the relevant machine learning tools for making these types of predictions, including regression, classification, and deep neural networks models.

We then use these predictions to better understand the operation of the legal system. Under what conditions do judges tend to make errors? Against which types of defendants do parole boards exhibit bias? Which jurisdictions have the most tax loopholes? Students will be introduced to emerging applied research in this vein. In a semester paper, students (individually or in groups) will conceive and implement an applied data-science research project.

851-0467-00L From Traffic Modeling to Smart Cities and Digital Democracies

W 3 credits 2S D. Helbing, R. K. Dubey

Abstract

This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution.

Objective

To collect credit points, students must actively contribute and give an individual, circa 20-minute presentation in the seminar on a subject agreed upon with the lecturer. After the presentation, it will be discussed and graded.

Content

This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will also reflect on the question of how democracy could be digitally upgraded, and how citizen participation could contribute to innovation, sustainability, resilience, and quality of life. This includes questions around collective intelligence and digital platforms that support creativity, engagement, coordination and cooperation.

Literature

Dirk Helbing
An Analytical Theory of Traffic Flow (collection of papers)

Michael Batty, Kay Axhausen et al.
Smart cities of the future

Books by Michael Batty:
How social influence can undermine the wisdom of crowd effect
Evidence for a collective intelligence factor in the performance of human groups
Optimal incentives for collective intelligence
Collective Intelligence: Creating a Prosperous World at Peace
Big Mind: How Collective Intelligence Can Change Our World
Programming Collective Intelligence

Urban architecture as connective-collective intelligence. Which spaces of interaction?
Build digital democracy
How to make democracy work in the digital age
Digital Democracy: How to make it work?
Proof of witness presence: Blockchain consensus for augmented democracy in smart cities
Iterative Learning Control for Multi-agent Systems Coordination

Decentralized Collective Learning for Self-managed Sharing Economies
Students need to present a new subject, for which they have not earned any credit points before.

Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Competencies

Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Method-specific Competencies

Analytical Competencies assessed
Decision-making fostered
Media and Digital Technologies assessed
Problem-solving assessed
Project Management fostered

Social Competencies

Communication assessed
Cooperation and Teamwork fostered
Customer Orientation fostered
Leadership and Responsibility fostered
Self-presentation and Social Influence fostered
Sensitivity to Diversity fostered

Personal Competencies

Negotiation fostered
Adaptability and Flexibility fostered
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

851-0391-00L Focus on the Human: Human-Centered Security and

W 3 credits 2S V. Zimmermann, A. Toth

Autumn Semester 2024

Data: 15.06.2024 12:39
Critical Thinking fostered

Analytical Competencies

Subject-specific Competencies

Method-specific Competencies

Analytical Competencies assessed

Decision-making assessed

Media and Digital Technologies fostered

Problem-solving assessed

Project Management assessed

Social Competencies

Cooperation and Teamwork assessed

Customer Orientation fostered

Sensitivity to Diversity fostered

Personal Competencies

Adaptability and Flexibility fostered

Creative Thinking fostered

Critical Thinking fostered

Integrity and Work Ethics fostered

Self-awareness and Self-reflection assessed

Self-direction and Self-management fostered

Abstract

After an introduction on usable security as the intersection of computer science and psychology, students will form teams and work on exemplary security- or privacy-related research questions. The teams will develop and evaluate a concept for a human-centered solution. Through input sessions and milestone presentations the human perspective will be incorporated and reflected upon.

Objective

The course makes students experience an exemplary human-centered design process. They will learn about and practically apply human-centered design and evaluation methods that will allow them to view their solution from the human perspective, e.g., the user, developer or website owner perspective. By taking part in the evaluation of other teams, they will also take the user perspective themselves.

Content

At the beginning of the course, the students will receive an introduction to usable IT security and privacy and relevant concepts. Afterwards, a selection of current research questions from that area will be presented. The students form teams and select one of the proposed research questions. This question will accompany the students throughout the semester. They will design and evaluate a concept for a human-centered solution to that question. To be able to do so, they will receive input on human-centered design and evaluation tools. Their progress and the inclusion of the human perspective will be subject to feedback in milestone presentations.

The students' human-centered solution can take the form of a concept (e.g., a concept for a product or app), interface (e.g., a visual or tangible interface), or prototype (e.g., sketches, a click-dummy or a built prototype). The solution will then be subject to evaluations. The solutions will be user-tested by members of other teams that thereby take the perspective of a user themselves. In addition, the solutions will be analyzed from different stakeholders’ perspectives, such as developers or website owners.

Finally, the students will reflect on potential changes that result from the evaluations and their consequences.

Literature Recommendations:


Prerequisites / notice

This course is especially recommended after the related lecture "851-0390-00 G Human-centered IT Security and Privacy". However, previous participation in the lecture is not a requirement and not necessary for succeeding in the course.

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Method-specific Competencies

Analytical Competencies assessed

Decision-making assessed

Media and Digital Technologies fostered

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Project Management assessed

Social Competencies

Communication fostered

Cooperation and Teamwork assessed

Customer Orientation fostered

Sensitivity to Diversity fostered

Personal Competencies

Adaptability and Flexibility fostered

Creative Thinking fostered

Critical Thinking fostered

Integrity and Work Ethics fostered

Self-awareness and Self-reflection assessed

Self-direction and Self-management fostered

851-0125-65L

A Sampler of Histories and Philosophies of Mathematics

Particularly suitable for students D-CHAB, D-INFK, D-ITET, D-MATH, D-PHYS

Abstract

This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

Objective

The course aims are:

1. To introduce students to the historicity of mathematics
2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
3. To develop critical reflection concerning the nature of mathematical objects
4. To introduce various theoretical approaches to the philosophy and history of mathematics
5. To open the students’ horizons to the plurality of mathematical cultures and practices

Competencies

Subject-specific Competencies

Concepts and Theories assessed

Method-specific Competencies

Analytical Competencies assessed

Social Competencies

Sensitivity to Diversity fostered

Personal Competencies

Critical Thinking fostered

851-0453-00L

Artificial Intelligence and Human Values

W 3 credits 2G M. Boenig-Liptsin, K. Wodajo

Abstract

This course introduces students to the ethical, political and legal debates and transformations in relation to Artificial Intelligence and provides students with concepts and methods from the constructivist and interpretive social sciences to work towards responsible and democratic human-technology futures.

Objective

The main objectives of the course are to enable students to 1) identify the ways in which human values and developments of AI technologies are entangled, 2) articulate what is significant about contemporary transformations in AI and society, and 3) participate and shape the relationship between human values and AI as citizens and professionals.
Content
The growing presence of AI tools for public use, for public administration, inside corporations and in scientific research raises many questions about the ethical, political, legal consequences of these technologies. This course is built around multiple sites of encounter among human values and AI, including bodies, persons, cities, labs, law, and environment. In each site, we inquire about what and whose values are being prioritized and with what consequences. The course also investigates existing best-practices around how to "align" human values with AI (e.g., human-centric design, alignment, reproducibility, transparency, explainability) and introduces students to regimes of ethics and governance of AI being proposed in jurisdictions around the world. Students learn to unpack the values and assumptions in existing techniques and frameworks for the design and governance of AI and to engage constructively with diverse stakeholders to shape the human-technology future towards aims that are reflexive, responsible, and democratic.

851-0272-00L The Cutting Edge of Social Brain Imaging W 2 credits 2S E. Cross, R. Moffat
Abstract
This seminar introduces the fundamentals and latest research developments of brain imaging in real-world contexts. We explore topics from imaging multiple people’s brains simultaneously as they interact to neuro-ethics and neuro-art, while maintaining a strong focus on critical evaluation of research practices and applications of brain imaging of and during social interaction.

Objective
- To familiarize students with current concepts, theories, methods, and findings from social brain-imaging sciences
- To develop a critical view of extant findings and the tools for evaluating the quality of evidence and data, as well as ethical implications

Content
Rapid advances in the technologies and empirical approaches used in imaging the human brain have opened exciting windows into how the human brain coordinates social interaction. These advances include imaging the brain’s function during real social interactions, training behaviours with feedback based on real-time brain activity, and even generating art directly from brain signals. With them, these advances have brought novel ethical implications regarding their implementation in research and potentially, their use by the public, for both therapeutic and possible “neurohacking” applications. In this seminar, students will be introduced to various neuroimaging approaches for social neuroscience generally, as well as to approaches for measuring social brain function in real life, and will gain insights into related ethical considerations.

The seminar builds on the active participation of students in reading, presenting, and critically discussing selected papers in the field. In a final small-group assignment, students are required to integrate and elaborate upon topics covered in the seminar by presenting and debating a novel research proposal for addressing a timely research question related to the use of brain imaging in the context of social interactions. No prior experience or knowledge in brain imaging is required.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

851-0392-00L Privacy Quantification and Usable Protection Mechanisms W 3 credits 2S N. Zufferey, V. Zimmermann
Abstract
Students will gain an overview of the main privacy metrics that are used to evaluate privacy risks related to the use of a given technology. They will also be introduced to the concepts of privacy/utility balance and usable security. Practical exercises and reading of recently published scientific articles will be used to present practical cases of the theoretical tools presented in class.

Objective
This course aims to provide the students with a global knowledge of the concepts related to privacy, and the methodology and tools to identify, analyze, and address threats while taking the user into account in the process. They will adopt a “privacy mindset”, thus enabling them to automatically take privacy into account, in a usable way, when designing or analyzing a system.

Content
First, the course will introduce the different definitions and approaches of privacy (e.g., privacy by control, privacy by design) as well as the ethical concerns and considerations related to information security and privacy research (e.g., responsible disclosure, full disclosure).

Second, the students will be introduced to the different methods, properties, and metrics to assess and/or guarantee a certain level of privacy. They will be introduced to the properties and metrics related to anonymization (e.g., k-anonymity, l-diversity), data aggregation (e.g., randomized responses, ε-differential privacy), as well as other privacy assessment methodologies (e.g., inferential privacy).

Third, the course will address usability issues and the role of individuals (i.e., users) in privacy management (i.e., usable security and privacy) and the design of privacy-enhancing technologies. In this context, we will analyze the main concepts seen during the course and discuss their advantages and disadvantages in terms of usability, as well as their implementation for mass-market and large-scale technologies.

Across all three parts of the course, practical exercises, as well as recent research articles reading, and presentations will be used as a complement to support the concepts seen in class, as well as to provide concrete examples of methodologies related to the assessment of privacy in general.
Subject-specific Competencies

The objectives in this course are to (1) gain an overview of important questions pertaining to international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions in this policy area and how to address them in a conceptually and methodologically meaningful and insightful way; (3) gain an overview of important global and regional environmental problems and how they are or could be solved.

Concepts and Theories

- to familiarize students with concepts, models, methods, brain and behavioral findings related to aesthetic experience.
- to develop a critical understanding in evaluating the theoretical and empirical findings in neuroaesthetics.
- to animate the acquired knowledge to critically debate and discuss the conceptual and empirical issues related to the science of aesthetic experience.

Analytical Competencies

- to develop creative thinking.
- to develop effective critical thinking.
- to develop an appreciation of the interdisciplinary methods used in the neuroaesthetics field – ranging from neuroscience, psychology, and art appreciation.
- to develop an understanding of the interdisciplinary nature of the discipline situated at the intersection of neuroscience, psychology, and art appreciation.

Social Competencies

- to foster and develop a critical understanding in evaluating the theoretical and empirical findings in neuroaesthetics.
- to foster engagement of students in reading, presenting, and critically discussing selected papers in the field.
- to foster engagement of students in reading, presenting, and critically discussing selected papers in the field.

Personal Competencies

- to foster engagement of students in reading, presenting, and critically discussing selected papers in the field.
- to foster self-confidence in presentation.
- to foster self-confidence in presentation.

Creative Thinking

- to foster engagement of students in reading, presenting, and critically discussing selected papers in the field.
- to foster creative thinking.
- to foster creative thinking.

Negotiation

- to foster engagement of students in reading, presenting, and critically discussing selected papers in the field.
- to foster negotiation.
- to foster negotiation.

Social Competencies

- to foster engagement of students in reading, presenting, and critically discussing selected papers in the field.
- to foster leadership and responsibility.
- to foster leadership and responsibility.

Personal Competencies

- to foster engagement of students in reading, presenting, and critically discussing selected papers in the field.
- to foster adaptability and flexibility.
- to foster adaptability and flexibility.

Literature

Reading materials and slides will be available via Moodle.

Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2617 of 2653
The course deals with the basic legal framework for doing e-business as well as using information technology. It discusses a variety of fostered legal concepts and rules to be taken into account in practice, be it when designing and planning new media business models, be it when implementing online projects and undertaking information technology activities. fostered

The objective is knowing and understanding key legal concepts relevant for doing e-business, in particularly understanding how e-business is regulated by law nationally and internationally, how contracts are concluded and performed electronically, which rules have to be obeyed in particular in the Internet with regard to third party and own content and client data, the concept of liability applied in e-business and the role of the law in the practical implementation and operation of e-business applications. fostered

The course deals with the basic legal framework for doing e-business as well as using information technology. It discusses a variety of fostered legal concepts and rules to be taken into account in practice, be it when designing and planning new media business models, be it when implementing online projects and undertaking information technology activities. fostered

This seminar will introduce key topics, theories and methodology in human-computer interaction (HCI) and usability, with a focus on applying them to real situations.
Objective
Presentations will cover the basics of human-computer interaction and selected topics:

- History of HCI
- Research ethics
- Literature reviews
- Participant-free methods: cognitive walkthrough and heuristic evaluation
- Card sorting and information architecture
- Usability studies
- Unmoderated research and diary studies
- Surveys
- User Logs and metric frameworks

On a weekly basis, students will conduct authentic research in class covering the topics above. They will submit their in-class research results regularly and also present their findings to the class once per semester.

The final project demonstrates class topic adoption by deeply exploring one HCI problem using the covered methods and tools. Students will choose a research topic and execute their research plan. They will individually write a formal report including problem definition, literature review, methodology, findings and discussion.

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0735-10L</td>
<td>Startups and Law</td>
<td>2V</td>
<td>P. Peyrot</td>
</tr>
<tr>
<td></td>
<td><strong>Particularly suitable for students of D-ITET, D-MAVT.</strong></td>
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<tr>
<td>Abstract</td>
<td>The students shall obtain a basic knowledge about the legal environment of entrepreneurs. They shall be able to recognize and evaluate legal issues connected to an entrepreneurial activity and suggest possible solutions.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>The students shall obtain the following competence:</td>
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<tr>
<td></td>
<td>- They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise.</td>
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<td></td>
<td>- They shall be able to contribute to the legal management of the company and to discuss legal issues.</td>
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<td></td>
<td>- They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company.</td>
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<tr>
<td>Lecture notes</td>
<td>A comprehensive script will be made available online on the moodle platform.</td>
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<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0738-01L</td>
<td>The Role of Intellectual Property in the Engineering and Technical Sector</td>
<td>2V</td>
<td>K. Houshang Pour Islam</td>
</tr>
<tr>
<td></td>
<td><strong>Particularly suitable for students of D-BAUG, D-BIOL, D-BSSE, D-CHAB, D-ITET, D-MAVT.</strong></td>
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<tr>
<td>Abstract</td>
<td>The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.</td>
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<td>The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.</td>
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<td></td>
<td>Topics covered during the lecture will include:</td>
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<td></td>
<td>- The importance of innovation in industrialised countries</td>
<td></td>
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<tr>
<td></td>
<td>- An overview of the different forms of intellectual property</td>
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<tr>
<td></td>
<td>- The protection of technical inventions and how to safeguard their commercialisation</td>
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<td></td>
<td>- Patents as a source of technical and business information</td>
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<td></td>
<td>- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The lecture addresses students in the fields of engineering, science and other related technical fields.</td>
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<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Prerequisites / notice</th>
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</thead>
<tbody>
<tr>
<td>851-0101-86L</td>
<td>Complex Social Systems: Modeling Agents, Learning, and Games</td>
<td>3S</td>
<td>D. N. Dallisan, D. Carpentries, D. Helbing</td>
</tr>
<tr>
<td></td>
<td><strong>Prerequisites: Basic programming skills, elementary probability and statistics.</strong></td>
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</tr>
<tr>
<td>Abstract</td>
<td>This course introduces mathematical and computational models to study techno-socioeconomic systems and the process of scientific research. Students develop a significant project to tackle techno-socio-economic challenges in application domains of complex systems. They are expected to implement a model and to communicate their results through a project report and a short oral presentation.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>See your own field of study in a wider context (&quot;Science in Perspective&quot;), e.g. see the psychological, social, economic, environmental, historical, ethical or philosophical connections and implications. Learn to think critically and out of the box. Question what you believe you know for sure. Get to know surprising, counterintuitive properties of complex (non-linearly interacting, networked, multi-component) systems. Learn about collaboration.</td>
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</tbody>
</table>
By the end of the course, the students should be able to better understand the literature on complex social systems, develop their own models for studying specific phenomena and report results according to the standards of the relevant scientific literature by presenting their results both numerically and graphically.

At the end of the course, the students will deliver a report, computer code and a short oral presentation. To collect credit points, students will have to actively contribute and give a circa 30 minutes presentation in the course on a subject agreed with the lecturers, after which the presentation will be discussed. The presentation will be graded.

Students are expected to implement themselves models of techno-socio-economic processes and systems, particularly agent-based models, complex networks models, decision making, group dynamics, human crowds, or game-theoretical models. Credit points are finally earned for the implementation of a mathematical or empirical model from the complexity science literature, its presentation, and documentation by a project report.

The lecture slides will be presented on the course Moodle after each lecture.

Social Self-Organization

Traffic and related self-driven many-particle systems
Reviews of Modern Physics 73, 1067
https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.73.1067

An Analytical Theory of Traffic Flow (collection of papers)
https://www.researchgate.net/publication/261629187

Pedestrian, Crowd, and Evacuation Dynamics
https://www.research-collection.ethz.ch/handle/20.500.11850/45424

The hidden geometry of complex, network-driven contagion phenomena (relevant for modeling pandemic spread)
https://science.sciencemag.org/content/342/6164/1337

The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.

Good programming skills and a good understanding of probability & statistics and calculus are expected.

Students need to present a new subject, for which they have not earned any credit points before.

Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Chatham House rules apply to this course. Materials may not be shared without previous written permission.

This course explores the automation of decisions in the legal system. We delve into the machine learning tools needed to predict judge decision-making and ask whether techniques in model explanation and algorithmic fairness are sufficient to address the potential risks.

This course introduces students to the data science tools that may provide the first building blocks for a robot judge. While building a working robot judge might be far off in the future, some of the building blocks are already here, and we will put them to work.

Abstract

851-0760-00L Building a Robot Judge: Data Science for Decision-Making
Does not take place this semester.
Particularly suitable for students of D-INFK, D-ITET, D-MTEC.

Objective
Data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, there are serious risks that automated systems could replicate or amplify existing legal biases and rigidities. Given the stakes, these technologies force us to think carefully about notions of fairness and justice and how they should be applied.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is a criminal defendant to commit another crime? How much additional revenue will this new tax law collect? Students will investigate and implement the relevant machine learning tools for making these types of predictions, including regression, classification, and deep neural networks models.

We then use these predictions to better understand the operation of the legal system. Under what conditions do judges tend to make errors? Against which types of defendants do parole boards exhibit bias? Which jurisdictions have the most tax loopholes? Students will be introduced to emerging applied research in this vein. In a semester paper, students (individually or in groups) will conceive and implement an applied data-science research project.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Semester</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0467-00L</td>
<td>From Traffic Modeling to Smart Cities and Digital Democracies</td>
<td>3</td>
<td>2S</td>
<td>D. Helbing, R. K. Dubey</td>
</tr>
</tbody>
</table>

Abstract
This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution.

Objective
To collect credit points, students must actively contribute and give an individual, circa 20-minute presentation in the seminar on a subject agreed upon with the lecturer. After the presentation, it will be discussed and graded.

Content
This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will also reflect on the question of how democracy could be digitally upgraded, and how citizen participation could contribute to innovation, sustainability, resilience, and quality of life. This includes questions around collective intelligence and digital platforms that support creativity, engagement, coordination and cooperation.

Literature
Dirk Helbing
An Analytical Theory of Traffic Flow (collection of papers)
Michael Batty, Kay Axhausen et al.
Smart cities of the future
Books by Michael Batty:
How social influence can undermine the wisdom of crowd effect
Evidence for a collective intelligence factor in the performance of human groups
Optimal incentives for collective intelligence
Collective Intelligence: Creating a Prosperous World at Peace
Big Mind: How Collective Intelligence Can Change Our World
Programming Collective Intelligence
Urban architecture as connective-collective intelligence. Which spaces of interaction?
Build digital democracy
How to make democracy work in the digital age
Digital Democracy: How to make it work?
Proof of witness presence: Blockchain consensus for augmented democracy in smart cities
Iterative Learning Control for Multi-agent Systems Coordination
Decentralized Collective Learning for Self-managed Sharing Economies
Students need to present a new subject, for which they have not earned any credit points before.
Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Prerequisites / notice
Chatham House rules apply to this course. Materials may not be shared without previous written permission.

Competencies
<table>
<thead>
<tr>
<th>Subject-specific Competencies</th>
<th>Method-specific Competencies</th>
<th>Social Competencies</th>
<th>Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Negotiation</td>
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<tr>
<td>Techniques and Technologies</td>
<td>Decision-making</td>
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<td>Adaptability and Flexibility</td>
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<td>Media and Digital Technologies</td>
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<td>Critical Thinking</td>
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<td>Problem-solving</td>
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<td>Integrity and Work Ethics</td>
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<td>Project Management</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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851-0732-06L
Law & Tech
W 3 credits 2S
A. Stremitzer, J. Merane

Data: 15.06.2024 12:39
Autumn Semester 2024
Page 2621 of 2653
Abstract
This course introduces students to scientific and technological developments that require regulation or enable legal innovation. We focus particularly on the challenges to current law posed by prominent near-future technologies.

Objective
The course is designed for a wide range of ETH students as well as for law students who are keen to deepen their understanding of cutting-edge technology. It offers an overview of key legal areas important for technology regulation, complemented by guest lectures on emerging technological trends.

In previous years, the course has featured esteemed speakers from various sectors, including industry leaders like Google, NGOs such as Digital Society Switzerland and The European Consumer Organization, regulatory bodies like the Swiss Competition Commission, and noted academics.

The course is open to ETH students through the Science in Perspective program of the Department of Humanities, Social and Political Sciences.

Content
The planned course outline is below.

- Overview of Law and Technology
- Fundamental Rights
- AI & Discrimination
- Landmark Big Tech Cases
- Regulation of Digital Platforms & Content Moderation
- Online Consumer Protection
- Law and Tech Scholarship Series

A number of recent regulations will be discussed, including the EU’s AI Act, the Digital Services Act (DSA), and the Digital Markets Act (DMA), as well as emerging internet phenomena, like ChatGPT.

Prerequisites / notice
You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for “Law & Tech (851-0732-06L, HS 2024)” and enroll.

Competencies

<table>
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<tr>
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<th>Social Competencies</th>
<th>Personal Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Creative Thinking</td>
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<tr>
<td>assessed</td>
<td>assessed</td>
<td>assessed</td>
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Social Competencies

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<tbody>
<tr>
<td>Communication</td>
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<td>assessed</td>
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Personal Competencies

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<th>Competencies</th>
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<tbody>
<tr>
<td>Creative Thinking</td>
</tr>
<tr>
<td>assessed</td>
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</table>

851-0391-00L Focus on the Human: Human-Centered Security and Privacy Lab

W 3 credits 2S V. Zimmermann, A. Toth

Abstract
After an introduction on usable security as the intersection of computer science and psychology, students will form teams and work on exemplary security- or privacy-related research questions. The teams will develop and evaluate a concept for a human-centered solution.

Objective
The course makes students experience an exemplary human-centered design process. They will learn about and practically apply human-centered design and evaluation methods that will allow them to view their solution from the human perspective, e.g., the user, developer or website owner perspective. By taking part in the evaluation of other teams, they will also take the user perspective themselves.

Content
At the beginning of the course, the students will receive an introduction to usable IT security and privacy and relevant concepts. Afterwards, a selection of current research questions from that area will be presented. The students form teams and select one of the proposed research questions. This question will accompany the students throughout the semester. They will design and evaluate a concept for a human-centered solution to that question. To be able to do so, they will receive input on human-centered design and evaluation tools. Their progress and the inclusion of the human perspective will be subject to feedback in milestone presentations.

The students’ human-centered solution can take the form of a concept (e.g., a concept for a product or app), interface (e.g., a visual or tangible interface), or prototype (e.g., sketches, a click-dummy or a built prototype). The solution will then be subject to evaluations. The solutions will be user-tested by members of other teams that thereby take the perspective of a user themselves. In addition, the solutions will be analyzed from different stakeholders’ perspectives, such as developers or website owners.

Finally, the students will reflect on potential changes that results from the evaluations and their consequences.

Literature


Prerequisites / notice
This course is especially recommended after the related lecture "851-0390-00 G Human-Centered IT Security and Privacy".

However, previous participation in the lecture is not a requirement and not necessary for succeeding in the course.
This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

Objectives

1. To introduce students to the historicity of mathematics
2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
3. To develop critical reflection concerning the nature of mathematical objects
4. To introduce various theoretical approaches to the philosophy and history of mathematics
5. To open the students' horizons to the plurality of mathematical cultures and practices

Competencies

- Subject-specific Competencies: Concepts and Theories
- Method-specific Competencies: Analytical Competencies, Decision-making, Media and Digital Technologies, Problem-solving, Project Management
- Social Competencies: Communication, Cooperation and Teamwork, Customer Orientation, Sensitivity to Diversity
- Personal Competencies: Adaptability and Flexibility, Creative Thinking, Critical Thinking, Integrity and Work Ethics, Self-awareness and Self-reflection, Self-direction and Self-management

851-0125-65L A Sampler of Histories and Philosophies of Mathematics

851-0453-00L Artificial Intelligence and Human Values

851-0392-00L Privacy Quantification and Usable Protection Mechanisms
Contract Design I is taught by Professor Stremitzer and aims to bridge the gap between economic contract theory, contract law, and the practice of contract design. This course is particularly available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, DMATH, D-MTEC, D-INF, and D-MAVT.

- **Title:** Contract Design I
- **Type:** W
- **ECTS:** 3 credits
- **Hours:** 2V
- **Lecturers:** A. Stremitzer, A. Tacconelli

**Abstract**

Contract Design I is taught by Professor Stremitzer and aims to bridge the gap between economic contract theory, contract law, and the practice of contract design. In this course, we take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction takes place and then engineer contracts that achieve the desired outcome.

We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting and apply the theoretical insights to real-life case studies ranging from purchases & sales of assets, oil & gas exploration, movie financing, production & distribution, construction & development, M&A deals, venture capital financing, to executive compensation and many other types of transactions. The course follows a flipped-classroom model: You will watch learning videos specifically produced for this course ahead of class. We will use class time to discuss real-world case studies. The videos will be made available before the lecture each week and need to be watched ahead of coming to class. Computer-graded quizzes at the beginning of each class will test students' understanding of the concepts introduced in the videos.

As the emphasis of this class is on class discussion, attendance is mandatory. Absent important reasons, you cannot miss class more than twice.

The lectures will be recorded but only made available to those who miss lectures with excused absence.

For ETH students: Your grade will consist of two parts:

1. **Assignments:** You will take weekly computer-based quizzes during class time. Thus, it is important that you attend the lectures to be able to finish the quizzes and pass this course.
2. **Take-home questions:** You will compose short responses to take-home questions on case studies we assign and upload them ahead of class (Part/Fail).

Note that UZH and UNISG students enrolling in this course need to earn more ECTS for completing this course than ETH students (due to curricula reasons). This is why UZH and UNISG students must complete a written assignment in addition to the weekly quizzes and take-home questions. UZH students also have to complete an additional group project.

**Literature**


Max 80 ETHZ and 80 UZH Students

Number of participants limited to 160.

**Prerequisites**

Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, DMATH, D-MTEC, D-INF, and D-MAVT.

**Lectures**

A. Stremitzer, A. Tacconelli

**Contact**

lucas.gericke@gess.ethz.ch or Serge von Steiger (serge.vonsteiger@gess.ethz.ch).
**Competencies**

**Subject-specific Competencies**
- Concepts and Theories
  - assessed
- Techniques and Technologies
  - assessed

**Method-specific Competencies**
- Analytical Competencies
  - assessed
- Decision-making
  - assessed
- Problem-solving
  - assessed

**Social Competencies**
- Communication
  - assessed
- Cooperation and Teamwork
  - assessed
- Customer Orientation
  - assessed
- Negotiation
  - assessed

**Personal Competencies**
- Creative Thinking
  - assessed

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**Network Analysis**

**Subject-specific Competencies**
- Concepts and Theories
  - fostered
- Techniques and Technologies
  - assessed

**Method-specific Competencies**
- Analytical Competencies
  - assessed
- Decision-making
  - fostered
- Problem-solving
  - assessed

**Social Competencies**
- Communication
  - fostered
- Self-presentation and Social Influence
  - fostered
- Sensitivity to Diversity
  - fostered

**Personal Competencies**
- Adaptability and Flexibility
  - fostered
- Creative Thinking
  - assessed
- Critical Thinking
  - assessed
- Integrity and Work Ethics
  - fostered
- Self-awareness and Self-reflection
  - fostered

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**Introduction to Cybersecurity Politics**

- Concepts and Theories
  - fostered
- Techniques and Technologies
  - assessed
Creative Thinking assessed

Literatur für die einzelnen Sitzungen wird auf Moodle bereitgestellt.

Supervised Research (Law, Economics, and Data Communication)

Understanding is a central goal of science and mathematics, but what exactly is the nature of scientific and mathematical understanding?

Analytical Competencies assessed

Decision-making fostered

Media and Digital Technologies fostered

Problem-solving assessed

Communication fostered

Cooperation and Teamwork fostered

Sensitivity to Diversity fostered

Creative Thinking assessed

Critical Thinking assessed

Self-direction and Self-management fostered

The Role of Technology in National and International Security Policy

The lecture provides an introduction to the role of security and military technologies in the formulation and implementation of national and international security policies. The focus is on challenges posed by new and developing technologies, the transformation of military capabilities, and the question of regulation.

Participants will gain an in-depth overview of the many ways in which technology is becoming part of security policies and practices, in both civilian and military contexts.


The lecture is being supported by a website on Moodle. If you have any questions, please contact Fabio Schmocker (fabio.schmocker@sipo.gess.ethz.ch)

The lecture allows students to develop and apply analytical and critical thinking skills in the context of national and international security policies. It also fosters subject-specific competencies in mathematics, philosophy, and political science.

The main objective of this seminar is to gain an in-depth understanding of these recent philosophical developments.

Philosophical Perspective

Understanding is a central goal of science and mathematics, but what exactly is the nature of scientific and mathematical understanding? In this seminar, we will read and discuss a number of key philosophical contributions on understanding in philosophy of science, philosophy of mathematics, and epistemology. You will also practice your skills in giving clear and engaging oral presentations.

The main objective of this seminar is to gain an in-depth understanding of the recent literature on understanding in the philosophy of science, the philosophy of mathematics, and epistemology. Another practical objective is to increase your skills in giving clear and engaging oral presentations.

Students must have some data science and/or statistics experience. Some programming experience in Python, Stata, or R is required. Apply tools from data science and social science to a new project, potentially in a group, to develop a paper or app. Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

Understanding is a central goal of science and mathematics: scientists seek to understand various phenomena in the natural world, while mathematicians aim to increase our understanding of the mathematical world. But what exactly is the nature of understanding in science and mathematics? This issue has been largely neglected in twentieth century philosophy of science, philosophy of mathematics, and epistemology. Yet, in the past twenty years, there has been a regain of philosophical interest into the notion of understanding, leading to a flourishing literature. The aim of this seminar is to gain an in-depth understanding of these recent philosophical developments.

To this end, we will read a number of key philosophical contributions on understanding in philosophy of science, philosophy of mathematics, and epistemology. Along the way, we will address general issues on understanding such as: What is the relation between understanding and knowledge? Does understanding necessarily require explanation? How can understanding be transmitted? What exactly is the value of understanding? We will also look into specific case studies of scientific and mathematical understanding.

Each session will be decomposed into three blocks. In block 1 and 2, we will have a short presentation (~15 minutes) of a contribution in the philosophy of understanding followed by a discussion. Block 3 will be methodological and will be concerned with how to give good oral presentations, an essential skill in academia. We will use this block to debrief on the presentations of the day and see how they could be improved. We will also discuss resources on best practices in oral communication.

Network Modeling

Particularly suitable for students of D-MATH, D-INFK and in the MSc Data Science

Students are required to have basic knowledge in inferential statistics, such as regression models.

Social Network Science is a distinct domain of data science that focuses on relational systems. Various models have been proposed to describe structures and dynamics of networks, including statistical and mathematical methods. In this course, the emphasis is placed on the statistical analysis of (social) systems and their connection to social theories and data sources.
Objective

The following topics will be covered:

- Introduction to network models and their applications
- Stylized models:
  * uniform random graph models
  * small world models
  * preferential attachment models
- Models for testing hypotheses while controlling for the network structure:
  * Quadratic assignment procedure regression (QAP regression)
- Models for testing hypotheses on the network structure:
  * Models for one single observation of a network: exponential random graph models (ERGMs)
  * Models for panel network data: stochastic actor-oriented models (SAOMs)
- Models for testing hypotheses while controlling for the network structure:
  * Quadratic assignment procedure regression (QAP regression)

The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

Content

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- Introduction to network models and their applications
- Stylized models:
  * uniform random graph models
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  * Models for panel network data: stochastic actor-oriented models (SAOMs)
  * Models for relational event data: dynamic network actor models (DyNAMs)

The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

Lecture notes

Slides and lecture notes are distributed via the associated course moodle.

Literature


Prerequisites / notice

Students are required to have basic knowledge in inferential statistics and should be familiar with linear and logistic regression models.
fostered

Analytical Competencies


Literatur

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

After you received your logon information you can enrol to courses at:
https://studentservices.uzh.ch/uzh/application#/Logon

The lecture provides an introduction to the role of security and military technologies in the formulation and implementation of national and international security policies. The focus is on challenges posed by new and developing technologies, the transformation of military capabilities, and the question of regulation.

Objective

Participants will gain an in-depth overview of the many ways in which technology is becoming part of security policies and practices, in both civilian and military contexts.

Content

The lecture is an introduction to global cybersecurity politics. The focus is on challenges posed by new and developing technologies, the transformation of military capabilities, and the question of regulation.

Objective

On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

Lecture notes

A script with background information and comments on the literature will be made available at the beginning of the semester.

Literature

For each session will be available on Moodle. A script with background information and comments on the literature will be made available at the beginning of the semester.

Competencies

Subject-specific Competencies

Analytical Competencies

Decision-making

Problem-solving

Social Competencies

Communication

Leadership and Responsibility

Sensitivity to Diversity

Negotiation

Personal Competencies

Creative Thinking

Critical Thinking

Environmental Ethics (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: 07SM3002

Please register at:
https://www.uzh.ch/cmsssl/de/studies/application/chnobilit_yin.html

The lecture is being supported by a website on Moodle. If you have any questions, please contact Fabio Schmocker (fabio.schmocker@sipo.gess.ethz.ch)

The lecture provides an introduction to the role of national and international security policy. Participants will gain an in-depth overview of the many ways in which technology is becoming part of security policies and practices, in both civilian and military contexts.

Objective

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Objective

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### Supervised Research (Law, Economics, and Data Science)

**Number**: 851-0763-00L  
**Type**: W  
**ECTS**: 3  
**Title**: Project in Behavioural Finance  

**Abstract**
This is a supervised student project for 3 ECTS, supervised by the professorship of Elliott Ash (D-GESS). Students will adapt tools from econometrics and machine learning to questions in law, data science, and social science.

**Objective**
Students must have some data science and/or statistics experience. Some programming experience in Python, Stata, or R is required.

**Prerequisites / Notice**
Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

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### D-MTEC

#### Project in Behavioural Finance

- **Number**: 851-0252-10L  
- **Type**: W  
- **ECTS**: 3  
- **Title**: Project in Behavioural Finance  

**Abstract**
In this seminar, students will study cognitive processes, behaviour and the underlying biological response to financial decisions. Research methods such as asset market experiments, lottery games, risk preference assessment, psychometrics, neuroimaging and psychophysiology of decision processes will be discussed. Financial bubbles and crashes will be the core interest.

**Objective**
This course has four main goals:
1. To learn about the most important topics within Behavioural Finance  
2. To learn to effectively select, review and present information using modern telecommunication tools  
3. To practice working on group projects in hybrid working conditions (online + in-person)  
4. To solve an applied behavioral finance business case stemming from an industry partner

**Content**
The course takes place entirely online. The objective is to prepare the students for the future work in online and hybrid arrangements. Throughout the semester, students work on solutions to real business cases stemming from a company partner. They can receive feedback and guidance from project leaders of the industry partner and from the academic supervisors. In the final meeting of the semester, students pitch solutions to their business cases.

**Prerequisites / Notice**
Students from all domains of ETH and all levels of education are welcome in the course.

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### Principles of Macroeconomics

**Number**: 363-0565-00L  
**Type**: W  
**ECTS**: 3  
**Title**: Principles of Macroeconomics  

**Abstract**
This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

**Objective**
This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

**Content**
Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, how do you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

**Lecture notes**
The course Moodle page contains announcements, course information and lecture slides.

This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filippini).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: fostered
- Negotiation: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### Literature


### Prerequisites / notice

This course “Einführung in die Mikroökonomie” (363-1109-00L) is intended for Bachelor students and LE 363-0503-00 “Principles of Microeconomics” for Master students.

### Abstract

The course introduces basic principles, problems and approaches of microeconomics. It describes economic decisions of households and firms, and their coordination through perfectly competitive markets.

### Objective

Students acquire a deeper understanding of basic microeconomic models. They acquire the ability to apply these models in the interpretation of real world economic contexts.

Students acquire a reflective and contextual knowledge on how societies use scarce resources to produce goods and services and distribute them among themselves.

### Content

Market, budget constraint, preferences, utility function, utility maximisation, demand, technology, profit function, cost minimisation, cost functions, perfect competition, information and communication technologies

### Lecture notes

Course material in e-learning environment: https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php

### Literature


### Prerequisites

This course is only for students enrolled in a Bachelor's degree programme.

Students enrolled in a Master's degree programme may attend “Principles of Microeconomics” (LE 363-0503-00L) instead.

Note for D-MAVT students: If you have already successfully completed “Principles of Microeconomics” (LE 363-0503-00L), then you will not be permitted to attend it again.

### 351-1109-00L Introduction to Microeconomics

GESE (Science in Perspective):

This course is only for students enrolled in a Bachelor's degree programme.

Students enrolled in a Master’s degree programme may attend “Principles of Microeconomics” (LE 363-0503-00L) instead.

Note for D-MAVT students: If you have already successfully completed “Principles of Microeconomics” (LE 363-0503-00L), then you will not be permitted to attend it again.

Students acquire a deeper understanding of basic microeconomic models. They acquire the ability to apply these models in the interpretation of real world economic contexts.

Students acquire a reflective and contextual knowledge on how societies use scarce resources to produce goods and services and distribute them among themselves.

### Content

Market, budget constraint, preferences, utility function, utility maximisation, demand, technology, profit function, cost minimisation, cost functions, perfect competition, information and communication technologies

### Lecture notes

Course material in e-learning environment: https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php

### Literature


### Prerequisites

This course “Einführung in die Mikroökonomie” (363-1109-00L) is intended for Bachelor students and LE 363-0503-00 “Principles of Microeconomics” for Master students.

### Competencies

#### Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: fostered

#### Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: fostered
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: fostered

#### Social Competencies
- Communication: fostered
- Cooperation and Teamwork: fostered
- Customer Orientation: fostered
- Leadership and Responsibility: fostered
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: fostered
- Negotiation: fostered

#### Personal Competencies
- Adaptability and Flexibility: fostered
- Creative Thinking: fostered
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: fostered
- Self-direction and Self-management: fostered

### 851-0742-00L Contract Design I

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for “Contract
This course introduces students to the data science tools that may provide the first building blocks for a robot judge. While building a working robot judge might be far off in the future, some of the building blocks are already here, and we will put them to work.

We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting and apply the theoretical insights to real-life case studies ranging from purchases & sales of assets, oil & gas exploration, movie financing, production & distribution, construction & development, M&A deals, venture capital financing, to executive compensation and many other types of transactions.

The course follows a flipped-classroom model: You will watch learning videos specifically produced for this course ahead of class. We will use class time to discuss real-world case studies. The videos will be made available before the lecture each week and need to be watched ahead of coming to class. Computer-graded quizzes at the beginning of each class will test students' understanding of the concepts introduced in the videos.

As the emphasis of this class is on class discussion, attendance is mandatory. Absent important reasons, you cannot miss class more than twice.

The lectures will be recorded but only made available to those who miss lectures with excused absence.

For ETH students: Your grade will consist of two parts:
1) You will take weekly computer-based quizzes during class time. Thus, it is important that you attend the lectures to be able to finish the quizzes and pass this course.
2) You compose short responses to take-home questions on case studies we assign and upload them ahead of class (Pass/Fail).

Note that UZH and UNISG students enrolling in this course need to earn more ECTS for completing this course than ETH students (due to curricula reasons). This is why UZH and UNISG students must complete a written assignment in addition to the weekly quizzes and take-home questions. UZH and UNISG students also have to complete an additional group project.

UZH and UNISG students should check out the description of the class at their respective home institutions.

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If you have any questions regarding the course, please write an email to the teaching assistants, Lucas Gericke (lucas.gericke@gess.ethz.ch) or Serge von Steiger (serge.vonsteiger@gess.ethz.ch).

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Contract Design I (851-0742-00L; Fall 2023) is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, DMATH, D-MTEC, D-INFK, and D-MAVT.

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Abstract
This course introduces students to scientific and technological developments that require regulation or enable legal innovation. We focus particularly on the challenges to current law posed by prominent near-future technologies.

Objective
The course is designed for a wide range of ETH students as well as for law students who are keen to deepen their understanding of cutting-edge technology. It offers an overview of key legal areas important for technology regulation, complemented by guest lectures on emerging technological trends.

In previous years, the course has featured esteemed speakers from various sectors, including industry leaders like Google, NGOs such as Digital Society Switzerland and The European Consumer Organization, regulatory bodies like the Swiss Competition Commission, and noted academics.

The course is open to ETH students through the Science in Perspective program of the Department of Humanities, Social and Political Sciences.

Content
The planned course outline is below.

- Overview of Law and Technology
- Fundamental Rights
- AI & Discrimination
- Landmark Big Tech Cases
- Regulation of Digital Platforms & Content Moderation
- Online Consumer Protection
- Law and Tech Scholarship Series

A number of recent regulations will be discussed, including the EU’s AI Act, the Digital Services Act (DSA), and the Digital Markets Act (DMA), as well as emerging internet phenomena, like ChatGPT.

Prerequisites / notice
You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for "Law & Tech (851-0732-06L, HS 2024)" and enroll.

Competencies
Subject-specific Competencies
- Concepts and Theories
- Analytical Competencies
- Media and Digital Technologies

Method-specific Competencies
- Communication
- Critical Thinking

Social Competencies
- Creative Thinking
- assessed

Personal Competencies
- assessed

Prerequisites / notice
This course is especially recommended after the related lecture "851-0390-00G Human-Centered IT Security and Privacy". However, previous participation in the lecture is not a requirement and not necessary for succeeding in the course.

851-0391-00L Focus on the Human: Human-Centered Security and Privacy Lab
W 3 credits 2S V. Zimmermann, A. Toth

Abstract
After an introduction on usable security as the intersection of computer science and psychology, students will form teams and work on exemplary security- or privacy-related research questions. The teams will develop and evaluate a concept for a human-centered solution. Through input sessions and milestone presentations the human perspective will be incorporated and reflected upon.

Objective
The course makes students experience an exemplary human-centered design process. They will learn about and practically apply human-centered design and evaluation methods that will allow them to view their solution from the human perspective, e.g., the user, developer or website owner perspective. By taking part in the evaluation of other teams, they will also take the user perspective themselves.

Content
At the beginning of the course, the students will receive an introduction to usable IT security and privacy and relevant concepts. Afterwards, a selection of current research questions from that area will be presented. The students form teams and select one of the proposed research questions. This question will accompany the students throughout the semester. They will design and evaluate a concept for a human-centered solution to that question. To do so, they will receive input on human-centered design and evaluation tools. Their progress and the inclusion of the human perspective will be subject to feedback in milestone presentations. The students’ human-centered solution can take the form of a concept (e.g., a concept for a product or app), interface (e.g., a visual or tangible interface), or prototype (e.g., sketches, a click-dummy or a built prototype). The solution will then be subject to evaluations. The solutions will be user-tested by members of other teams that thereby take the perspective of a user themselves. In addition, the solutions will be analyzed from different stakeholders’ perspectives, such as developers or website owners. Finally, the students will reflect on potential changes that results from the evaluations and their consequences.

Literature

Prerequisites / notice
This course is especially recommended after the related lecture "851-0390-00G Human-Centered IT Security and Privacy". However, previous participation in the lecture is not a requirement and not necessary for succeeding in the course.
Analytical Competencies
Concepts and Theories

Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management

Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Sensitivity to Diversity

Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Subject-specific Competencies

Abstract
This is a supervised research project for 3 ECTS, supervised by the professorship of Elliott Ash (D-GESS). Students will adapt tools from econometrics and machine learning to questions in law, data science, and social science.

Objective
Apply tools from data science and social science to a new project, potentially in a group, to develop a paper or app.

Literature

Comprehensiveness
Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

Complain

Does not take place this semester.

ECTS
W 3 credits W

N. Zufferey, V. Zimmermann


Comprehensiveness
Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

Complain

Does not take place this semester.

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N. Zufferey, V. Zimmermann


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Complain

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ECTS
W 3 credits W

N. Zufferey, V. Zimmermann


Comprehensiveness
Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

Complain

Does not take place this semester.
The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.

Contracts are agreements between parties to engage in transactions. A good contract creates value by giving parties the right incentives to meet their objectives. A good contract designer scrutinizes the economic situation in which parties find themselves and tailors the contract to the challenges at hand. To help you become sophisticated contract designers, we draw from insights for which more than half a dozen Nobel Prizes were awarded in the past two decades and transfer them to the art of writing real-world contracts. In other words, Contract Design will provide you with analytical tools to design contracts that help you be better lawyers, business leaders, and startup founders.

We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting and apply the theoretical insights to real-life case studies ranging from purchases & sales of assets, oil & gas exploration, movie financing, production & distribution, construction & development, M&A deals, venture capital financing, to executive compensation and many other types of transactions.

The course follows a flipped-classroom model: You will watch learning videos specifically produced for this course ahead of class. We will use class time to discuss real-world case studies. The videos will be made available before the lecture each week and need to be watched ahead of coming to class. Computer-graded quizzes at the beginning of each class will test students' understanding of the concepts introduced in the videos.

As the emphasis of this class is on class discussion, attendance is mandatory. Absent important reasons, you cannot miss class more than twice.

The lectures will be recorded but only made available to those who miss lectures with excused absence.

For ETH students: Your grade will consist of two parts:
1) You will take weekly computer-based quizzes during class time. Thus, it is important that you attend the lectures to be able to finish the quizzes and pass this course.
2) You compose short responses to take-home questions on case studies we assign and upload them ahead of class (Pass/Fail).

Note that UZH and UNISG students enrolling in this course need to earn more ECTS for completing this course than ETH students (due to curricula reasons). This is why UZH and UNISG students must complete a written assignment in addition to the weekly quizzes and take-home questions. UZH students also have to complete an additional group project.

UZH and UNISG students should check out the description of the class at their respective home institutions.

Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, DMATH, D-MTEC, D-INFK, and D-MAVT.

If you have any questions regarding the course, please write an email to the teaching assistants, Lucas Gericke (lucas.gericke@geiss.ethz.ch) or Serge von Steiger (serge.vonsteiger@geiss.ethz.ch).

The Role of Intellectual Property in the Engineering and Technical Sector

Abstract
The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.

Objective
In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

Prerequisites / notice
The lecture addresses students in the fields of engineering, science and other related technical fields.
fostered assessed

**851-0735-10L** Startups and Law

*Particularly suitable for students of D-ITET, D-MAVT.*

**Abstract**
The students shall obtain a basic knowledge about the legal environment of entrepreneurs. They shall be able to recognize and evaluate legal issues connected to an entrepreneurial activity and suggest possible solutions.

**Objective**
The students shall obtain the following competences:
- They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise.
- They shall be able to contribute to the legal management of the company and to discuss legal issues.
- They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company.

**Lecture notes**
A comprehensive script will be made available online on the moodle platform.

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories
  - Problem-solving
- Personal Competencies
  - Critical Thinking
  - Self-awareness and Self-reflection

**851-0703-00L** Introduction to Law

**Abstract**
This class introduces students into basic features of the legal system. Fundamental issues of constitutional law, administrative law, private law and the law of the EU are covered. The focus is on legal problems related to space. Active participation is expected in short interactive sequences.

**Objective**
Students are able to identify basic structures of the legal system. They understand selected topics of public and private law. They are able to apply the fundamentals in more advanced law classes and to recognize the relevance of law in their own field.

**Content**
Basic concepts of law, sources of law.
Private law: Contract law (particularly contract for work and services), tort law, property law.
Public law: Human rights, administrative law, procurement law, procedural law.
Insights into the law of the EU.

**Lecture notes**
Jaap Hage, Bram Akkermans (Eds.), Introduction to Law, Cham 2017 (Online Resource ETH Library)

**Literature**
Further documents will be available online (https://moodle-app2.let.ethz.ch/course/view.php?id=22904).

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Problem-solving
- Social Competencies
  - Communication
  - Negotiation
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics

**851-0047-01L** World Politics Since 1945: The History of International Relations (Without Exercises)

**Abstract**
This lecture series provides students with an overview of the development of international relations since the end of World War II. The first part of the series deals with the development of and changes in Cold War security policy structures. The second part deals with the period after the transformation of 1989/91; the focus here is on current issues in international security policy.

**Objective**
By the end of the semester, participants should have a solid knowledge of the history and theoretical foundations of International Relations since the end of the Second World War.

**Content**
cf. "Diploma Supplement"

**Prerequisites / notice**
The lecture is being supported by a website on Moodle. If you have any questions, please contact Fabio Schmocker (fabio.schmocker@sipo.gess.ethz.ch)

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Problem-solving
  - Leadership and Responsibility
  - Sensitivity to Diversity
  - Negotiation
- Social Competencies
  - Communication
- Personal Competencies
  - Creative Thinking

**851-0725-00L** History Part One: Europe (The Cradle of Modernity, Britain, 1789-1914)

**Abstract**
A range of fundamental processes have transformed European societies in the course of the 19th and the 20th centuries. This lecture series looks at several key aspects of these modernization processes and ask about their continuing relevance for our times. The regional focus lies on the Britain, where these processes took place for the first time.

**Objective**
At the end of this lecture course, students can: (a) highlight the most important changes in the "long nineteenth century" in Britain (b) explain their long-term effects (also for other European countries; and (c) relate these changes to global developments today.

**Content**
The thematic foci include: Industrialization, urban growth, democratisation and mass politics, shifting gender roles and ideals, and the emergence of consumerism and leisure culture.

**Lecture notes**
Power Point Slides and references will be made available in digital form during the course of the semester.

**Literature**
Mandatory and further reading will be listed on the course plan that is made available as from the first session.

**Prerequisites / notice**
This lecture series does not build upon specific previous knowledge by the students.

**Competencies**
- Subject-specific Competencies
  - Concepts and Theories
  - Analytical Competencies
  - Sensitivity to Diversity
  - Critical Thinking
- Personal Competencies

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Environmental Ethics (University of Zurich)  
W  3 credits  2V  University lecturers

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: 07SMEEE266

Please register at:
https://www.uzh.ch/cmsssl/de/studies/application/chmobiity.html

after you received your logon information you can enrol to courses at:
https://studentservices.uzh.ch/uzh/application#/Logon

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

Abstract
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.

Objective
On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

Introduction to Cybersecurity Politics  
W  3 credits  2G  M. Dunn Cavelti, F. J. Egloff

Abstract
The lecture is an introduction to global cybersecurity politics. The focus is on the strategic use of cyberspace by state and non-state actors (threats) and different answers to these new challenges (countermeasures).

Objective
Participants learn to assess the advantages and disadvantages of cyberspace as a domain for strategic military operations. They understand the technical basics of cyber operations and know how technology and politics are interlinked in this area. They understand the security challenges for and the motivations of states to be active in cyberspace offensively and defensively and they are familiar with the consequences for international politics.

Content
We start with an overview of cybersecurity issues from 1980 to today and look at events and actors responsible for turning cybersecurity matters into a security political issue with top priority. After familiarizing ourselves with the technical basics, we look at different forms of cyberviolence and trends in cyber conflicts (technique in social and political practice). Then, we turn to countermeasures: we compare national cybersecurity strategies, examine international norms building, and scrutinize concepts such as cyber-power and cyber-deterrence (technique in social and political regulatory contexts).

Lecture notes
A script with background information and comments on the literature will be made available at the beginning of the semester.

Literature
Literature for each session will be available on Moodle.

Prerequisites / notice
The lecture is being supported by a website on Moodle.

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The Role of Technology in National and International Security Policy  
W  3 credits  2G  M. Leese, A. Dossi

Abstract
The lecture provides an introduction to the role of security and military technologies in the formulation and implementation of national and international security policies. The focus is on challenges posed by new and developing technologies, the transformation of military capabilities, and the question of regulation.

Objective
Participants will gain an in-depth overview of the many ways in which technology is becoming part of security policies and practices, in both civilian and military contexts.

Content

Literature
Literatur für die einzelnen Sitzungen wird auf Moodle bereitgestellt.

Prerequisites / notice
The lecture is being supported by a website on Moodle. If you have any questions, please contact Fabio Schmocker (fabio.schmocker@sipo.gess.ethz.ch)

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Focus on the Human: Human-Centered Security and Privacy Lab  
W  3 credits  2S  V. Zimmermann, A. Toth

The course is particularly suitable for all students who

https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

https://studentservices.uzh.ch/uzh/application#/Logon

Mind the enrolment deadlines at UZH:
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https://www.uzh.ch/cmsssl/en/studies/application/deadline.html
have already completed the course “Human-centered IT Security and Privacy” as some of the concepts introduced will practically be applied in this course. However, the relevant literature and necessary material will be provided to all students and basic concepts will be briefly summarized so that all interested students can participate.

### Abstract
After an introduction on usable security as the intersection of computer science and psychology, students will form teams and work on exemplary security- or privacy-related research questions. The teams will develop and evaluate a concept for a human-centered solution. Through input sessions and milestone presentations the human perspective will be incorporated and reflected upon.

### Objective
The course makes students experience an exemplary human-centered design process. They will learn about and practically apply human-centered design and evaluation methods that will allow them to view their solution from the human perspective, e.g., the user, developer or website owner perspective. By taking part in the evaluation of other teams, they will also take the user perspective themselves.

### Content
At the beginning of the course, the students will receive an introduction to usable IT security and privacy and relevant concepts. Afterwards, a selection of current research questions from that area will be presented. The students form teams and select one of the proposed research questions. This question will accompany the students throughout the semester. They will design and evaluate a concept for a human-centered solution to that question. To be able to do so, they will receive input on human-centered design and evaluation tools. Their progress and the inclusion of the human perspective will be subject to feedback in milestone presentations.

The students’ human-centered solution can take the form of a concept (e.g., a concept for a product or app), interface (e.g., a visual or tangible interface), or prototype (e.g., sketches, a click-dummy or a built prototype). The solution will then be subject to evaluations. The solutions will be user-tested by members of other teams that thereby take the perspective of a user themselves. In addition, the solutions will be analyzed from different stakeholders’ perspectives, such as developers or website owners. Finally, the students will reflect on potential changes that result from the evaluations and their consequences.

### Literature
Literature Recommendations:


Prerequisites / notice
This course is especially recommended after the related lecture "851-0390-00 G Human-Centered IT Security and Privacy". However, previous participation in the lecture is not a requirement and not necessary for succeeding in the course.

### Competencies

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### Prerequisites

- Some programming experience in Python, Stata, or R is required. Some experience with data science and social science is highly recommended.
- Some experience with data science or statistics is required.

### References


Data: 15.06.2024 12:39 Autumn Semester 2024 Page 2637 of 2653
Mechanisms

Abstract
Students will gain an overview of the main privacy metrics that are used to evaluate privacy risks related to the use of a given technology. They will also be introduced to the concepts of privacy/utility balance and usable security. Practical exercises and reading of recently published scientific articles will be used to present practical cases of the theoretical tools presented in class.

Objective
This course aims to provide the students with a global knowledge of the concepts related to privacy, and the methodology and tools to identify, analyze, and address threats while taking the user into account in the process. They will adopt a "privacy mindset", thus enabling them to automatically take privacy into account, in a usable way, when designing or analyzing a system.

Content
First, the course will introduce the different definitions and approaches of privacy (e.g., privacy by control, privacy by design) as well as the ethical concerns and considerations related to information security and privacy research (e.g., responsible disclosure, full disclosure).

Second, the students will be introduced to the different methods, properties, and metrics to assess and/or guarantee a certain level of privacy. They will be introduced to the properties and metrics related to anonymization (e.g., k-anonymity, l-diversity), data aggregation (e.g., randomized responses, \( \varepsilon \)-differential privacy), as well as other privacy assessment methodologies (e.g., inferential privacy).

Third, the course will address usability issues and the role of individuals (i.e., users) in privacy management (i.e., usable security and privacy) and the design of privacy-enhancing technologies. In this context, we will analyze the main concepts seen during the course and discuss their advantages and disadvantages in terms of usability, as well as their implementation for mass-market and large-scale technologies.

Across all three parts of the course, practical exercises, as well as recent research articles reading, and presentations will be used as a complement to support the concepts seen in class, as well as to provide concrete examples of methodologies related to the assessment of privacy in general.

Literature


Competencies
Subject-specific Competencies
- Concepts and Theories
- assessed
- Techniques and Technologies
- assessed
- Analytical Competencies
- fostered
- Communication
- fostered
- Critical Thinking
- fostered
- Integrity and Work Ethics
- fostered

Method-specific Competencies
- Creative Thinking
- fostered

Social Competencies
- Communication
- fostered

Personal Competencies
- Communication
- fostered

D-PHYS
851-0101-86L Complex Social Systems: Modeling Agents, Learning, and Games
Prerequisites: Basic programming skills, elementary probability and statistics.

Abstract
This course introduces mathematical and computational models to study techno-socioeconomic systems and the process of scientific research. Students develop a significant project to tackle techno-socio-economic challenges in application domains of complex systems. They are expected to implement a model and to communicate their results through a project report and a short oral presentation.

Objective
See your own field of study in a wider context ("Science in Perspective"), e.g., see the psychological, social, economic, environmental, historical, ethical or philosophical connections and implications. Learn to think critically and out of the box. Question what you believe you know for sure. Get to know surprising, counterintuitive properties of complex (non-linearly interacting, networked, multi-component) systems. Learn about collaboration.

Content
By the end of the course, the students should be able to better understand the literature on complex social systems, develop their own models for studying specific phenomena and report results according to the standards of the relevant scientific literature by presenting their results both numerically and graphically.

At the end of the course, the students will deliver a report, computer code and a short oral presentation. To collect credit points, students will have to actively contribute and give a circa 30 minutes presentation in the course on a subject agreed with the lecturers, after which the presentation will be discussed. The presentation will be graded.

Students are expected to implement themselves models of techno-socio-economic processes and systems, particularly agent-based models, complex network models, decision making, group dynamics, human crowds, or game-theoretical models. Credit points are finally earned for the implementation of a mathematical or empirical model from the complexity science literature, its presentation, and documentation by a project report.

Lecture notes
The lecture slides will be presented on the course Moodle after each lecture.
Prerequisites / notice

The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.

Good programming skills and a good understanding of probability & statistics and calculus are expected.

Students need to present a new subject, for which they have not earned any credit points before.

Good scientific practices, in particular citation and quotation rules, must be properly complied with.

Chatham House rules apply to this course. Materials may not be shared without previous written permission.

Competencies

Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: fostered
- Problem-solving: assessed
- Project Management: assessed

Social Competencies

- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: fostered
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: fostered

Personal Competencies

- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: fostered
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed


851-0763-00L Supervised Research (Law, Economics, and Data Science) W 3 credits E. Ash

Does not take place this semester.

Abstract

This is a supervised student project for 3 ECTS, supervised by the professorship of Elliott Ash (D-GESS). Students will adapt tools from econometrics and machine learning to questions in law, data science, and social science.

Objective

Apply tools from data science and social science to a new project, potentially in a group, to develop a paper or app.

Prerequisites / notice

Some programming experience in Python, Stata, or R is required. Some experience with data science or statistics is required.

851-0125-65L A Sampler of Histories and Philosophies of Mathematics Particularly suitable for students D-CHAB, D-INFK, D-ITET, D-MATH, D-PHYS W 3 credits 2V R. Wagner

Abstract

This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

Objective

The course aims are:
1. To introduce students to the historicity of mathematics
2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
3. To develop critical reflection concerning the nature of mathematical objects
4. To introduce various theoretical approaches to the philosophy and history of mathematics
5. To open the students' horizons to the plurality of mathematical cultures and practices

Competencies

Subject-specific Competencies

- Concepts and Theories: assessed

Method-specific Competencies

- Analytical Competencies: assessed

Social Competencies

- Sensitivity to Diversity: fostered

Personal Competencies

- Critical Thinking: fostered

D-USYS

Number Title Type ECTS Hours Lecturers

860-0023-00L International Environmental Politics W 3 credits 2V T. Bernauer
The objectives in this course are to (1) gain an overview of important questions pertaining to international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions in this policy area and how to address them in a conceptually and methodologically meaningful and insightful way; (3) gain an overview of important global and regional environmental problems and how they are or could be solved.

The course deals with how and why international problem-solving efforts (cooperation) in environmental politics emerge and evolve, and under what circumstances such efforts are effective. Based on concepts and theories of political economy, political science, and public policy, various examples of international environmental policy-making are examined, for example international efforts to reduce air pollution, manage international water resources, mitigate and adapt to global warming, protect the stratospheric ozone layer, address biodiversity challenges, deal with plastic waste, and prevent pollution of the oceans.

Reading materials and slides will be available via Moodle.

Credits and Exam
After passing a written test at the end of the course (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test). Visiting students (e.g., from the University of Zurich, exchange students) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory. Students who obtain a grade of < 4.0 for the test will have a second chance (see table below). Students who did not participate in the test on 18 December 2023 will not have access to the repeat test unless they submit compelling and documented (e.g. medical, other exam in parallel at ETH) reasons for why they were unable to participate in the first test. It covers all contents of the lectures and the reading assignments. Visiting students (e.g., from the University of Zurich or other universities) are subject to the same conditions. Registration for the course in the mystudies system of ETH is compulsory. No separate registration for the exam is required, registration for the course as such covers everything. The exam will take place on campus, either in the F3 lecture hall or in a computer room. That is, you must be present in person at ETH Zurich on the exam date/time.

Enrolment
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: 07SMEEE266

Please register at:
https://www.uzh.ch/cmsssl/de/studies/application/chmobilit yin.html
after you received your logon information you can enrol to courses at:
https://studentservices.uzh.ch/uzh/application##/Logon
Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.

On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

This course presents the basics of public policy analysis and the specific characteristics of Swiss environmental policy. Policy instruments, actors and processes are addressed from a political science perspective both theoretically as well as by means of current Swiss environmental policy examples.

Beyond acquiring basic knowledge about public policy analysis, this course teaches students how to analytically address current and concrete questions of environmental policy. Through exercises the students learn about political science concepts and frameworks as well as real-life political decision-making processes. The well-grounded examination of complex political conflict situations is an important precondition for the entry into the (environmental policy) workforce or a future research career.

The processes of change, overuse or destruction of the natural environment through humans have historically placed high demands on social and political institutions. In the interplay between the environment, society and economy, the environmental policy field encompasses the sum of public measures that have the goal to eliminate, reduce or avoid environmental degradation. The course systematically presents the basics of environmental policy instruments, actors, programs and processes as well as their change over time. Invited practitioners will provide us with insight regarding the current developments in forest, water and spatial planning policies. A key aspect is the distinction between politics and political science and specifically environmental policy.

The reader and additional lecture material and exercises will be posted on Moodle.

This is a supervised student project for 3 ECTS, supervised by the professorship of Elliott Ash (D-GESS). Students will adapt tools from econometrics and machine learning to questions in law, data science, and social science.

Students must have some data science and/or statistics experience. Some programming experience in Python, Stata, or R is required.
Life and Death

Abstract

This course explores the relation between the scientific investigation of life and cultural notions of death from a historical perspective (assuming there is no such thing as the scientific investigation of death). While the course covers the times from antiquity up to the present, the main emphasis will be placed on the modern life sciences since the 19th century.

Objective

There is only one certainty in life: death. This brute fact has animated much thought and work in theology, art and philosophy - but also in the natural sciences, such as biology and medicine. Questions regarding health and disease, evolution, extinction and immortality have played a crucial role in this connection. This course aims to explore above relations - the relations between the scientific investigation of life and cultural notions of death - from a historical perspective (assuming there is no such thing as the scientific investigation of death). While the course covers the times from antiquity up to the present, the main emphasis will be placed on the modern life sciences since the 19th century.

Mediation in Environmental Planning: Theory and Case Studies

Abstract

This course is intended to demonstrate how environmental decisions can be optimized and conflicts better dealt by using mediation. Case studies will focus on construction of windmills for electricity purpose, landfills, sustainable city-planning or Human-Wildlife Conflict and Coexistence.

Objective

- Develop comprehension of legal and social responses to environmental conflicts
- Recognize the most important participative techniques and their ranges
- Develop concepts for doing and evaluating mediation processes
- Estimate the potential and limitations of cooperative environmental planning
- Train communicative skills (presentation, moderation, discussion design, negotiation), especially by participating at a mediation

Content

To this end, we will look at the most important techniques of mediation and put them into the context of today's legislation, participation and conflict culture. The potential and limitations of the individual techniques will be discussed using current Swiss and international case studies, namely in the field of windenergy as well of landfills and Human-Wildlife Conflict and Coexistence (wolves, bears, elephants). Students can do conflict analyses, for instance, as part of individual and group analyses and a half-day mediation-simulation, develop technique concepts and train their own communicative and negotiation skills.

Language Courses of the UZH and ETH Zurich

A maximum of 3 credit points from language courses may be recognised in the category "Science in Context" throughout the entire bachelor's and master's degree program. Moreover, the following restrictions apply: In the case of the European languages English, French, Italian and Spanish, only advanced language courses from level B2 will be credited. German language courses are credited from level C2.

Only the courses listed below will be recognized as "Science in Perspective" courses.

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kursegebuehren1.html
Registration dates: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse.html

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<td>W</td>
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<td>1G</td>
<td>University lecturers</td>
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<td>851-0815-04L</td>
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<td>W</td>
<td>2 credits</td>
<td>2G</td>
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The course is organized around the communicative tasks that participants learn to perform. These relate to the university environment and are addressed both in terms of essential language skills at B2 level and of extra-linguistic skills (cultural knowledge, gestures, etc.) required to deal with these situations.

Objective
The objective of this course is to familiarize participants with the performance of communicative tasks specific to the academic world and, in so doing, to consolidate their general production and comprehension skills (oral and written) at B2 level.

<table>
<thead>
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<td>1</td>
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<td>851-0816-05L</td>
<td>French B2-C1: Textual Grammar</td>
<td>2</td>
<td>1G</td>
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<td>851-0826-06L</td>
<td>Italian B2-C1: Outside the Classroom</td>
<td>2</td>
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<td>851-0826-03L</td>
<td>Italian B2-C1: Language Structure</td>
<td>2</td>
<td>2G</td>
<td>University lecturers</td>
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</table>
This course is designed for Bachelor's and Master's students from all disciplines who wish to improve their English from C1 towards C2. The aims of the course are to:

- Introduce participants to a variety of literary texts in English
- Help participants to develop critical, creative, and personal approaches to analyzing literary texts and by extension become more astute readers in general
- Provide participants with an opportunity to enhance and practice their argumentation skills in discussions and in writing
- Improve the ways in which participants organize their ideas and arguments in a sustained, coherent, and logical manner
- Improve participants' grammatical and lexical repertoire through reading and discussion
- Impart a life-long interest in literature written in English

The course is open to participants who have already reached C1-level English. The course enhances participants' appreciation and understanding of literature in English. Through the analysis and interpretation of literary texts, participants improve their analytical and English language skills; their grammar skills through writing; and their vocabulary through reading, discussions, and writing.

Objective

The aims of the course are to:

- Introduce participants to a variety of literary texts in English
- Help participants to develop critical, creative, and personal approaches to analyzing literary texts and by extension become more astute readers in general
- Provide participants with an opportunity to enhance and practice their argumentation skills in discussions and in writing
- Improve the ways in which participants organize their ideas and arguments in a sustained, coherent, and logical manner
- Improve participants' grammatical and lexical repertoire through reading and discussion
- Impart a life-long interest in literature written in English

851-0823-00L  English Language and Literature (C1-C2)

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kurgsbuehren1.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse.html

Abstract

The course gives participants the opportunity to broaden and intensify their knowledge of complex morphosyntactic structures. The objective is to improve their proficiency in expressing complex content. The aim is that at the end of the course, participants understand a wide range of texts and are able to express themselves clearly and effectively in a wide variety of oral and written situations.

Objective

The course helps participants to explore various ways in which they can express complex thoughts and ideas through different types of subordinate clauses, including consecutive, concessive, and hypothetical sentences, and indirect speech. Using a range of written and oral activities, participants also practice aspects of grammar that often pose difficulties at an advanced level: verb tenses and modes, use of articles and pronouns, adjectives and past participle agreement, choice of prepositions, and word order. At the same time, the course focuses on vocabulary expansion.

851-0832-10L  Advanced English for Academic Purposes (C1-C2)

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kurgsbuehren1.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse.html

Abstract

This course is designed for Bachelor’s and Master’s students from all disciplines who wish to improve their English from C1 towards C2 level and train their language skills at mastery level. Selected academic English features are included to add value to the course to meet standard entrance requirements by leading universities and colleges worldwide.

Objective

Participants should already have reached C1 level (advanced) as defined in the Common European Framework of Reference for Languages (CEFR). The course is also open to participants whose level is above C1.

The course aims to train and develop linguistic skills at mastery level, with a focus on formal and informal academic lexis, on listening and oral communication skills, and on increasing fluency, accuracy, and complexity of spoken language. Students will work on writing well-structured descriptive texts and argumentative essays, with the aim of fulfilling the language requirements for study at an English-speaking university or following university Master’s courses held in English.

851-0846-01L  Spanish B2: Starter

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kurgsbuehren1.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse.html

Abstract

The grammar in this course focuses on the introduction of the “imperfecto de subjuntivo” and the “pluscuamperfecto de subjuntivo”. The corresponding indicatives are also included. Various text types are focused on, and participants give simple oral presentations on a topic from their field of study. Participants also practice their oral expression and discussion skills.

Objective

Participants improve their understanding of grammatical usage by investigating written and spoken texts. They put newly acquired language patterns into practice when writing and speaking, and they acquire vocabulary on current contemporary issues; they also acquire specialist vocabulary from their fields of study.

Participants are able to write clear and detailed texts on scientific issues from their specific fields of study.
This course is designed for participants with no previous knowledge of Portuguese. Participants are able to use Modern Greek adequately in selected areas. They have basic vocabulary skills, which they can use actively.

2 credits

In this course, participants improve their comprehension of written and oral texts that deal with current issues, as well as of scientific texts from participants' own fields of study. They are able to analyse various points of view and can create clear and detailed oral and written texts on scientific issues from their field of study, while taking a position and expressing definite views on these issues.

851-0849-00L Brazilian Portuguese A1 No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

W 2 credits 2G University lecturers

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kursegebuehren1.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse.html

Abstract

The most important grammar topics of this course are past tense forms, subordinate clauses, linking devices, reported speech, periphrastic verb constructions, and verbs that express change. The course also deals with topics that typically cause problems for higher level learners, including ser/estar, por/para, and indicative and subjunctive forms of verbs.

Objective

In this course, participants improve their comprehension of written and oral texts that deal with current issues, as well as of scientific texts from participants' own fields of study. They are able to analyse various points of view and can create clear and detailed oral and written texts on scientific issues from their field of study, while taking a position and expressing definite views on these issues.

851-0849-01L Brazilian Portuguese A2 No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

W 2 credits 2G University lecturers

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kursegebuehren1.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse.html

Abstract

This course is designed for participants with no previous knowledge of Portuguese.

In the course, participants learn simple basic vocabulary, common daily idiomatic expressions, and fundamental grammar. The focus is on the phonetic features of Portuguese language. Intercultural and cultural issues relating to Brazil are also taken into consideration.

Objective

Participants can understand and form simple questions, messages, and requests.

851-0849-02L Brazilian Portuguese B1 No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

W 2 credits 2G University lecturers

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kursegebuehren1.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse.html

Abstract

This course is designed for participants with a basic knowledge of Portuguese (level A1).

The course deals with everyday topics. Participants practice simple forms of communication as these occur in daily life. Lexical and linguistic structures are taught within these contexts. Intercultural and socio-cultural issues relating to Brazil are also taken into consideration.

Objective

Participants can talk and write about themselves and everyday topics using simple sentences. They can take part in simple daily conversations, understand and write simple messages, describe an event in a time sequence, and express wishes, assumptions, and recommendations.

851-0885-09L Modern Greek Language I A1.1 No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

W 2 credits 2G University lecturers

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kursegebuehren1.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse.html

Abstract

Modern Greek I leads to A1.1 level on the Common European Framework of Reference for Languages. It is the first part of a four-semester Modern Greek course. The goal of the course is for participants to acquire basic language skills in speaking, listening comprehension, and reading and writing Greek script. The focus is also on building basic vocabulary and on acquiring basic grammar.

Objective

Participants are able to use Modern Greek adequately in selected areas. They have basic vocabulary skills, which they can use actively. They can read and write Greek script well. They can filter out a general overview from the information presented on Greek websites. The focus is on speaking, reading comprehension, and listening comprehension skills at A1.1 level of the Common European Framework of Reference for Languages, and on the development of cultural competence. Special importance is attached to an academic environment and student life. Content areas that are embedded in various communicative tasks include: Giving information about yourself, your job, your studies, your place of residence, and your personal preferences; and conducting simple, everyday conversations (including ordering food and drink, shopping, and inquiring about places).
Participants are able to use Swedish adequately in selected areas. The focus is on speaking, listening comprehension, and reading, and writing. The focus is also on grammar structures, vocabulary extension.

**Objective**

Participants are able to use Modern Greek adequately in selected areas. They improve their listening comprehension skills and expand their vocabulary. They can read a simple text fluently and can answer content questions in speech and in writing. They understand Greek as the language of instruction and have developed strategies needed to ask questions in Greek. The focus is on speaking, reading comprehension, and writing skills at A2.1 level of the Common European Framework of Reference for Languages and on developing cultural competence. Special importance is attached to an academic environment and student life. Content areas that are embedded in various communicative tasks include: Describing an apartment, people, and objects; making comparisons; talking about past experiences and future plans; participating in interviews; asking for permission; giving advice; making appointments; and acting out dialogues.

**Course fees:**

**Registration dates:**

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**Abstract**

Modern Greek III leads to A2.1 level on the Common European Framework of Reference for Languages. It is the third part of a four-semester Modern Greek course. The goal of the course is for participants to expand their language skills in speaking and listening comprehension, reading, and writing. The focus is also on grammar structures, vocabulary extension.

**Objective**

Participants are able to use Modern Greek adequately in selected areas. They improve their listening comprehension skills and expand their vocabulary. They can read a simple text fluently and can answer content questions in speech and in writing. They understand Greek as the language of instruction and have developed strategies needed to ask questions in Greek. The focus is on speaking, reading comprehension, and writing skills at A2.1 level of the Common European Framework of Reference for Languages and on developing cultural competence. Special importance is attached to an academic environment and student life. Content areas that are embedded in various communicative tasks include: Describing an apartment, people, and objects; making comparisons; talking about past experiences and future plans; participating in interviews; asking for permission; giving advice; making appointments; and acting out dialogues.

**Course fees:**

**Registration dates:**

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**Abstract**

Swedish I leads to A1.2 level on the Common European Framework of Reference for Languages. The course is the first part of a two-semester Swedish course. The goal of the course is for participants to gain basic language skills in speaking, listening comprehension, reading, and writing.

**Objective**

Participants are able to use Swedish adequately in selected areas. The focus is on speaking, reading comprehension, and listening comprehension skills at A1.2 level of the Common European Framework of Reference for Languages, and on developing cultural competence. Special importance is attached to an academic environment and student life. Content areas that are embedded in various communicative tasks include: Greetings, introducing yourself, and speaking about yourself (including about your personal and professional identity and your interests); and asking for information and requesting services.

**Course fees:**

**Registration dates:**

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**Abstract**

Swedish II leads to A2.1 level on the Common European Framework of Reference for Languages. The course is the second part of a two-semester Swedish course. The goal of the course is for participants to extend their skills in speaking, listening comprehension, reading, and writing. Participants expand their skills in basic grammar, extend their vocabulary and improve their pronunciation.

**Objective**

Participants are able to use Swedish adequately in selected areas. The focus is on speaking, listening comprehension, and reading comprehension skills at A2.1 level of the Common European Framework of Reference for Languages, and on developing cultural competence. Special importance is attached to an academic environment and student life. Content areas that are embedded in various communicative tasks include: Talking about your relatives and family; talking about past and future events; expressing your views on things you (don't) like; expressing your opinion; and requesting information (including about directions and the weather).

**Course fees:**

**Registration dates:**

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**Abstract**

Russian I is the first part of a five-semester Russian course. The course leads to A1.1 level on the Common European Framework of Reference for Languages. The goal of the course is to introduce participants to the Cyrillic alphabet and to Russian phonetics; participants build up a basic vocabulary, learn the basics of Russian grammar, and are introduced to Russian culture.

**Objective**

Participants are able to use Russian adequately in selected areas. The focus is on speaking, reading comprehension, and listening comprehension skills at A1.1 level of the Common European Framework of Reference for Languages, and on developing cultural competence. Special importance is attached to an academic environment and student life. The course deals with the following content: Reading and writing Russian script; saying hello and goodbye; introducing yourself; asking for someone’s name; addressing someone; apologizing; indicating your country and place of origin and residence; stating your profession; talking about family; talking about your wellbeing; asking about prices; and ordering items in a café.

**Course fees:**

**Registration dates:**

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**Abstract**

Russian III is the third part of a five-semester Russian course. The course leads to A2.1 level on the Common European Framework of Reference for Languages. The goal of the course is to introduce participants to the Cyrillic alphabet and to Russian phonetics; participants build up a basic vocabulary, learn the basics of Russian grammar, and are introduced to Russian culture.

**Objective**

Participants are able to use Russian adequately in selected areas. The focus is on speaking, reading comprehension, and listening comprehension skills at A2.1 level of the Common European Framework of Reference for Languages, and on developing cultural competence. Special importance is attached to an academic environment and student life. The course deals with the following content: Reading and writing Russian script; saying hello and goodbye; introducing yourself; asking for someone’s name; addressing someone; apologizing; indicating your country and place of origin and residence; stating your profession; talking about family; talking about your wellbeing; asking about prices; and ordering items in a café.

**Course fees:**

**Registration dates:**
Objective
Participants are able to use Russian adequately in selected areas. The focus is on speaking, reading comprehension, and listening comprehension skills at A2.1 level on the Common European Framework of Reference for Languages, and on developing cultural competence. Special importance is attached to an academic environment and student life. The course deals with the following content: Talking about food and meals; indicating packaging and quantities; talking about things you need or that you have to buy; talking to people while shopping; naming food establishments, crockery, and cutlery; extending invitations and responding to invitations; asking for explanations of unfamiliar terms; expressing congratulations and wishes; describing daily routines; describing actions in the present, past, and future; and explaining how you get to work.

851-0863-00L Arabic III A2.1
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Objective
Participants are able to use the Arabic language adequately in selected areas. The focus is on speaking; reading and listening comprehension skills at A2.1 level on the Common European Framework of Reference for Languages, and on developing cultural competence. Special importance is attached to an academic environment and student life. The course deals with the following content: Talking about the weather; naming the seasons and months; understanding activities offered to tourists; expressing agreement, disagreement, and indifference; making appointments; talking about holiday plans and arrangements; expressing prohibitions; making comparisons; talking about learning; indicating date and year; saying what you are interested in and what you are doing; giving biographical details; saying what you would like to do; making and obtaining recommendations; passing on information.

851-0877-00L Chinese I A1.1
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Objective
Participants are able to use the Arabic language adequately in selected areas and can conduct themselves in a culturally appropriate manner. To this end, the following content is dealt with: Talking about your life; daily routines; expressing wishes, commands, and eventualities; and talking about language and language learning (meta-language skills). Culturally, the focus is on useful phrases and appropriate conduct on important occasions such as holidays, weddings, births, and deaths. In terms of grammar, this course attaches particular importance to the systematization of the Arabic verbal system.

851-0855-00L Russian V A2.2+
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Objective
Participants are able to use Russian adequately in selected areas. The focus is on speaking, reading comprehension, and listening comprehension skills at A2.1 level on the Common European Framework of Reference for Languages, and on developing cultural competence. Special importance is attached to an academic environment and student life. The course deals with the following content: Talking about food and meals; indicating packaging and quantities; talking about things you need or that you have to buy; talking to people while shopping; naming food establishments, crockery, and cutlery; extending invitations and responding to invitations; asking for explanations of unfamiliar terms; expressing congratulations and wishes; describing daily routines; describing actions in the present, past, and future; and explaining how you get to work.

851-0861-01L Arabic I A1.1
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Objective
Participants are able to use the Arabic language adequately in selected areas. The focus is on speaking; reading and listening comprehension skills at A1.1 level on the Common European Framework of Reference for Languages; learning Arabic script; and the reading and writing of Arabic script.

851-0863-00L Arabic III A2.1
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Objective
Participants are able to use the Arabic language adequately in selected areas. The focus is on speaking; reading and listening comprehension skills at A1.1 level on the Common European Framework of Reference for Languages; learning Arabic script; and the development of cultural competence. The following content areas are embedded in various communicative tasks: Greeting each other, introducing yourself and speaking about yourself (personal and professional identity, place of residence), making simple phone calls, requesting information, and making appointments.
Chinese I leads to A1.1 level on the Common European Framework of Reference for Languages. It is the first part of a five-semester Chinese course. The goal of the course is to introduce participants to standard modern spoken Chinese and to the Chinese script, with a focus on oral skills. The main focus is on communicating in everyday situations.

Objective
Participants are able to use the Chinese language adequately in selected areas and can conduct themselves in a culturally appropriate manner. The focus is on oral language skills at A1.1 level of the Common European Framework of Reference for Languages. There is a special focus on university and student life. Participants are familiar with the basics of pronunciation, Chinese script, and the writing of Chinese characters by hand and digitally. Regarding writing, the focus is on passive skills.

The following topics are integrated into various communicative situations:
- Greetings, farewells, thanking people, and other polite expressions
- Introducing oneself (name, age, work, where you come from, etc.)
- Talking about how to get in touch with others (phone, social media, etc.)
- Providing information and asking about locations
- Discussing Chinese and other languages and dialects
- Talking about families

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<td>851-0879-00L</td>
<td>3 credits</td>
<td>University lecturers</td>
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</table>

Chinese III A2.1
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zurich".

Course fees:

Registration dates:

Japanese I leads to A1.1 level on the Common European Framework of Reference for Languages. It is the first part of a five-semester Japanese course. The goal of the course is for participants to learn the basic vocabulary and sentence structures needed to communicate in everyday situations. This includes an introduction to Hiragana and Katakana syllabic writing and its use in word processing.

Objective
Participants are able to use the Japanese language adequately in selected areas and can conduct themselves in a culturally appropriate manner. The focus is on oral language skills at A1.1 level of the Common European Framework of Reference for Languages. There is a special focus on university and student life. Participants are familiar with the basics of pronunciation, Chinese script, and the writing of Chinese characters by hand and digitally. Regarding writing, the focus is on passive skills.

The following topics are integrated into various communicative situations:
- Greetings, farewells, thanking people, and other polite expressions
- Introducing oneself (name, age, work, where you come from, etc.)
- Talking about how to get in touch with others (phone, social media, etc.)
- Providing information and asking about locations
- Discussing Chinese and other languages and dialects
- Talking about families

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<th>Course Code</th>
<th>Credits</th>
<th>University Lecturers</th>
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<tbody>
<tr>
<td>851-0881-00L</td>
<td>3 credits</td>
<td>University lecturers</td>
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</tbody>
</table>

Japanese I A1.1
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zurich".

Course fees:

Registration dates:

Japanese III leads to A2.1 level on the Common European Framework of Reference for Languages. It further develops participants' skills in standard modern spoken Chinese and in reading Chinese characters. The goal of the course is for participants to communicate in and deal with more complex everyday situations. There is a special focus on university and student life.

Objective
Participants are able to use the Chinese language adequately in selected areas and can conduct themselves in a culturally appropriate manner. The focus is on oral language skills at A2.1 level of the Common European Framework of Reference for Languages; reading and (digital) writing skills are fostered simultaneously.

The following topics are integrated into various communicative situations: Talking about food, going to a restaurant, directions, and public transport.

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<th>Course Code</th>
<th>Credits</th>
<th>University Lecturers</th>
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<td>851-0883-00L</td>
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</table>

Japanese II A2.1
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zurich".

Course fees:

Registration dates:

Japanese III leads to A2.1 level on the Common European Framework of Reference for Languages. It is the third part of a five-semester Japanese course. The goal of the course is to give participants the opportunity to practice colloquial Japanese, read texts in Sino-Japanese mixed script, use and extend their basic vocabulary and sentence structures, and practice listening comprehension.

Objective
Participants are able to use the Japanese language adequately in selected areas. The focus is equally on fostering speaking, listening, writing, and reading skills at A1.1 level of the Common European Framework of Reference for Languages, as well as on the development of cultural competence. Special importance is attached to an academic environment and student life. In addition, the two syllabic writing systems and the use of Japanese computer word processing are learnt. Content areas that are embedded in various communicative tasks include: Greetings, introducing yourself, and talking about yourself (personal and professional identity, studies, interests, daily life); asking for information; and requesting services.

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<tr>
<th>Course Code</th>
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<th>University Lecturers</th>
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<tbody>
<tr>
<td>851-0882-00L</td>
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<td>University lecturers</td>
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</table>

Japanese III A2.1
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zurich".

Course fees:

Registration dates:

Japanese V A2.2 - B1.1
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zurich".

Course fees:
The aim of this course is to expose the participants to the language with a musical approach using linguistic and cultural resources.

851-0856-06L Spanish B2-C1: The Realities of the Hispanic World
Does not take place this semester.

Objective
Participants are able to communicate orally in specific situations and read everyday texts in Sino-Japanese mixed script. The focus is equally on fostering speaking, listening, writing, and reading skills at A2.1/B1.1 level of the Common European Framework of Reference for Languages, as well as on the development of cultural competence. The following content from daily interactions is dealt with: Various daily activities (logical sequences, expressing regrettable and gratifying events), distinguishing between, and using, deferential and informal language.

851-0827-01L French B2-C1: Society and Current Issues
Does not take place this semester.

Objective
The main objective of this course is to develop participants' written comprehension and expression and, more specifically, to explore the implicit and cultural aspects of a variety of text genres (academic writing, essays, investigative journalism). This course aims to improve participants' language skills through the acquisition of precise and context-specific vocabulary. It also raises their awareness of the argumentative character of written texts, words or expressions used in writing, and various types of discourse and language registers.

851-0849-03L Brazilian Portuguese A2-B2: Urban Popular Music
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Objective
The main objective of this course is to develop participants' written comprehension and expression and, more specifically, to explore the implicit and cultural aspects of a variety of text genres (academic writing, essays, investigative journalism). This course aims to improve participants' language skills through the acquisition of precise and context-specific vocabulary. It also raises their awareness of the argumentative character of written texts, words or expressions used in writing, and various types of discourse and language registers.
Objective
The course aims to visual observation, development of ideas, presentation, and interaction. Some basic elements of movie-making are presented. The participant gets familiarized with images, customs, dialogs and vocabulary, carrying out an observation, analysis, and comment of these elements. Glossaries of different linguistic regions are created.

851-0856-04L  Spanish B2-C1: Grammar and Communication
Does not take place this semester.
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees:

Registration dates:

Abstract
The main subject matter of this course includes a systematic discussion of the usage of past tenses; subordinate clauses; linking expressions: reported speech; periphrastic verb constructions; and verbs of change. In addition, participants undertake individual reading of various text types, with a particular emphasis on technical subjects and/or subjects related to their fields of study.

Objective
In this course, participants acquire oral and written academic communication skills; they acquire knowledge of the grammar areas relevant to B2-C1 level of the Common European Framework Reference for Languages; and they consolidate previously acquired grammar.

Does not take place this semester.
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees:

Registration dates:

Abstract
This course offers participants the opportunity to carry out a "case study" based on a topical issue in order to practice and improve the four language skills by developing a fictitious but plausible scenario that requires the use of specific rhetorical, lexical, and pragmatic tools.

Objective
The main objective of this course is to give participants an opportunity to practice and improve the four language skills (speaking and listening comprehension, writing and reading comprehension) through "case studies." Participants present a complex topic and interact by defending a point of view and/or responding to objections. In addition, the course allows participants to develop their knowledge of Francophone culture (the media and the press).

851-0820-01L  French B2-C1: Language and Cinema
Does not take place this semester.
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees:

Registration dates:

Abstract
This course offers participants a choice of films that reflect recent issues in order to raise their awareness of the ongoing concerns of contemporary French cinema, and also to enable them to improve their speaking skills, mainly through oral presentations.

Objective
The primary objective of this course is to develop participants' listening comprehension skills and more specifically, to improve their understanding of implicit and cultural meanings of the films on the program. It further aims to raise participants' awareness of the history, aesthetics, and contemporary issues of French cinema. The second objective of the course is to improve participants' speaking skills, especially by giving them the opportunity to produce structured presentations and to express their personal, informed, and nuanced opinions.

851-0834-17L  Spanish B2: Oral Interaction
Does not take place this semester.
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees:

Registration dates:

Abstract
Participants practice a range of oral interactions, such as casual and formal conversation, interviews, debates, negotiations, and presentations. They discuss current issues and their fields of study and/or work.

Objective
The course aims to expose participants to a range of conversational situations, providing them with tools that help them to improve their ability to perform various tasks linguistically and socially.

851-0826-04L  Italian B2-C1: Language and Literature
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees:

Registration dates:

Abstract
Participants practice a range of oral interactions, such as casual and formal conversation, interviews, debates, negotiations, and presentations. They discuss current issues and their fields of study and/or work.

Objective
The course aims to expose participants to a range of conversational situations, providing them with tools that help them to improve their ability to perform various tasks linguistically and socially.
Abstract
The course approaches the Italian language through short stories, relevant both for their linguistic structures and content, which is related to historical and sociological realities typical for Italy. Participants deepen their lexical and syntactic competence by means of oral and written presentations, class discussions, reflections on the structures of the stories, and targeted exercises.

Objective
The course offers participants the opportunity to:
- Better understand complex literary texts
- Be able to grasp nuances of meaning expressed through certain lexical and syntactical choices more effectively
- Learn how to express themselves clearly and in a differentiated way
- Understand through short narrative texts some cultural and social realities typical of Italy

851-0826-05L Italian B2: Italian for Academic Purposes
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees:

Registration dates:

Abstract
In this course, participants examine and write/prepare various academic text genres, including scientific essays, abstracts, oral presentations, and handouts.

Objective
The course aims to deepen participants' mastery of academic language. By reading scientific texts and listening to university lectures, participants analyze and study the linguistic structures of these text genres and learn specialist vocabulary from their field of study.

851-0879-01L Chinese V 2.2+
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees:

Registration dates:

Abstract
Chinese V concludes the five-semester Chinese course. Chinese V goes beyond level A2.2 of the Common European Framework of Reference for Languages and includes some B1-level skills. The goal is to further develop oral skills, and listening and reading comprehension skills on selected topics. There is a special focus on university and student life.

Objective
Participants are able to talk about selected topics and understand simple, authentic texts, audio sequences, and videos related to these topics. The focus is on oral language skills. Listening and reading comprehension and (digital) writing skills are also practiced, with the additional support of digital tools.

The following topics are integrated into various communicative situations:
- Travel: Destinations of choice; organizing and describing a trip, etc.
- Education and training: Your career; your current academic or professional situation; comparing the Swiss and Chinese education systems.

851-0867-00L Arabic I-III (Fast Track) A1-A2.1
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees:

Registration dates:

Abstract
Arabic I-III (fast track) is an intensive course that leads to A2.1 level on the Common European Framework of Reference for Languages. The target group are people who: understand or speak an Arabic dialect and wish to learn Standard Arabic; have learnt to read Arabic fluently during a religious education; or have already learnt some basic Arabic and wish to invest time in an intensive course.

Objective
Participants are able to use the Arabic language adequately in selected areas and can conduct themselves in a culturally appropriate manner. To this end, the following content is dealt with: Talking about your life; daily routines; expressing wishes, commands, and eventualities, talking about language and language learning (meta-language skills), writing messages and short texts. In terms of grammar, this course attaches particular importance to the basic principles of the grammar of Standard Arabic and its verbal system. Among the cultural and meta-language skills are the creation of awareness regarding the difference between the Arabic varieties and registers.

Prerequisites / notice
In all cases, knowledge of Arabic script is a prerequisite.

851-0826-07L Italian B2: Communicative Forms and Strategies
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees:

Registration dates:

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Abstract
Participants improve their skills in
• Expressing their opinions and formulating hypotheses in different sequences and tenses
• Reporting on news, information, and questions from others
• Grammar and vocabulary at B2 level

Texts on everyday topics provide the learning context. Participants gain practice through interacting with others and consolidate their skills through written exercises.

Objective
At the end of the course, participants can:
• Express themselves in various ways using formulations and structures appropriate to the given oral, written, and communicative context
• Use current tools such as DeepL and Chat GPT to improve their learning

851-0890-00L Latin Reading Course: "Scripta manent...": A selection of Latin classics
W 2 credits 2G University lecturers

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kursegebuehren1.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse.html

Abstract
The topic of the course is a wide variety of texts from the Latin classics. The focus will deliberately not be on a single author or genre, but on a wide variety of excerpts from different authors.

Objective
Students learn about new content and its different aspects and should be able to place the different aspects in a larger context and contrast them (content focus).

Content
The selection of texts is not fixed, but will be adapted to the preferences of the course participants. Various texts will be presented for selection, and the participants will have a say in how the course will proceed over the course of the semester.

Most of the texts are prepared at home and discussed in class.

Lecture notes
Die im Kurs verwendeten Unterrichtsmaterialien werden den Teilnehmenden zugestellt bzw. in den Stunden verteilt oder auf einer elektronischen Unterrichtsplattform verfügbar gemacht.

Prerequisites / notice
Der Kurs richtet sich an Teilnehmende mit Lateinkenntnissen (Matura, Latinum).

851-0881-05L Japanese I A1.1 (Part 2)
W 2 credits 2U University lecturers

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kursegebuehren1.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse.html

Abstract
This course is the second part of the two-semester course in which the entire content of Japanese I A1.1 is learned.

The goal of the course is for participants to learn the basic vocabulary and sentence structures needed to communicate in everyday situations. This includes an extension of existing knowledge of Hiragana and Katakana syllabic writing and its use in word processing.

Objective
Participants will have adequate language in selected everyday situations. Special consideration is given to an academic environment and student life.

The Japanese I (Part 1) and Japanese I (Part 2) courses aim to cover the entire content of Japanese I A1.1 in two semesters. They are designed so that busy participants who can only attend Japanese classes once a week can slowly but steadily acquire A1.1 proficiency over the course of two semesters.

The focus is equally on fostering speaking, listening, writing, and reading skills at A1.1 level of the Common European Framework of Reference for Languages, as well as on the development of cultural competence. In addition, the two syllabic writing systems and the use of Japanese computer word processing are expanded.

Content areas that are embedded in various communicative tasks include: talking about yourself (personal and professional identity, interests, daily routine, etc.), asking for information, and requesting services.

Prerequisites / notice
Special admission requirement: Attendance of the course Japanese I A1.1 (Part 1) or equivalent knowledge.

851-0819-00L French B2: Points of View on Current Affairs
W 2 credits 1G University lecturers

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kursegebuehren1.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse.html

Abstract
In this course, we deal with current affairs from the French-speaking world through various media, both written and audio-visual. Each topic is approached from a different perspective, with an emphasis on group discussion. At the end of the course, participants choose and present one current topic from the French-speaking world and lead a discussion on their topic.

Objective
The objectives of this course are to provide the tools (linguistic and cultural) necessary to understand and address francophone current affairs. Participants work on specific vocabulary related to current affairs and communicative competence (expressing opinions; expressing agreement or disagreement; arguing). By the end of the course, participants are able to give a presentation in French on a chosen topic and propose and lead a discussion. The emphasis of the course is on oral interaction skills and written and oral comprehension (newspaper articles, reports, documentaries).
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<thead>
<tr>
<th>Key for Type</th>
<th>Description</th>
<th>ECTS</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
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<td>W+</td>
<td>Eligible for credits and recommended</td>
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<td>O</td>
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<td>W</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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**Key for Hours**

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<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
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<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
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<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
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<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.